



China's energy security: Oil and gas

Kang Wu*

FGE – FACTS Global Energy Hawaii, 1110 University Avenue, Suite 202, Honolulu, HI 96826, USA



HIGHLIGHTS

- Identified China's key energy security strategies during the 12th Five-Year Program (FYP) and previous FYPs.
- Provided a unique insight into China's rising oil imports.
- Reviewed China's overseas oil and gas investment as a key energy security measure.
- Assessed China's strategic petroleum reserves program and the future growth.
- Provided a comprehensive coverage of China's unconventional gas development, including both coal-bed methane and shale gas.

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ABSTRACT

China is currently the largest energy consuming country in the world. Until the early 1990s, China had long been a net energy exporter. The country became a net oil importer in 1993, the first time since the 1960s. For China, energy security first means oil supply security. China turned into a net natural gas importer in 2007 and then a net coal importer in 2009. In other words, China is now a net importer of all three types of fossil energy—oil, natural gas, and coal.

In the context of rising oil imports and implementation of China's 12th Five-Year Program from 2011 to 2015, this paper examines China's energy security strategies with a focus on three leading elements, namely overseas oil investment, strategic petroleum reserves (SPR) and unconventional gas development. Our findings suggest that the Chinese government has promoted overseas investment strongly; its SPR program has been established though the progress for Phase II has been slower than expected and the government intends to boost the unconventional gas sector development. However, the challenges are enormous as well. As for future research, other elements for each dimension of energy security should be reviewed to reach a comprehensive conclusion about how well China has done and what steps are needed to move forward.

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1. Introduction

As the largest energy consuming country in the world, China consumed 2.61 billion metric tons of oil equivalent (mmtoe) of primary commercial energy (PCE) in 2011, ahead of the United States' 2.27 mmtoe (BP, 2012). If non-commercial biomass is included, China's total PCE was much higher.

Coal plays a dominant role in China's energy scene, accounting for some 70 percent of its PCE consumption. In 2011, China produced 3.5 billion tons (bt) of coal and consumed nearly 3.7 bt, with the gap filled with imports (FGE, 2012). On a heat equivalent basis, China accounted for nearly half of the world's total coal use (BP, 2012). Until 2009, China had been a net coal exporter for several decades. However, the imports have grown

rapidly since the beginning of last decade, reaching an all-time high of 222 million tons (mmt), up sharply from the 2003 imports of merely 11 mmt. In the meantime, coal exports have been declining. In 2011, China exported only 15 mmt of coal, down significantly from the peak level of 94 mmt in 2003 (FGE, 2012).

The Chinese government has been trying to limit coal use and promote the use of other energy sources, but has so far not been successful. In the current the 12th FYP, the Chinese government is trying to make new efforts to rein in the use of coal but it is a challenging task not only for the next few years but over the long run. As the world's largest coal producer and consumer, the importance of coal for the country's economic development and energy use will not diminish overnight (Wu, 2012a). China's use of coal use will likely continue to increase. While most of the coal will be met domestically, imports are expected to increase as well.

Oil, which is the focus of this paper, is the second-largest component of PCE in China, accounting for 18 percent in 2011. Driven by the transportation, petrochemical, and residential sectors, China's

* Corresponding author. Tel.: +1 808 944 3637; fax: +1 808 946 6320.

E-mail address: kwu@hawaii.edu

use of petroleum products has been growing rapidly for the past two decades. The country's growing dependence on imported oil since the early 1990s is a great concern for the government.

Natural gas currently accounts for a much lower share in PCE consumption (5 percent in 2011) than oil and coal. In 2011, China consumed 141 billion cubic meters (m³) of natural gas (FGE, 2012), of which one-quarter was imported pipeline as well as liquefied natural gas (LNG). The government is keen to increase gas production (including unconventional gas) and consumption drastically. There is no doubt that the share of natural gas in China's overall primary energy consumption will continue to grow.

Compared with coal and oil, the size of the natural gas market for demand and supply is much smaller. However, China recently surpassed Japan to become the largest natural gas consuming country in Asia. China began importing LNG in 2006 and importing natural gas by pipeline from Turkmenistan via Kazakhstan at the end of 2009. In 2011, the net imports of natural gas (LNG and pipeline gas combined) accounted for 21 percent of China's total natural gas use. This share is expected to increase quickly between 2015 and 2020.

China has accelerated nuclear power development since the early 2000s after slow growth during much of the 1990s. As of mid-2012, there were 14 nuclear reactor generators in operation, with a combined capacity of 12.6 GW (gigawatts). However, at present, nuclear power accounts for less than one percent of the PCE use in China. Despite the call for reassessment in the aftermath of Japan's March 2011 earthquake/tsunami that caused massive damage to the Japan's Fukushima Daiichi nuclear power plants, China's ambitious nuclear power program remains in place. Currently, nuclear power plants with a total capacity of 33.6 GW are under construction and more are approved and being planned (Wang and Wu, 2012). By the end of the 12th FYP, China will have the largest nuclear power generating capacity in Asia.

