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Coal-based synthetic natural gas vs. imported natural gas in China: a net energy perspective

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ABSTRACT

China has two choices to meet the gap between its gas demand and supply in the short term: coal-based synthetic natural gas and imported natural gas. China currently faces the following question: between coal-based synthetic natural gas and imported natural gas, which is the better choice for China? To provide a reference for policy makers and investors, this paper compares the energy efficiency of the Datang coal gasification project, which is the first demonstration project in China, with that of imported natural gas by an energy return on investment analysis. The results show that when the environmental inputs are not considered, the energy return on investment values of coal-based synthetic natural gas with different boundaries range from 1.7:1 to 6.9:1. The values of the total imported natural gas decreased from 14.5:1 in 2009 to 7.5:1 in 2014 and then increased to 9.2:1 in 2015. When the environmental inputs are considered, the energy return on investment values of coal-based synthetic natural gas and that of imported natural gas decrease to 1.4:1–3.4:1 and 5.9:1–9.6:1, respectively. Regardless of whether the environmental inputs are considered, imported natural gas generally has a better energy return on investment than coal-based synthetic natural gas. These results suggest that from a net energy perspective, policy makers and investors should encourage to import more natural gas and be prudent about developing the coal gasification industry.

1. Introduction

The demand for natural gas (NG) as a replacement for more expensive, less environmentally friendly, and less efficient fuels has increased significantly in China. However, due to soaring gas demand, domestic gas production cannot meet the demand (Fig. 1). As a result, China began importing liquefied NG (LNG) in 2006. In China, the gap between domestic production and demand will increase rapidly in the future; according to the BP energy outlook 2035 (BP, 2015), this gap is expected to increase to 254 billion cubic metres (bcm) in 2035.

China has two choices to meet the demand for gas. The use of China's relatively abundant coal reserves to produce synthetic natural gas (SNG) is one way to relieve the pressure that is associated with NG shortages. As of October 2013, the Chinese government has approved ten large SNG projects with a total capacity of 67.1 bcm/y (Li et al., 2014). The other choice is imported natural gas (ING). Fig. 2 shows China's supplies of ING from different countries via LNG and pipelines in 2014.

The development of SNG has been controversial. Prior to 2013, the Chinese central government maintained a restrictive policy on the development of SNG and halted all SNG development except for 4 selected demonstration projects. However, in March 2013, months before the commercial commencement of the first SNG demonstration plant, the Chinese government suddenly changed its cautious and restrictive policy on SNG and began encouraging its development (Yang, 2015). Parallel to its more positive attitude to SNG, the Chinese government started to stimulate the development of ING, i.e. by providing importers with subsidies. However, for a long time, China's NG prices have been determined by the government, which has resulted in imported gas prices being higher than the domestic market prices. ING companies are experiencing

List of abbreviations: BOG, boil-off gas; CIF, cost, insurance, and freight; EROI, energy return on investment; ENI, environmental inputs; FOB, free on board; GDP, gross domestic product; ING, imported natural gas; LNG, liquefied natural gas; IO, imported oil; LCA, life-cycle assessment; NG, natural gas; SNG, coal-based synthetic natural gas; PM, particulate matter; VOC, volatile organic compounds.

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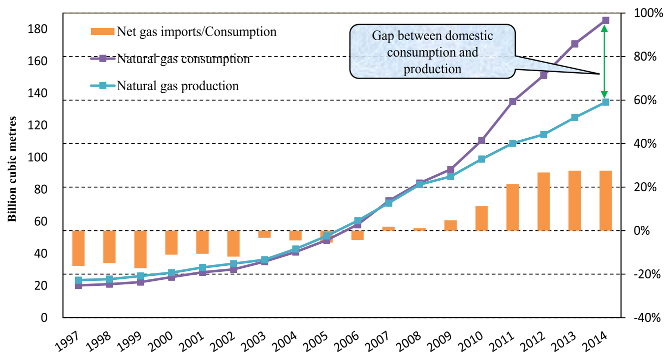

Fig. 1. Natural gas production and consumption in China.

