Energy Policy 117 (2018) 58–65

Contents lists available at ScienceDirect

Energy Policy

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

Coal-to-liquids projects in China under water and carbon constraints

Meiyu Guo[a], Yuan Xu[b,*]

[a] *Department of Geography, Hong Kong Baptist University, Hong Kong, China*
[b] *Department of Geography and Resource Management & Institute of Environment, Energy and Sustainability, The Chinese University of Hong Kong, Hong Kong, China*

ARTICLE INFO

Keywords:
Coal to liquids
Carbon capture and storage
Energy and water
China

ABSTRACT

Coal-to-liquids projects have become more and more significant in China, while water and carbon constraints as well as profitability concerns make them highly controversial for policy makers. This article analyzes the situations and shows that the limitation of coal resources could be relaxed through using coal in far regions, especially in Xinjiang, which are less developed at present. Coal-to-liquids projects could greatly reduce the negative influence of transportation costs. The limitation of water resources might also be solved with desalinating fossil water from deep saline aquifers. Since water costs are only a small fraction of the total cost, the economy of coal-to-liquids projects are not affected much. In addition, the use of fossil water could promote carbon dioxide capture and storage (CCS) and reduce CO_2 emissions. However, given the current coal and oil prices, the potential profitability of those projects with or without CCS is seriously negative in all major coal producing regions.

1. Introduction

Since becoming a net oil-importing country in 1993, China's oil import has been increasing rapidly. In 2013, it reached 342 million tons, which accounted for 69% of China's total oil consumption (National Bureau of Statistics of China, 2016). This high oil dependency gives a great pressure to China's energy security and forces the government to pay more attentions on its domestic oil production. Apart from oil and natural gas reserves, China is rich in coal. In 2015, China's proved coal reserves were about 126 billion tons and accounted for more than 12% of the world's reserves (BP, 2016). It is the biggest coal producer and consumer in the world.

As an alternative supply of oil in China, coal-to-liquids (CTL) has received much attention in recent years. In 2014, the National Development and Reform Commission (NDRC), the National Energy Administration (NEA) and the Ministry of Environmental Protection (MEP) jointly issued a plan for energy industry to strengthen the work on air pollution control, in which coal-to-liquids (CTL) was specified as an important and cleaner source of oil with expected production of 10 million tons in 2017 (NDRC et al., 2014). By 2015, the completed production capacity of CTL projects in China has reached 0.3 million ton/year locating mainly in Shanxin, Shaanxi and Inner Mongolia (Sublime China Information Group, 2015). However, the coal-to-liquids plan faces severe constraints from especially coal, water and CO_2 perspectives.

First, China's coal resources are unevenly distributed with serious transportation constraints, and only limited reserves are of high quality. Based on geographical locations, China's provinces are divided into five regions in terms of coal production and consumption (Table 1), which are coastal provinces, North China coal region, Xinjiang, Guizhou and the rest China. It shows that coal distribution, consumption and production regions in China are sharply divided. Most of coal resources were consumed in coastal provinces with only 2.9% of coal resources and 8.2% of coal production, while North China coal region has more than 43% of coal resources and nearly 70% of coal production, but only 23.5% of consumption. Because of the uneven distribution, demand and supply of coal resources, China has a great scale of coal transport, mainly by railway. The typical distances from three major coal production regions, Xinjiang, Guizhou and North China coal region, to a coastal province are also listed in Table 1, which shows that Xinjiang with abundant coal resources is the farthest one to the major coal consumption area. Transportation cost occupies a big share of the total cost of coal production. In addition, China's railway transportation capacity for coal resources is significantly restricted. These explain the paradox of the distribution and the production of China's coal. For example, in 2014, Xinjiang only produced 3.7% of China's coal output while its coal resources have a share of 39.6% (National Bureau of Statistics of China, 2016). However, the coastal region owns only 2.9% of China's total coal resources, but produced 8.2% of the total output. Furthermore, China's high-quality coal reserves is limited. The bituminous and anthracite coal comprises 54% of China's total coal reserves, while the proportion of coal with sulfur content below 1% is only about

* Corresponding author.
E-mail address: yuanxu@cuhk.edu.hk (Y. Xu).

https://doi.org/10.1016/j.enpol.2018.02.038
Received 27 July 2017; Received in revised form 15 December 2017; Accepted 24 February 2018

Table 1
China's coal production and consumption regions.

	Coal Resources (Sinton, 2004)	Coal Production in 2014 (National Bureau of Statistics of China, 2016)	Coal Consumption in 2014 (National Bureau of Statistics of China, 2016)	Typical distance to a coastal province (km) (Huochepiao, 2017)	Total Water Resources (National Bureau of Statistics of China, 2016)
Coastal Provinces	2.9%	8.2%	40.0%	0	27.3%
North China coal region	43.7%	65.3%	23.5%	673	3.8%
Xinjiang	39.6%	3.7%	3.7%	4047	2.7%
Guizhou	4.2%	4.8%	3.0%	1552	4.5%
The rest China	9.6%	18.0%	29.8%		61.7%

Notes: (1) Coastal provinces include Liaoning, Tianjin, Beijing, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi and Hainan. North China coal region covers Shanxi, Shaanxi, Ningxia and Inner Mongolia. The rest China includes Gansu, Tibet, Qinghai, Sichuan, Chongqing, Yunnan, Hunan, Hubei, Jiangxi, Heilongjiang, Jilin, Henan and Anhui. (2) The typical distance to a coastal province is calculated as the railway length from a key location in the coal production region to a consumption or transport center in a coastal province. For North China Coal Region, the distance is calculated between Datong, Shanxi province, to Qinhuangdao (a harbor city), Hebei province. The typical distance for Xinjiang is taken as the railway length between Urumuqi and Shanghai. From Guiyang, Guizhou province to Guangzhou, Guangdong province, the train travels 1552 km.