Hydropower has traditionally been given high priority by the government, and several large hydroelectric projects in southwest China are planned. At the start of 2012, China's installed hydroelectric power generating capacity exceeded 230 GW, though it accounted for only about 6 percent of China's PCE use (BP, 2012) it will continue to be an important source of primary energy for China for decades to come.

Beyond hydropower, China has been aggressive in promoting the development of other forms of renewable energy such as wind power, solar power, biofuels (O'Kray and Wu, 2010). At the start of 2012, China had the largest installed wind power generating capacity at around 63 GW. Key targets include reducing carbon emission intensity by 40–45 percent by 2020 from the 1990 levels, and to increase the share of renewable energy to 15 percent of total PEC also by 2020.

In the context of rising oil imports and implementation of China's 12th Five-Year Program (FYP), from 2011 to 2015, this paper examines China's energy security strategies with a focus on three leading elements, namely management of rising oil imports, overseas oil investment, strategic petroleum reserves (SPRs) and unconventional gas development. The rest of the article is organized as follows: Section 2 identifies the key elements of energy security for China as a way to introduce the methodology, including a discussion of China's increasing oil imports as a premise, followed by a literature review concerning China's energy security strategies and description of data used in the paper. Section 3 reviews how each key dimension of energy security involves in China.

2. Dimensions of energy security for China and identification of the key elements

The issue of energy security can be assessed in four—economic, geopolitical, and environmental, and military and national security

—dimensions. The discussion of the military and national security dimension of energy security goes beyond the scope of this study. The main focus of the economic dimension of energy security is to ensure China's long-term economic growth. For decades, the Chinese government has been successful in maintaining high economic growth. However, one of the biggest challenges is energy supply, for which not only huge amounts of total energy are required, but also high quality fuels and security of energy supply. The geopolitical dimension of energy security is to reduce China's energy vulnerabilities. Since the early 21st century, China has begun to look to Africa, Russia, Central Asia, and even Canada as possible alternative sources of its future oil and gas imports. The environmental dimension of energy security is to avoid ecological degradation and disasters where energy resource extraction and use occur. Although there are advocates within the country who advocate use of more coal to address rising energy security concerns, the mainstream view is to continue China's current transformation to cleaner energy products of higher quality.

To effectively address the issue of energy security for China in the context of various dimensions discussed above, we identify three key elements: China's overseas oil investments, SPRs, and unconventional gas development. Through discussion of these elements, we can determine the progress that China has achieved and challenges ahead. Before we provide a literature review for China's evolving energy security strategies, we discuss briefly the country's increasing oil imports as a premise with regard to the emergence of energy security as an issue for China.

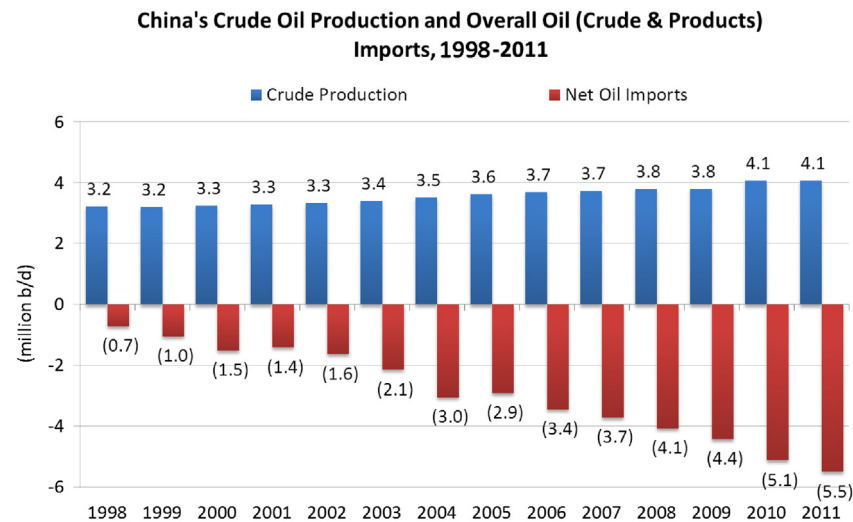
2.1. China's increasing oil imports: a premise for the rise of energy security as an issue

After five decades of development, China became the world's fifth-largest oil producer in 2011 (after Saudi Arabia, Russia, the US, and Iran). For most years since 1970, China was a net oil (crude and products) exporter until 1993, and a net crude oil exporter until 1996. The net oil exports (crude and products combined) peaked in 1985. Net oil imports increased from less than 540 thousand b/d in 1998 to 2.9 million b/d in 2005, and an all-time high of 5.5 million b/d in 2011 (see Fig. 1).