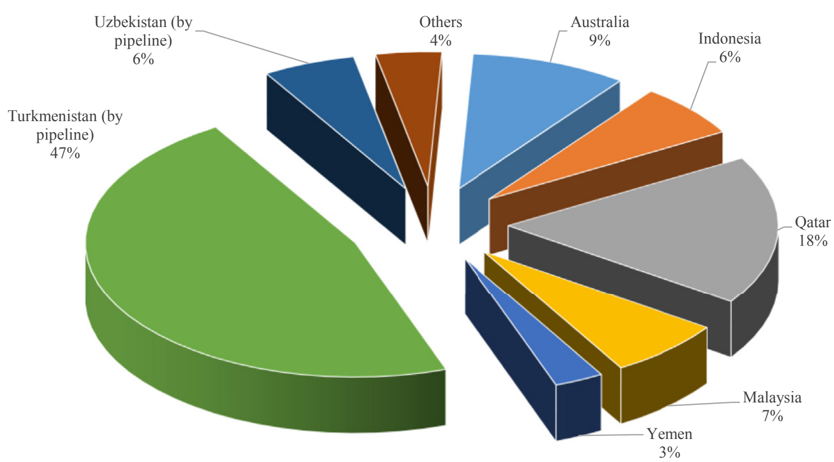

Fig. 2. Imported natural gas from different countries via LNG and pipelines in 2014.

considerable losses because of the relatively low terminal ING prices (Kong et al., 2015). Currently, China is facing the following question: is SNG or ING the better choice for China?

To answer this question, this study compares the energetic performance of SNG and ING in China using an energy return on investment (EROI) analysis, which is a useful approach for assessing the availability of an energy source. This paper calculates the EROI for the Datang SNG project in Chifeng, Hexigten, Inner Mongolia, which was the first SNG demonstration project in China, and estimates the EROIs of ING from different countries to China.

2. Literature review

EROI is a method to calculate how much energy is returned from one unit of energy that is invested in an energy-producing activity, which allows one to evaluate the energy production physically rather than monetarily (Hall, 2011). The concept of EROI originated from ecology (Xu et al., 2014). The term EROI was first used by, and it subsequently received significant attention in the journal Science (Hu et al., 2013). EROI has more utility than other metrics because it allows the fuels to be ranked and estimates to be made of their changing ease of extraction over time, which can also be interpreted as the difference between the effects of technology and depletion.

The methodologies for calculating EROI have been widely variable. Specifically, published values of EROI for similar fuels are sometimes significantly different as a result of the use of different boundaries and variables (Hall et al., 2014). However, in 2011, a standard was proposed by Murphy et al. (2011). The proposed standard included several boundaries, where different factors are included. This standard allows researchers to state which EROI they are referring to in their calculations. Atlason and Unnthorsson (2014a) presented a new EROI factor called the ideal EROI, or $EROI_{ide}$, which is the ratio between the inputs within the $EROI_{stnd}$ boundaries and the theoretical maximum output from a given system. $EROI_{ide}$ provides the theoretical upper boundary of the EROI of a given system and can be used to estimate the potential for improvement.

The EROI has been constantly improved in terms of the calculation method, boundary determination and applications. Many EROI studies have focused on oil and gas (Cleveland et al., 1984; Freise, 2011; Gagnon et al., 2009; Guilford et al., 2011; Hu et al., 2011, 2013). Almost all these analyses have shown that the EROI for oil and gas is high but is decreasing. Other papers have focused on other energy resources, such as coal (Cleveland et al., 1984; Hu et al., 2013), shale gas (Aucott and Melillo, 2013; Dale et al., 2013; Yaritani and Matsushima, 2014), tight gas (Sell et al., 2011), oil shale (Brandt, 2008, 2009; Cleveland and O'Connor, 2011), hydropower (Weißbach et al., 2013; Atlason and Unnthorsson, 2014b), wind (Brown and Ulgiati, 2002; Wagner and Pick, 2004), bio-fuels (Atlason and Unnthorsson, 2014b; Weißbach et al., 2013), wind (Brown and Ulgiati, 2002; Wagner and Pick, 2004), bio-fuels (Agostinho and Ortega, 2013; Aitken et al., 2014), and solar (Dale and Benson, 2013; Kubiszewski et al., 2009; Raugei et al., 2012). However, the peer-reviewed literature has paid only minimal attention to the EROIs of SNG ($EROI_{SNG}$) and ING ($EROI_{ING}$). Only a few papers have investigated the EROI of imported oil ($EROI_{IO}$), such as Hall et al. (2009) and Lambert et al. (2014). Moreover, the effects of environmental pollution control on the EROI have been ignored.

3. Methods

The general EROI equation is given in Eq. (1).

$$EROI = \frac{\text{Energy returned(outputs)}}{\text{Energy required(inputs)}} \quad (1)$$

Because the numerator and denominator are usually in the same units, the ratio is dimensionless and is often expressed as x:1, such as 10:1.

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