63% (Sinton et al., 2004). Coal in southwest China, especially in Guizhou province, has the worst quality with average sulfur content at a dry basis of 2.43% and only 13.2% of total coal resources has a sulfur content lower than 0.5% (Sinton et al., 2004). In addition, although the total reserves of coal in China is significant, its reserve-to-production ratio was only about 30 years in 2015 (BP, 2016).

Second, China's major coal production regions are facing to severe water constraints. Table 1 shows the availability of water resources in the five regions. For North China coal region and Xinjiang that have 83.3% of China's coal resources, the share of total water resources is only 6.5%. Furthermore, they have the highest withdrawal-to-availability ratio of water resources in the world, generally over 0.4 and even reach 0.8 (National Bureau of Statistics of China, 2015). However, water is a vital part in coal-to-liquids projects and coal-to-liquids conversion is classified as a highly water intensive process (Mielke et al., 2010; Rong and Victor, 2011; Zhang et al., 2009). In this sense, it is difficult to meet the substantial water demand for coal-to-liquids projects by withdrawing water from current sources.

Third, under the pressure of carbon reduction in the Paris Agreement era, China's CTL projects face to both opportunities and challenges. In the Intended Nationally Determined Contribution (INDC) submitted for the Paris Agreement in 2015, China committed to peak its CO_2 emissions by around 2030 and lower carbon intensity by 60–65% from the 2005 level (NDRC, 2015). On the one hand, though coal reliance needs to be cut, promoting the clean use of coal would be a significant measure in addition to consumption reduction considering the abundant coal resources in China. CTL projects can provide coal-based substitutes for conventional oil, and at the same time realize the clean use of coal by reducing the emissions from direct combustion (The State Council, 2014). On the other hand, China's CTL projects face to the challenges of carbon reduction in industrial process, for example, the uncertainties of carbon capture and storage (CCS) technologies (Fu et al., 2015), especially after the initiation of China's carbon emission trading pilots in seven areas. Though compulsory measures for carbon emission reduction in oil and gas industry are still lacking in China, a domestic market-based emission trading system has been established, which indicates the significance of Chinese Certified Emission Reductions (CCER) and shapes a picture of future national regulations and trading system of carbon emissions (Zhang et al., 2014).

On July 17, 2014, the NEA issued regulations to guide and restrict the development of CTL projects motivated by concerns over coal and water constraints in China (National Energy Administration, 2014). Stricter approval standards have been adopted to new CTL projects: firstly, provinces with net imports of coal are not allowed to develop CTL projects due to the constraints of coal resources; secondly, CTL projects cannot use groundwater, compete for water resources with agricultural, domestic and ecological uses or get start in the areas that have exceeded the standards of water withdrawal and water pollution. In addition, carbon emission concerns also put pressure on the government to reject new CTL projects.

This article analyzes the potential impacts of these constraints on China's CTL projects development. Section 2 sets up and describes an integrated CTL system composed of a CTL plant, a combined-cycle power plant, a hybrid cooling system, fossil water withdrawal and concentrate disposal, desalination and water treatment plants and a CO_2 capture and storage system. Section 3 analyzes the potential of China's CTL projects development based on the proposed CTL system from an economic perspective considering the constraints of water resources and CO_2 emissions. Sensitivity analyses are performed. Section 4 draws the main conclusions of the paper that China's development of CTL projects can technically realize the clean use of coal and release the pressure of high oil dependency even considering the constraints of water resources and carbon emissions; however, under the current prices of coal and oil, CTL projects are estimated to be unprofitable in all major coal producing regions in China.

2. An integrated CTL system

Because of the concern of water scarcity, the coal-to-liquids systems in this article also include a combined cycle power plant to provide electricity, a desalination plant to desalinate fossil water, a water treatment plant to recycle waste water, a fossil water extraction and concentrate disposal station, and a carbon storage station. The whole system scheme is showed in Fig. 1. Major components in the system are described in details.

2.1. The cogeneration plant

The basic parameters of the coal-to-liquids plant and the combined cycle power plant of the baseline coal-to-liquids system are listed in

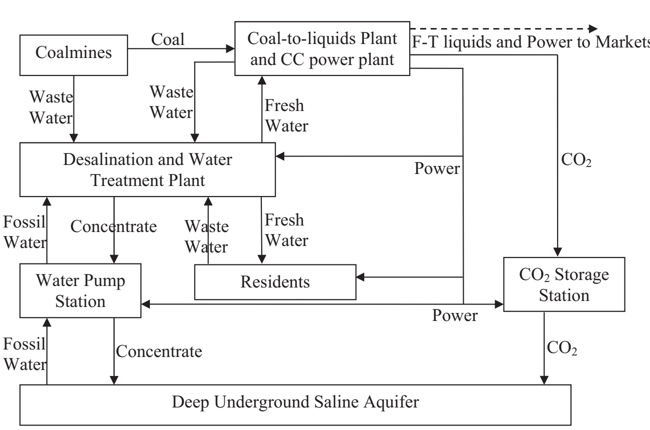

Fig. 1. Scheme of the F-T liquids system.