Oil demand growth has been strong in China since the early 1990s, driven primarily by the transportation, petrochemical, and road construction sector as well as expanding foreign trade. Total petroleum product consumption, including direct burning of crude oil, amounted to 9.5 million b/d in 2010, up from 3.1 million b/d in 1995 and 6.5 million b/d in 2005 (FGE, 2013).

Over the next five to ten years, China's crude oil production is expected to increase moderately, but on the demand side, total petroleum product consumption is expected to increase continuously. As a result, the gap between the total petroleum product demand and the domestic crude output is growing fast. China's net oil imports are expected to rise from 5.5 million b/d in 2010 to 7.3 million b/d in 2015 and 9.6 million b/d in 2020.

China has a huge refining capacity and is largely self-sufficient in producing most of the main petroleum products it needs except for fuel oil, LPG, and naphtha. China's main need is for crude oil (Wu, 2012c, 2011). In fact, over 90 percent of China's net oil imports in 2011 were in the form of crude oil. This share is set to increase. China imports crude oil from the Middle East (51 percent of the total in 2011), Africa (24 percent of the total), Russia, Central Asia, and Latin America (22 percent of the total) and the remaining three percent from other parts of the world. In 2011, net oil imports accounted for 53 percent of the country's total oil consumption (up from 45 percent in 2008), as compared to 58 percent for the US (down from 65 percent in 2008)—the world's largest oil consuming country (FGE, 2013; BP, 2012). The difference between China and the US is that the



Source: FGE 2013

Fig. 1

US demand is expected to be flat or to decline over the coming decades while the Chinese demand will continue to grow.

Under these circumstances, securing future oil and gas supply to meet China's growing demand has become vital for the country. Since the beginning of the millennium, the Chinese government has increasingly made energy security a high priority in its five-year program and long-term energy planning. Among many measures taken and planned by the Chinese government, diversification of oil and gas supply sources and increasing overseas oil and gas investments are two of the key strategies.

2.2. China's evolving energy security strategies

Despite the fact that China became a net oil importer in 1993, between 1993 and 1998, the net imports were no more than 750 thousand b/d and their share in total oil consumption was under 20 percent. Since then, however, both the volume of imports and their relative share have increased rapidly. Net oil imports as a share of total oil consumption increased from 18 percent in 1998 to 45 percent in 2005 and 57 percent in 2011 (FGE, 2013).

Adding to the concern about rising import dependence are price volatility in the global oil markets and instability in the Middle East. Energy security became a key issue for China's top policy makers in the late 1990s and featured prominently in the country's 10th FYP (2001 to 2005). At the strategic level, the government set the following as one of four energy strategies for energy developments through 2005—to optimize the energy mix while ensuring overall energy security (www.xinhua.net, 2000). Specifically for oil and gas, the establishment of strategic petroleum reserves (SPRs) was written into the 10th FYP for the first time. The plan called for the establishment of a petroleum storage system to ensure petroleum supply security and enhance the government's capability for stabilising the market. During the 10th FYP, the target was to create limited amounts of national SPRs as well as storage by individual enterprises. Diversification of petroleum imports was also emphasized to reduce the overall risk of supply interruptions (Wu, 2012a).

To formulate national energy security strategies, elements suggested by scholars and experts and considered by the

government in the early 2000s included the following (Xu and Yang, 2004; Zhang, 2002; Qin, 2004; Wu, 2007, 2009):

- Adjust energy consumption and production structures and reduce dependence on oil through coal gasification, liquefaction development of nuclear power, etc.
- Establish strategic upstream oil and gas reserves in certain parts of the country, as well as enhance domestic oil and gas exploration and production activities.
- Actively participate in the formation of a regional community and establish a regional energy security system.
- Establish an oil futures market.
- Diversify the sources of oil and gas imports and increase the share of oil and gas imports from Russia and Central Asia.
- Strengthen overseas investment by state oil companies, particularly in the Middle East, Asia Pacific, Russia, and Central Asia.
- Participate in varied trading channels to avoid transaction risks.
- Increase the investment in oil and gas infrastructure and open more channels for imports.
- Establish government controlled SPRs.
- Increase mandatory oil reserves for large oil companies.

