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Analysis of energy efficiency and carbon dioxide reduction in the Chinese pulp and paper industry

Lihong Peng [a,*], Xiaoling Zeng [a], Yejun Wang [a], Gui-Bing Hong [b]

[a] College of the Environment & Ecology, Xiamen University, Xiang'an South Road, Xiang'an District, Xiamen 361102, China
[b] Department of Chemical Engineering and Biotechnology, National Taipei University of Technology, No. 1, Sector 3, Zhongxiao East Road, Taipei City 106, Taiwan

HIGHLIGHTS

- Energy efficiency in pulp and paper industry changes markedly from 1985 to 2010.
- This paper will identify better opportunities for energy conservation in China.
- This paper will also confirm better opportunities for CO_2 emission mitigation.
- The negative factors do exist in the pulp and paper sector.
- Energy efficient policies are suggested, especially in short term.

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ABSTRACT

Pulp and paper production, an energy-intensive process, is among the main light industries contributing to energy saving and pollution emission reduction in China. The improvement of energy efficiency is essential for energy consumption and sustainable development. This study analyzes the negative factors in the pulp and paper sector by calculating energy efficiency from the lengthways time and investigating the gap between China and foreign countries through a horizontal comparison. Accordingly, energy efficiency has increased in the Chinese pulp and paper industry with years of efforts, but its transformation remains unclear. Furthermore, the energy-saving potential, energy cost saving, and carbon dioxide emission reduction in the pulp and paper industry are evaluated according to the Twelfth Five-year Plan (2011–2015). The results show that the pulp and paper industry has further capabilities for energy-saving and carbon dioxide emission reduction by improving energy efficiency in China, resulting in great economic benefit. In brief, new technology and energy structure adjustment are long-term strategies for energy conversation, with changes in the scale of mills expected to provide huge opportunities to improve energy efficiency in China within a short period.

1. Introduction

According to the International Energy Agency (IEA, 2012), 27.9% of the total final energy consumption in 2010 was due to various industries. Global carbon dioxide (CO_2) emission from energy consumption has grown at over 1.5% per year, from around 20 $GtCO_2$ in 1990 to over 26 $GtCO_2$ by 2005 (IPCC, 2007). Approximately, 36% of CO_2 emissions are derived from manufacturing industries, particularly pulp and paper, chemical, cement, iron and steel, and petrochemicals (IEA, 2007). Globally, the total industrial CO_2 emission was 13.21 $GtCO_2$ in 2010; Asia was the region with the fastest industrial greenhouse gas (GHG) emission growth between 2005 and 2010 (IPCC, 2014). The pulp and paper industry is an energy-intensive industry with a key function in CO_2 emissions. The pulp and paper industry accounted for 1.7% of the industry energy demand in China in 2010, and ranked above the light industry. The calculated CO_2 emissions of 39 Chinese industrial branches show that the pulp and paper industry was in the top 10 list (Li et al., 2012). Energy efficiency is one of the most significant and cost-effective methods for reducing energy use and CO_2 emissions in the coming decades (Worrell et al., 2009). Energy efficiency reduces energy resource depletion rates and mitigates

* Correspondence to: Room A117, College of the Environment & Ecology, Xiamen University, Xiang'an South Road, Xiang'an District, Xiamen 361102, China. Fax: +86 592 2181916.
E-mail addresses: lhpeng@xmu.edu.cn (L. Peng), xlzeng@stu.xmu.edu.cn (X. Zeng), wangyj@stu.xmu.edu.cn (Y. Wang), lukehong@ntut.edu.tw (G.-B. Hong).

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GHG emissions. It also provides options at low costs for both saving energy and choosing emission-reducing measures.

Studies worldwide are identifying diverse opportunities for sector-specific and cross-cutting energy-efficiency improvement and CO_2 emission mitigation for industrial sectors. The energy efficiency of the sector can be reduced through the wide-scale development of the best available technologies (BAT) (IPCC, 2014). Moreover, BAT Conclusions for the Production of Pulp, Paper, and Board was addressed on September 26th, 2014 in EU; it was designed to further raise the energy efficiency in this sector. The technical and cost-effective fuel-efficiency potentials in 2005 accounted for 16% and 19%, respectively, of the total fuel used in the cement industry in Thailand (Hasanbeigi et al., 2010). A cross-country comparison of the physical production data on developments in energy efficiency in the pulp and paper industry had been conducted (Farla et al., 1997). Potential savings for final energy use resulting from applicable sustainability options in pulp and paper making were estimated in 1994 and 2006 in the United States (Xu et al., 2013). The energy efficiency, energy saving potential, and CO_2 emission of the German paper industry were analyzed comprehensively (Fleiter et al., 2012). Opportunities for energy efficiency and GHG emission reduction, as well as the energy efficiency technologies, for the paper industry in the United States have been examined (Martin et al., 2000; Kramer et al., 2010; Xu et al., 2014). Empirical evidence on the potential of electricity efficiency improvement was presented by the Swedish pulp and paper industry (Blomberg et al., 2012). Technical energy measures in the Swedish pulp and paper mills that enhance energy efficiency to achieve CO_2 reduction and determine its cost had been investigated (Mõllersten et al., 2003). To reduce energy use and GHG emissions, 36 emerging technologies were evaluated (Kong et al., 2014a). Given that energy use reduction can save cost, the Pulp and Paper Research Institute of Canada illustrates the potential for reducing energy consumption and GHG by benchmarking. The aforementioned studies are only a few of the many studies that have been conducted on energy efficiency in the pulp and paper industry.

