Energy Policy ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Analysis of rationality of coal-based synthetic natural gas (SNG) production in China

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HIGHLIGHTS

- Life cycle costing was applied on the coal-based SNG.
- The SNG was compared with conventional fuels of three residential applications.
- The SNG is not so cost-effective except of household use.
- Ecological compensation policy is useful to deal with the transfer of pollutions.

ARTICLE INFO

Article history:
Received 7 January 2014
Received in revised form
11 March 2014
Accepted 14 April 2014

Keywords:
Synthetic natural gas (SNG)
Life cycle costing
Environmental emission

ABSTRACT

To alleviate the problem of the insufficient reserves of natural gas in China, coal-based synthetic natural gas (SNG) is considered to be a promising option as a source of clean energy, especially for urban use. However, recent study showed that SNG will not accomplish the task of simultaneous energy conservation and CO_2 reduction. In this paper, life cycle costing is made for SNG use in three main applications in residential sector: heating, household use, and public transport. Comparisons are conducted between SNG and coal, natural gas, liquefied petroleum gas (LPG), diesel, and methanol. The results show that SNG is a competitive option only for household use. The use of SNG for heating boilers or city buses is not as cost-effective as expected. The biggest shortcoming of SNG is the large amount of pollutants generated in the production stage. At the moment, the use of SNG is promoted by the government. However, as shown in this paper, one can expect a transfer of pollution from the urban areas to the regions where SNG is produced. Therefore, it is suggested that well-balanced set of environmental damage-compensating policies should be introduced to compensate the environmental losses in the SNG-producing regions.

1. Introduction

As recently reported, China has surpassed U.S. to become the country with the largest energy consumption in the world (Zhang and Yang, 2013). In 2012, the total energy consumption in China reached 3.62 billion (10^9) tonnes of standard coal equivalent (tce) (National Bureau of Statistics of China (NBSC), 2013). The structure of Chinese energy resources is different than that in U.S., Japan, or EU (Cao and Bluth, 2013). Coal was the dominant energy source, satisfying 67.4% of the national energy demand, followed by oil, 19.0%, and natural gas, 5.3% (NBSC, 2013). The coal-dominant structure causes a dangerous air pollution which becomes one of the most acute environmental hazards. A well-known example is air quality in Beijing. There, the thick fog and haze, caused mainly by vehicles and high coal consumption, could often limit the visibility.

China has undertaken many actions to improve the situation. One of the examples is increasing use of clean energy e.g., natural gas and renewables (particularly wind and solar energy) (Zhang et al., 2013). The implemented policies resulted in the increased use of the non-coal energy sources from 9.6% in 2006 to 13% in 2011 (NBSC, 2012b). Natural gas is the favourable option for Chinese enterprises and government. This trend is justified by the strong demand for clean energy as well as the maturity of natural gas technologies.

In consequence, China increased its production of natural gas by 6.7% year to year to reach 107.2 billion m^3 in 2012 (NBSC, 2013). However, the current production level could not match the demand for natural gas. To handle this problem, China has signed many

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http://dx.doi.org/10.1016/j.enpol.2014.04.018
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Nomenclature

CG	coal gas
CIF	cost, insurance and freight
CRF	cost recovery factor
EU	European Union
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MEP	Ministry of Environmental Protection, China
MIIT	Ministry of Industry and Information Technology, China
MOR	Ministry of Railway, China
NBSC	National Bureau of Statistics of China
NDRC	National Development and Reform Commission, China
NG	natural gas
PM	particulate matters
SNG	synthetic natural gas
SPAs	sales and purchase agreements
tce	tonne of standard coal equivalent
VOC	volatile organic compounds

long-term LNG sales and purchase agreements (SPAs) as well as pipeline gas import contracts with Kazakhstan, Turkmenistan, Burma, Indonesia, Malaysia, Iran, Australia and Russia (Wang et al., 2013). According to the statistics of BP (2013), the import of LNG is 20 billion m^3 and pipeline gas 21.4 billion m^3 in 2012. It made 28% of natural gas consumption in China that year.