In addition to the above, other scholars have also recommended the following to the Chinese government to deal with China's energy security issues:

- Form a centralized government agency for energy management.
- Draft, discuss and implement a coherent national energy policy.
- Enhance energy information gathering and research capabilities.
- Establish efficient energy markets and get rid of elements in the energy managing system that hinder energy security formulation and implementation.
- Establish an energy security response system.
- Strengthen efforts to improve energy efficiency and conservation.
- Step up efforts with respect to clean coal technologies and coal efficiency.
- Divide domestic and global energy supply to different zones and define China's energy needs accordingly. Participate in or initiate more bilateral and multilateral cooperation on energy.
- Regard ocean transportation as an important element of China's energy security.

- Provide government and financial support to Chinese energy shipping companies.
- Encourage strategic cooperation between state oil and shipping companies.
- Use more nuclear power.
- Promote renewable energy development.

From 2006, the Chinese government renamed its long-held five-year plans to five-year program (FYP). The key features of energy security strategies during the 11th FYP (2006 to 2010) (www.gov.cn, 2006) include the following:

- Greater emphasis on energy security. The demand for more energy and achieving the right energy mix means that continuously rising energy imports are inevitable for China. How to manage the growth in imports and strike a balance between domestic energy development and increasing interaction with international energy markets is a huge task for the Chinese government.
- Acceleration of the development of China's SPRs. China is placing greater emphasis on the building of SPRs. The target size for the first phase was much larger than originally planned or expected.
- Greater emphasis on overseas sea-lane transportation security.
- Call for the survey and exploration of unconventional hydrocarbon resources such as coal-bed methane (CBM), shale oil, oil sands, and natural gas hydrates.

In the current 12th FYP (2011–2015) (www.sina.com, 2012), the Chinese government addressed the issue of overall energy use as a way to deal with the issue of energy security and for the first time suggested using unconventional gas, such as CBM and shale gas. In 2011, China's GDP (based on conventional exchange rates) accounted for a little over 10 percent of the world total but the share of its PCE was 22 percent (IMF, 2012). China consumed more PCE than the US but its total GDP was less than half that of the US. Equally striking is the difference between China and Japan, where China's GDP in 2011 was 24 percent higher than Japan's but it was nearly five times that of Japan. To address this issue, among the official targets set in the 12th FYP were to reduce the energy consumption intensity of GDP by 16 percent and carbon dioxide (CO₂) intensity of GDP by 17 percent by 2015 from 2010 levels. Also, non-fossil energy is to account for 11.4 percent of the total by 2015. The 12th FYP stresses the importance of energy resource security, energy conservation, diversification of energy supply and the development of new energy as overarching energy goals for the country.

3. Developments of the key elements of energy security for China

As mentioned earlier, we have identified three key elements to address the issue of energy security in China: overseas investments, SPRs, and unconventional gas development. This section presents both findings and discussions of the key elements of energy security for China. Data used in this paper are drawn from a variety of sources. Major sources are the database of FGE, an international consulting company, and industrial media, which are properly cited throughout the paper.

3.1. China's overseas investments

Overseas energy (in particular, oil and gas) investment has been viewed by the Chinese government as one of the most important areas to address its growing energy security concern.

The investment has been led by several Chinese national oil companies (NOCs): China National Petroleum Corporation (CNPC) and its listed company PetroChina (CNPC/PetroChina), China Petrochemical Corporation (Sinopec) and its listed company Sinopec Corp., China National Offshore Oil Corporation (CNOOC) and its listed company CNOOC Ltd., Sinochem, other Chinese companies, sovereign wealth funds, and financial institutions. Between the early 1990s and 2012, the cumulative investments by Chinese NOCs and other players amounted to more than US\$100 billion. In 2011, China's equity oil production from overseas operations reached an all-time high of 1.7 million b/d. That was more than 30 percent China's crude oil imports that year even though the fact is that the portion of these equity crudes shipped back to China was well below 50 percent (FGE, 2013). As Chinese companies continue to expand their overseas investments, they are turning to areas such as shale gas, deepwater drilling, Canadian oil sands (with revitalized interest), as well as the oil and gas potential in the Arctic (Wu, 2012b).

China began investing in overseas upstream oil and gas in the 1990s and has intensified its efforts in the latter part of the decade. Since 2000, encouraged by the Chinese government, the state oil companies have made a bigger push to expand overseas., "Going out" has become part of the overall investment strategy for every state oil company in China. In recent years, China has increased its overseas oil and gas asset investments in both numbers and size. For years, it has been competing fiercely with countries such as India, Japan, Korea and Brazil among others (Brown et al., 2008; Yong and Wu, 2012).

CNPC/Petro China leads in overseas upstream petroleum investment followed by Sinopec. China National Overseas Oil Company (CNOOC), through its publicly listed subsidiary CNOOC Limited, is third. In addition to these three, state oil trading company Sinochem Corporation, two non-oil state companies, China International Trust & Investment Company (CITIC) and ZhenHua Oil Company, and two Chinese sovereignty wealth funds (SWE) have also engaged or begun investing in overseas oil and gas.