Many studies in the Chinese pulp and paper sector differ in focus, energy situation, technology, and calculation of CO_2 emissions. Li (2011) analyzed the energy use and measures to save energy in the pulp and paper industry. Several studies have summarized the energy-saving technology and equipment in this industry (Guang, 2010; Liu et al., 2010; Zhang et al., 2009; Zhang, 2013). Kong et al. (2011) appraised the energy-saving potential and technology application during the papermaking process. Tang and Zhao (2012) discussed the methods to calculate the CO_2 emission factors on the basis of the production process in the pulp and paper industry. However, studies on the energy efficiency of the pulp and paper industry in China are limited. The potential of 23 technologies and measures to improve energy efficiency in Chinese pulp and paper sector can be evaluated using the bottom-up method (Kong et al., 2014b). Kong et al. (2013) identified the energy conservation potential and CO_2 mitigation opportunities at a paper mill in Guangdong Province through an energy audit. Lin (2012) analyzed six large papermaking enterprises in Nanning, where an energy efficiency appraisal system had been established. Sun et al. (2011) evaluated the energy efficiencies of 14 industrial sectors (including the pulp and paper sector) between 1987 and 2005.

This study analyzes the available energy saving and CO_2 emission mitigation potentials in the Chinese pulp and paper industry by combining energy efficiency indicator and a scenario analysis. First, changes in Chinese energy efficiency are determined by calculating the specific energy consumption (SEC) values of products in the pulp and paper industry from 1985 to 2010. Subsequently, we analyze the negative factors that degrade the energy efficiency of the sector by horizontally comparing different regions. In view of the current status of energy efficiency, detailed policy recommendations are discussed. This analysis can serve as a reference for energy efficiency improvement.

2. Methods

2.1. Material overview

In the pulp and paper industry, fibrous raw materials are converted into pulp, paper, and paperboard. The global paper and paperboard production was approximately 394 million tons in 2010. The share of paper and paperboard production in China has increased from 15.3% to 23.5% in five years. Fig. 1 shows the regional shares of paper and paperboard production in 2010. The pulp and paper sector is closely related to the national economy of China. With its rapid economic development, China has become one of the largest consumers of global paper products, with enormous opportunity for further development. China is currently the largest producer of paper and paperboard in the world, with a production of 92.7 million tons in 2010. The production rate is growing rapidly. It increased by 7.3% from 2009 to 2010.

In China, the number of pulp mill is far less than that of paper mill, only accounting for 3.7% in 2010. The paper industry is heterogeneous in company size (industrial enterprises above designated size), ranging from small and medium-sized firms to large companies. Small enterprises account for 88.7%, whereas large and medium companies account for only 11.3%. Only 10 firms produce more than 1,000,000 tons of paper and paperboard in 2010. The major share of paper production is in the form of uncoated printing paper, semi-chemical corrugated paper, liner board and white board paper, which is responsible for 71.4% of the total output in 2010. Meanwhile, the amount of pulp produced in 2010 was approximately 20.1 million tons. Only the United States produces more pulp than China. However, the growth rate of China's pulp output is 16.2%, whereas that of the United States is only 1.9%. Particularly, the pulp net import of China in 2010 is to be the first in the world, almost 2.7 times the rate of Germany. The types of pulp in China include wood pulp, non-wood-pulp, and recycled pulp, among which recycled pulp and non-wood-pulp are the main types produced. Fig. 2 shows the output of the pulp and paper industry in China from 1985 to 2010. Apparently, the Chinese pulp and paper industry, especially the paper and paperboard, underwent a massive production growth in 25 years.

2.2. General methods

The activity level, sector structure, and energy efficiency determine energy consumption in an industry sector (Phylipsen et al., 1997). Patterson proposed that energy efficiency is a generic

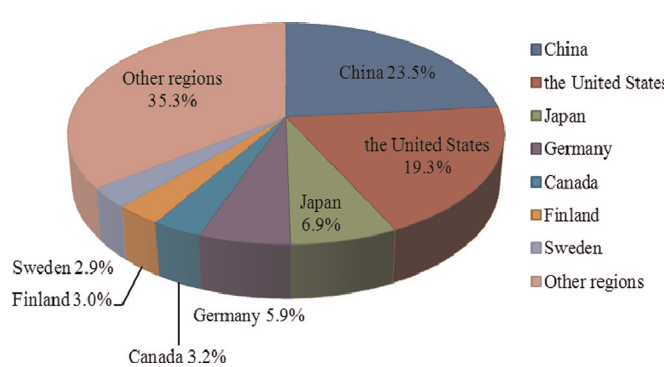

Fig. 1. Regional shares of paper and paperboard production in 2010.