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A short-term based analysis on the critical low carbon technologies for the main energy-intensive industries in China

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ABSTRACT

The thermal power industry, the cement industry and the iron & steel industry are among the top energy consumers and air-polluters in China, which have significant impacts on climate change. The annual productions of these three industry sectors are all ranked as the top one in the world. In order to assist the short-term policy making for the development of critical LCTs in China, an evaluation of the performance of low carbon technologies (LCTs) for the top three energy-intensive industries in China is conducted in this paper through multi-criteria decision making (MCDM) method. There are 31 LCTs identified for these three industries based on the criteria including environmental performance, technological performance, and economic performance. Based on the experts' evaluation, top 10 LCTs are selected as the critical LCTs which should be given priority in the short-term technology diffusion in China. Suggestions are provided for policy-makers on the carbon mitigation and cleaner production in the main energy-intensive industries in China.

1. Introduction

As the largest energy consumer and the second largest economy in the world (BP, 2015), China plays an important role in fighting climate change and reducing carbon emissions. In 2015, China submitted the Intended Nationally Determined Contributions (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC), and set a target to cut down carbon emissions by 60–65% per unit of GDP by 2030. The ambitious carbon mitigation target of the Chinese government put great pressure on those energy-intensive industries in China, such as the thermal power industry, the cement industry and the iron & steel industry, which are also the key economic pillar industries in China (Jim et al., 2015; Li et al., 2013, 2014). According to China Statistics Yearbook 2016 (National Development and Reform Commission of China, 2016), the energy consumption of the three energy-intensive industries alone accounted for 29% of total energy consumption in 2015. Despite the great efforts that China has paid to carbon mitigation, there is still large room for carbon mitigation in those major energy-intensive industries (Wang and Chang, 2014a).

The power generation sector, as one of major sources of Green House Gas (GHG) emissions, consumes a large quantity of fossil fuels every year in China (Liu et al., 2009; Chang and Wang, 2010). Since 2006, Although the percentage of thermal power generation in the total power generation has decreased since 2006, its generation capacity has been increasing quickly during the same period, as shown in Fig. 1. Ranking as the top 1 in the world, the Chinese power industry generated 5811 Terawatt-hours electricity in 2015, accounting for 24.1% of the world's total power generation (BP, 2016). According to *China Electric Power Industry Annual Development Report 2016* released by the China Electricity Council, the overall installed power generating capacity has reached 1.52 billion kilowatts by the end of 2015, in which the installed capacity of thermal power was 1.00 billion kilowatts, accounting for 65.92% of total capacity (China Electricity Council, 2016).

Although the renewable energy technologies, such as hydropower, wind and solar power, have developed rapidly during the past decades, thermal power is the primary source for power generation in China. As Xie et al. (2012) pointed out, the thermal power, especially coal-fired-power, remained as the most dominating form of energy generation, accounting for more than 70% of total energy consumption (Xie et al., 2012).

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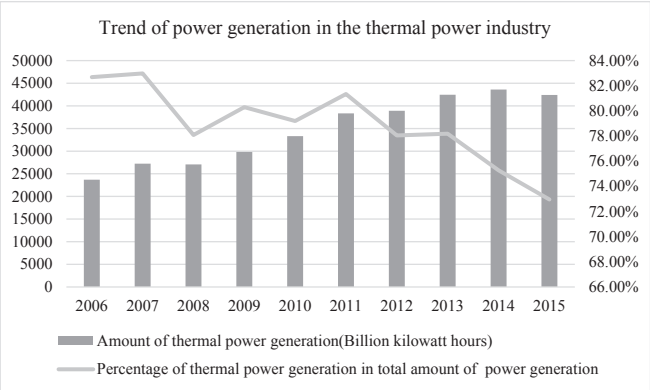

Fig. 1. The trend of power generation in the thermal power industry.

Another large energy consumer in China is the cement industry, which has also been identified as a critical emitter of air pollutant and environmental destroyer due to its contribution to Particulate Matter (PM), SO_2 and NO_x emission (Lei et al., 2011; Zhang et al., 2007; Ke et al., 2012). In China, the cement industry consumes 5%–8% of the country' total energy, and emits 15% of total GHG (Wen et al., 2015; Chen et al., 2014; Zhang et al., 2015a). Between 2006 and 2015, the cement production in China doubled as shown in Fig. 2. The cement production of China in 2016 was 2.41 billion tons, accounting for 57.38% of world cement production and ranked first in the world. China's clinker production was 200 million tons in 2016, accounting for 54.05% of world's cement clinker production and ranked the first in the world (U.S. Geological Survey, 2017).