CNPC/PetroChina is aiming to become an international oil and gas company, in both the upstream and downstream oil and gas business. Its overseas petroleum investment activities are concentrated in Africa, Central Asia, North America, South America and the Middle East. Overall, CNPC/PetroChina accounted for 57 percent of China's total overseas equity oil production in 2011 (Yong and Wu, 2012). CNPC/PetroChina aspires to become an international oil and gas company, both in the upstream and downstream oil and gas business. PetroChina aims to attain around 60 percent of planned production from overseas in 2020.

Sinopec began investing overseas later than CNPC/PetroChina and CNOOC but has caught up quickly in recent years. In 2011, Sinopec's overseas equity oil production accounted for 31 percent of China's total, which is way ahead of CNOOC's. Currently, Sinopec's oil and gas projects span Africa, Central Asia, North America, South America and the Middle East. At the same time, Sinopec has managed to secure engineering and construction contracts to build or upgrade refineries in other countries such as Iran. Sinopec seeks to become a multinational refining and petrochemical company with global competitiveness, and continues to view upstream oil asset acquisition/cooperation projects as an integral part of its globalization strategy, owing to the mismatch between the firm's crude requirements and refining capacities.

CNOOC's overseas operations began in the mid-1990s and its overseas upstream assets are more focussed on gas production. In 2011, China's overseas net oil production accounted for six percent of China's total, and came mainly from Africa and Asia, and to a lesser extent, North America. CNOOC continues to develop its

overseas operations, as part of its mid- to long-term strategy, to expand the scope for long-term development on the basis of meeting its “3Rs” targets, namely resources, risk, and return on investment.

Sinochem has become the fourth Chinese oil company to pursue overseas investment. In the early 2000s, Sinochem formed its first upstream oil and gas exploration and development company, solely for the purpose of investing in upstream projects outside of China. Compared with the other three Chinese state oil companies, Sinochem's overseas activities are less extensive. Its equity oil production from overseas projects accounted for four percent of China's total, and the Middle East, South America and Africa were the main areas of its overseas activities.

As far as energy is concerned, CITIC—through its Hong Kong-listed company CITIC Resources Holdings—has been investing in power plants and other power generation efforts. For the most part, their investments have been in China and Hong Kong, though they have, for example, also been involved in building power generators for Uzbekistan as part of a political effort to strengthen ties with that country.

Established in 2003, ZhenHua Oil is a small state-owned company. Its business includes overseas petroleum investment, oil trade and petrochemical investment in China. The parent company of ZhenHua Oil is China North Industries Group Corporation, which has links to the military. ZhenHua Oil's overseas operations include blocks in Syria, Kazakhstan and Pakistan.

In April 2012, Yanchang Petroleum signed an agreement with Hong Kong-listed oil and petrochemicals company, Sino Union and Towngas, to develop an onshore block in Madagascar.

China's two sovereign wealth funds (SWFs) (e.g., State Administration of Foreign Exchange and China Investment Corporation) have allocated funds for overseas stock investment in energy and resource related companies. Companies that have interest in the two SWFs include Total of France, BP of UK, Penn West Energy of Canada and others.

Motivations for Chinese NOCs to move overseas aggressively can be summarized as follows.

- Leverage on the Chinese government's growing concerns over energy security.
- Diversify sources of energy supplies.
- Expand to maintain competitiveness in domestic market and enhance global competitiveness.
- Seek international profits to offset any potential losses in the domestic market.
- Complement individual corporate strategies.
- Tap on the vast pool of energy resources in the international market including both conventional assets and unconventional assets.
- Develop technical know-how and capabilities through joint E&P projects with other NOCs and international oil companies.

With aforementioned motivations, coupled with the acceptance of overseas investment as an effective way of addressing the energy security issue by the Chinese government, Chinese NOCs are more aggressive than private companies—including international majors—in seeking international investment and more active than NOCs from most other countries as well in this regard. Clearly, Chinese NOCs have been taking advantage of the government's support and in the meantime, the Chinese government sees the global expansion of Chinese NOCs making China more secured in terms of energy supply. As such, the push by the Chinese NOCs to invest more globally and the desire of the government to have more secured energy (particularly oil and gas) supply are intertwined and work hand in hand, leading to growing

acquisition of energy assets globally by Chinese companies each year.

3.2. Strategic petroleum reserves

After years of hesitation and debate, China has embarked on the path to build its own SPRs since the early 2000s and has since viewed it as one of the most important elements for enhancing its energy security. The main goal of China's SPR program is to reduce the impact of a crude oil supply disruption. China first officially formalised the SPR program in the 10th FYP in 2001 and construction started on the 5.8 million m³ Zhenhai base three years later in June 2004 (Wu and Zhang, 2009). By the end of 2008, construction of Phase I was completed, with a total capacity of 16.4 million m³ or 103 million barrels. The four sites for Phase I are Zhenhai, Zhoushan, Huangdao, and Dalian as shown, which are all above ground, located in the coastal cities, and near refining centers.