Coal conversion, i.e., coal to synthetic natural gas (SNG), is another important way of increasing the supply of natural gas. The rich coal deposits are located in Inner Mongolia and Xinjiang. Both the regions are situated far away from the eastern coast, the major area of natural gas consumption. In both regions, several coal-based SNG plants have been constructed in recent years. As of October 2013, the Chinese government has approved ten large SNG projects with a total capacity of 67.1 billion m^3/y, as shown in Table 1 (Yang and Jackson, 2013; Xinhua News, 2013a). Moreover, there are about 54 SNG projects in a planning stage with a total capacity of 163.8 billion m^3/y of SNG (ICIS, 2013).

The growing interest in SNG stimulates scientific research and technical analysis focused on reaction kinetics, catalysts, system analysis and integration of this process. For example, Li et al. (2013a) proposed an enhanced fluidized bed methanation reactor with higher CO conversion, CH_4 selectivity and yield, and better carbon resistance than the fixed bed methanation reactor under high temperature. Liu et al. (2009) reported that the SNG processes using long flame coal has the efficiency around 45.98% while those with lignite has efficiency up to 52.57%. According to Li et al. (2013b), a SNG process applied to co-production of electricity could boost the energy efficiency by 11% compared to a single process.

However, there have been a few controversies whether large-scale development of SNG is really cost-effective and what its applications should be preferred. The technical maturity of SNG also evokes mixed reactions (Huo et al., 2013). Ding et al. (2013) argued that the coal-based SNG will not accomplish both the tasks of energy conservation and CO_2 reduction from the life cycle perspective. Yang and Jackson (2013) stated that CO_2 emissions, water needs and wider environmental impact associated with coal-based SNG are mostly neglected and could mislead China into an unsustainable development path. However, despite the above mentioned controversies, there is a serious risk of large-scale SNG investments due to the growing public pressure.

In China, the natural gas consumption is related mainly to four types of applications: residential, power generation, as raw material for chemical processing, and fuel for industry. In Fig. 1, there are shown data of natural gas consumption in 2000 and 2011. It could be seen that in 2000 the shares of the above mentioned sectors were 12%, 14%, 38%, and 36% (NDRC, 2012a). However, in 2011 these quotas were 36%, 17%, 23%, and 24% (NBSC, 2012a). It is observed that the proportion of natural gas used for residential purposes rised sharply. And simultaneously, there is a considerable decline in industrial use of natural gas.

The Chinese government has adopted the set of policies for regulating the use of natural gas from coal in different sectors (NDRC, 2012b). Natural gas is still allowed to be used for power generation and as industrial fuel. However, its use for chemicals production is now practically prohibited. For example, natural gas-based methanol production has been prohibited since 2007. At present, the use of natural gas for residential applications is favoured in China.

The use of natural gas is an important factor contributing to improvement of life quality of the residents and environment in urban areas. Therefore, it is estimated, that with the fast

Table 1
National government-approved SNG projects (Yang and Jackson, 2013; Xinhua News, 2013a).

Company	Location (Region/locality)	Planned capacity (billion m^3/y)
Datang	Inner Mongolia/Chifeng	4.0
Datang	Liaoning/Fuxin	4.0
Huineng	Inner Mongolia/Ordos	1.6
China Kingho Group	Xinjiang/Ili	5.5
CPI Corporation	Xinjiang/Ili	6.0
Xinwen Mining Group	Xinjiang/Ili	4.0
Guodian	Inner Mongolia/Hinggan League	4.0
CNOOC	Shanxi/Datong	4.0
Xinmeng Energy	Inner Mongolia/Ordos	4.0
SINOPEC	Xinjiang/Changji	30.0

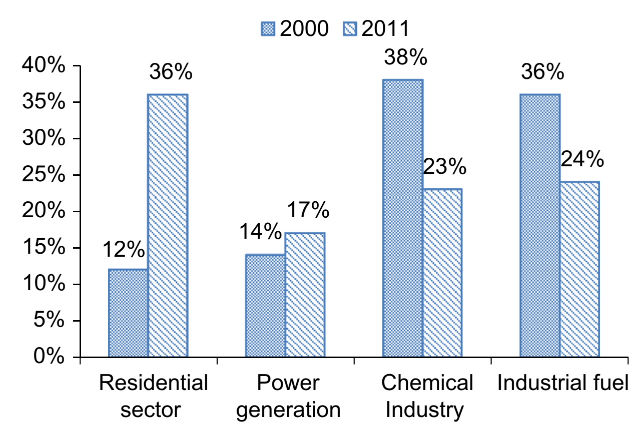

Fig. 1. The structure of natural gas consumption in China.