Due to its carbon-based metallurgy, the iron & steel industry has become one of the largest energy consumer and the third biggest CO_2 emitter in China (Zeng et al., 2009). In 2015, China's crude steel production reached 803.8 million tons, accounting for 49.6% of world crude steel production and ranked the first in the world (World Steel Association, 2016). According to the 2015 National Economic and Social Development Statistics Bulletin and the China Statistics Yearbook 2016 (National Bureau of Statistics of the People's Republic of China, 2015; National Development and Reform Commission of China, 2016), China's total energy consumption had reached 4.3 billion tons of standard coal in 2014. The biggest contributor was the Black Metal Smelting and Rolling Processing Sector, consuming 693.4 million tons of standard coal. This sector alone accounted for 16.3% of national energy consumption and ranked first in all the industry sectors. Within the Black Metal Smelting and Rolling Processing Sector, the majority of productivity came from the iron & steel industry (CHYXX, 2016).

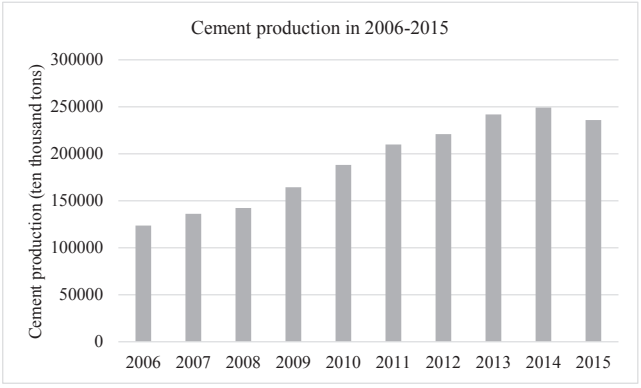

Fig. 2. Cement production of China in 2006–2015.

In recent years, the government has adopted a series of policies to promote LCTs and clean production in the energy-intensive industries (Wang and Chang, 2014b). The relevant policy and documentations in recent years are listed in Table 1 below.

Those government policies are mostly designed for the long-term development plan. However, there is a lack of short-term development guidance for the key energy-intensive industries such as the thermal power industry, the cement industry and the iron & steel industry. Due to the rapid technology development and upgrading speed, it is more meaningful to discuss the short-term strategies in LCTs diffusion than long-term ones. The determination of critical LCTs would assist policy-makers and industrial practitioners in China to conduct immediate promotion on the appropriate LCTs, and achieve low carbon development in a more effective way. The top energy-intensive industries in China, which consume extensively more energy than other industries, are considered to be of both low energy-efficiency and high carbon emissions (Li et al., 2014). As a developing country, China determines to achieve the carbon reduction target; however, it would never want to jeopardize industry capacity. It is, therefore, necessary to discuss the short-term strategies for carbon reduction plan including promoting of critical and effective low carbon technologies (LCTs) for these energy-intensity industries. The major challenge for the government would be transforming those large carbon emitters to cleaner production.

In order to achieve China's ambitious carbon reduction targets in a more efficient way, it is important to identify the critical LCTs for the energy-intensive and economic-significant industries. This paper sheds a light on the selection of the most critical LCTs to reduce carbon emissions in these three energy-intensive industries under a five-year short-term development view. The results can assist the short-term policy making for the government in targeting carbon emission for these energy-intensive industries in China.

2. Literature review

2.1. The role of LCTs

The role of LCTs in low carbon development and clean productions for energy-intensive industries had been discussed by researchers (Kemp and Volpi, 2008; Weyant, 2011; Wang and Chang, 2014b). For example, Pavic et al. (2016) considered that low carbon technologies (LCTs) were the essential link in the creation of sustainable energy future, redefines operation and planning concepts of traditional energy systems. Montalvo (2008) also stressed the importance of low carbon technologies in clean production and achieving low carbon target. In the research of He et al. (2012) discovered that the innovation of advanced LCTs was the foundation of low-carbon development and helped countries to enhance competitiveness in global market.

In the developing world, the LCT related topic also received great attention. Researchers Khosla et al. (2017) indicated the importance of low-carbon technology development and transfer for developing countries to assist in their growth, whilst fulfilling global climate objectives. Jacobsson and Bergek (2004) interpreted that technological innovation aiming for carbon reduction might lead to a complete transformation of the carbon-based socio-technical system. Qian (2012) believed that the transferring of LCTs from developed countries to developing countries could assist developing countries to reduce carbon emissions. Kennedy and Basu (2013) pointed out that LCTs could play a central role in meeting climate objectives, by exploiting sources of energy and allowing cheaper, cleaner and more efficient methods of converting energy into desired end use services. Furthermore, the importance of public support in LCT development was stressed by researcher