China is currently building the Phase II sites and aims to have them completed by 2013/2014, with a total planned storage capacity of 26.8 million m³ (169 million barrels). By 2015/2016, Phase III will bring the total SPR (Phases I, II and III) capacity to about 80 million m³ (500 million barrels).

While the four Phase I sites are all located at important coastal ports and above ground, the NDRC has shifted focus in selecting the Phase II sites. It has chosen sites in inland provinces, with access to various crude pipelines connecting to the international Kazakhstan-China, Russia-China, and maybe Myanmar-China crude. The NDRC is also testing underground facilities, with feasibility studies under way for several underground sites.

The National Petroleum Reserve Center (NPRC) was established in December 2007. In charge of the policy development and planning of SPRs, it is supervised by the National Energy Administration (NEA), which is under the National Development and Reform Commission (NDRC). The NPRC organizes reserve base construction, procures oil, and makes utilization and turnover decisions. During Phase I, CNPC/PetroChina, Sinopec, and Sinochem were responsible for facilities construction, maintenance, and reserve site filling, all implemented on behalf of the NPRC.

In Phase I, SPRs were built above ground near refining centers in the coastal cities of Zhenhai, Zhoushan, Huangdao, and Dalian. Construction began in 2004 and was completed at the end of 2008. The Phase II sites are all inland, with access to various crude pipelines from neighboring countries, e.g., Kazakhstan-China, Russia-China, and possibly Myanmar-China crude. The NDRC is also testing underground facilities.

The government appears to be allowing some flexibility in the operation of the SPR sites. In fact, there are signs that China has actually allowed crudes from the initial four Phase I sites to be drawn and refilled. Overall, China's SPRs can be divided into three categories: truly national SPRs, commercial storage by state oil companies, and commercial storage by local government or private companies.

3.3. Unconventional gas development

While there are three major unconventional gas reservoir types: tight gas, CBM, and shale gas, the focus here is only on CBM and shale gas. China has been producing tight gas since the late 1990s. It began exploring for and utilizing CBM in the 1990s but the development has progressed rather slowly. As for shale gas, China began researching it in the early 2000s, but the actual exploration activities did not start until the end of 2009. Thus, the history of shale gas development in China is much shorter.

The major questions surrounding China's unconventional are: Does China have reliable CBM and shale gas resources? Can

China's CBM industry overcome the hurdles it has been facing since the 1990s to have a healthy growth? How soon can China's shale gas sector take off? What are the challenges for CBM as well as shale gas developments? Does the government provide enough incentives? And ultimately, what is the future of unconventional gas development in China? These questions are addressed briefly in this section.

China has vast resources of both CBM and shale gas. Based on China's own survey, its CBM resources are massive, estimated at 36.81 trillion cubic meter (m^3) within the depth of 2000 m (m) beneath the surface (Wang, 2013). Despite this, the cumulative proven geological reserves at the start of 2012 were only 365 billion m^3 , a tiny fraction of the claimed resources.

Compared to CBM, the exploration of shale gas in China began at a much later stage. Current estimates for shale gas resources vary, ranging from 26 to 45 trillion m^3 . In April 2011, the US Energy Information Administration (EIA) released a report assessing the shale gas resources of 14 regions outside the US and put China's resources of shale gas at around 36 trillion m^3 (EIA, 2012).

China has not yet established proven reserves for shale gas. Locations where potential proven reserves are include: North China, Northeast China's Songliao Basin, Tarim Basin, Sichuan Basin and Ordos Basin in Northwest China.

In terms of production, after over one and a half decades, China is producing some CBM. Around half of the country's coal mines have a high concentration of methane. Since the 1990s, China has been exploring for and utilizing CBM. The extraction and utilization of CBM entered a new stage of development after the establishment of the state-owned China United Coalbed Methane Corp (CUCBMC) in 1996. However, the progress for CBM production and commercialization in China was slow during the subsequent ten plus years. As such, CUCBMC was restructured in 2007 and the Chinese government has since urged CUCBMC, the new comer PetroChina, and other players to step-up efforts to develop CBM.

There are two ways to produce CBM in China: (1) surface production where CBM is produced from dedicated wells, and (2) associate production where CBM is extracted from coal mines. In 2012, China produced 12.5 billion cubic meters (m^3) of CBM, of which 2.6 billion m^3 were from surface wells and 9.9 billion m^3 were from coal-mine extractions (see Wang, 2013). For surface CBM development, more than 5400 wells were drilled between the mid-1990s and the start of 2012. So far CBM capabilities have been established for 10 coal mines including Yangquan, Huainan, Huaibei, Shuicheng, Panjiang, Songzao, Jincheng, Fushun, Jixi, and Ningmei, each of which has a CBM production capacity of around 1 billion m^3 or higher. For surface CBM, demonstration, development, and production projects have been established at the Qinshui Basin of Shanxi Province, Fuxin Basin of Lianning Province, and Hancheng in the Ordos Basin of Shaanxi Province.

Only a little over 20 percent of China's CBM production in 2012 came from CBM wells and as much as 80 percent of the total comes from CBM extractions in coal mines. This is one of the challenges China is facing, where the surface production levels are very low. Given the fact that each year over 20 billion m^3 of CBM is emitted from coal mines, the extracted CBM accounts for less than half of the total.

Until late 2010, China had produced no commercial volumes of shale gas. However, since 2010, gas began to flow in various shale gas wells by PetroChina, Sinopec, and their partners. As of April 2012, 63 test wells had been drilled, including 58 shale gas wells (with 15 of these horizontal) and five shale oil wells. The Ministry of Land and Resources (MLR) held China's first round of shale gas bidding in July 2011, offering six blocks and in the end two were awarded to Sinopec and Henan CBM Company. In October 2012, the second round of shale gas bidding was held

by the MLR with 20 blocks being offered. In January 2013, 19 blocks were awarded to 16 domestic Chinese companies, including six state-owned enterprises, eight companies owned by local governments and two private-owned companies (Platt's, 2013).

Compared to CBM production, the actual utilization of CBM is even lower. While around three-quarters of CBM production from surface wells is used, only one-third of the extracted CBM is actually consumed. Altogether, the overall utilization of CBM was around 42 percent of total CBM production in China in 2012.

Many players are currently involved in the CBM business. Among them, PetroChina, CUCBMC, CNOOC, Shanxi Coal Group, and Sinopec are the major ones, followed by other coal companies. Sinopec and CNOOC are new to the CBM business. Prior to 2008, CUCBMC was dominant in China's CBM development but the role of PetroChina accelerated since its separation from CUCBMC. So far, however, PetroChina, CUCBMC, and CNOOC—after its acquisition of a 70 percent stake in CUCBMC in early 2013 (China Energy News, 2013)—are the leading players. Among others, Henan CBM Company, established in 2007, has also been active.

Foreign investors have been attracted to China's CBM business because of a series of preferential policies that encourage and support overseas investment. CUCBMC presently has cooperative CBM contracts with international companies from the US, Canada, Australia, and Hong Kong. Separately, PetroChina has contracts with 10 international companies from the US, UK, Canada, Australia, and Hong Kong.

Foreign participation has proved to be vital in the development of China's CBM sector. Firstly, it helps China obtain needed capital to develop the CBM sector rapidly, as E&P requires a large investment. Secondly, it helps China's domestic companies be free of the investment risks of CBM exploration because based on the contract terms, foreign investors will be responsible for the exploration cost themselves. Thirdly, the most important, is that foreign investors not only have mature and advanced CBM E&P technologies, but also management skills to develop a CBM industry system, which is particularly important for China's young CBM industry.

Shale gas has a much shorter history in terms of exploration. Although CNPC/PetroChina, Sinopec, CNOOC, Yanchang Petroleum Co., and foreign partners foreign companies have been conducting shale gas exploration activities, as mentioned earlier, the majority of the winners under the Chinese government's second round of shale gas bidding in early 2013 were other Chinese companies, including coal and power companies as well as companies owned by local governments.

With increasing pressure to promote coal mine safety, reduce greenhouse gas emissions and supply more clean energy, the Chinese government has increasingly paid considerable attention to the development and production of CBM. Since 2005, a series of development plans and preferential policies have been issued by the government to encourage the development and use of CBM, including tax reductions, financial support and other forms of support. Currently, these preferential policies and incentives cover the areas of value-added tax (VAT), accelerated depreciation, income tax, new equipment investment, CBM for power generation, resource tax, import duties, CMB pricing, and a subsidy on CBM production.

At present, China does not have separate policy incentives for shale gas. However, the same or similar policy measures and incentives for development of CBM are expected to apply to shale gas as well.

Although exploration, development, and utilization of CBM remains at low levels at present, the potential for China's CBM industry is still large due to the rich resources, solid government support with a series of preferential policies, and foreign participation.

China's plans for future CBM exploration, development, and production have been ambitious but the results have generally been disappointing. As it stands now, China has failed to reach most of the CBM targets in the 11th FYP. Under the 12th FYP (www.ndrc.gov.cn), the Chinese government set new targets to add 1 trillion m³ of proven geological reserves, produce 30 billion m³ of CBM and consume 24 billion m³. For shale gas, the 12th FYP (<http://zfxgk.nea.gov.cn>) called for proven geological reserves to reach 600 billion m³ and the production and consumption to reach 6.5 billion m³ in 2015 from nothing in 2010.

In the short run, China's CBM and shale gas developments face many challenges. Although the government is eager to develop unconventional gas, particularly the uncontested shale gas, the targets set by the Chinese government under the 12th FYP seem too ambitious. For shale gas, the challenges include complicated geological conditions, water shortages, technical and environmental constraints, disorganization of local companies outside the Chinese majors, issues related to transporting and sending shale gas to end markets, huge investment costs and unattractive economics of drilling, and fragmentation of the Chinese natural gas markets associated with low prices. For CBM, there are many impediments that have affected China's CBM development over the past 10 to 15 years. For the coming decade, in order to develop the CBM industry, China must overcome these challenges and take further specific and favorable measures and policies. First, China needs to make greater efforts to expand CBM exploration activities in order to significantly increase the proven part of the resources. Lack of funding for CBM development was one of the major obstacles in the past. Second, to overcome the unique and often difficult geological conditions for CBM E&P and to massively produce CBM, the Chinese must introduce advanced technologies and develop technologies of their own to achieve their targets. Third, as in the case of natural gas, the E&P of CBM have to be accompanied by the construction of pipelines to transport CBM to consuming centers. China should expand to construct more pipelines in the future. Fourthly, China has to establish the market-based regulatory framework and institutions for the healthy development of the CBM industry. Fifthly, is the problem of overlapping rights of CBM development vs. coal mining by various players, particularly among local coal mining companies. Finally, although a series of promotional policies have been issued, they are generally inadequate, vague, and temporary. The government should further specify the preferential tax and financial policies and make the support long term, transparent, and stable. For instance, the government should set a longer period of time, such as 20 or 25 years, for exempting CBM E&P from paying the resource tax. It should also increase the number of years where zero income tax is applied to CBM operations.

In the long run, however, China's unconventional gas development seems positive. If it can overcome the above challenges one by one, there are likely chances for the unconventional gas sector to take over. By 2030, CMB and shale could play important roles in boosting gas consumption in China, with potential impacts on pipeline gas and LNG.

4. Conclusions and policy implications

Two decades ago, China was a net exporter of coal and managed to satisfy its domestic oil demand and small base of natural gas use with domestic supplies. That has since changed fundamentally. China has not only has joined the ranks of many Asian countries in becoming a net importer of all types of fossil energy, but also become the largest coal importer, second largest oil importer, and a growing importer of natural gas in the world.

Still it took a few years for the Chinese government to realize the importance of energy security after China became a net oil importer in 1993. Energy security was given a prominent focus and high priority during the 10th FYP (2001 to 2005) with many measures entered into the implementation stage during the 11th FYP (2006 to 2010), with two elements standing out, namely the establishment of the SPRs and expansion of overseas energy investment. Under the current 12th FYP (2011 to 2015), the Chinese government has moved to address the management of overall energy use, diversification of energy supplies, energy conservation, and new energy development (including the development of unconventional gas) as broad ways to address the issue of energy security.

Our findings suggest that, first of all, the Chinese government has promoted overseas investment strongly. Secondly, its SPR program has been established though the progress in Phase II has been slower than expected. Last, but not the least, the government intends to boost the unconventional gas sector development. In a nutshell, the government now plans to triple the size of SPRs, encourage its NOCs to invest more aggressively overseas into areas such as unconventional gas, deepwater drilling, oil sands and other frontiers, and to set ambitious targets for the development, production, and consumption of CBM and shale gas at home.

However, the challenges are enormous. Unlike many other social and economic indicators where growth targets have often been exceeded during the five-year plans or programs, China has often failed to reach its energy efficiency, conservation, overall energy use, emission controls, CBM development and development of certain renewable energy resource targets, etc. Above all these, energy security is looming large for the Chinese government, and will undoubtedly become a bigger issue by the time the 12th FYP concludes. Under these circumstances, the Chinese government should address the following issues for each element discussed in this paper. For overseas oil investments, the challenge is for China to make wise decisions economically, environmentally, and politically. For SPRs, China should establish a system that SPR facilities truly address the issue of energy security rather than just another tool to manage oil supply and demand in the country. On unconventional gas development, China has much more to do to liberalize the market and provide sound economic incentives for domestic as well as foreign investment in this area.

As for future research, other elements for each dimension of energy security should be reviewed to reach a comprehensive conclusion about how well China has done and what steps are needed to move forward. Many elements are spelled in the literature review for China's energy security strategy. Eventually, the military and national security elements should be addressed as well.

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