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Energy-related GHG emissions of the textile industry in China

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ABSTRACT

As the sixth largest energy consuming industry sector in China, the textile industry is encountering great challenges in reducing Greenhouse Gas (GHG) emissions. Considering the existing studies have the limitation of lacking updated data and include limited energy sources, this study will conduct a comprehensive analysis of the GHG emissions in China's textile industry and analyze the emission characteristics. The results show that coal consumption is the main source of GHG emissions in China's textile industry. The second largest GHG emission source is electricity consumption, which is primarily from the Eastern China, Central China and Northern China Power Grids. A driving force factor analysis reveals that the order of intensity for the driving forces is the production scale, the energy intensity, the energy structure and the emission factors. In particular, the increasing scale of production is the main factor driving increasing GHG emissions; however, energy intensity reduction and energy structure optimization can effectively reduce GHG emissions. This study also summarizes the main energy saving measures being used by the textile industry in China. The measures used in the spinning, weaving and wetting processes are found to have high energy saving potential and a short payback period. Scenario analysis indicates that under the optimal technology application scenario, GHG emissions would be 34.3% less than emissions under the baseline scenario in 2030. Furthermore, GHG emissions per unit output value would be 0.18 t/million RMB, which approaches the advanced international level of 0.14 t/million RMB. Corresponding polices for reducing GHG emission in the textile industry need to be considered based on the implications indicated in this study.

1. Introduction

With the growing demand for textile products, global textile production has increased rapidly in recent years. According to WTO statistics, global textile production was approximately 140.84 million tons in 2012, an increase of 25.7% compared with 2008 (Zhu and Zhu, 2012). It is expected that global textile production will continue to grow at a rate of approximately 6.5% in the near future (Xu and Jiang, 2009). The textile industry is one of China's traditional pillar industries and has maintained rapid growth after China's reform and opening. China is currently the world's largest textile production country (Chen and Fu, 2011), with total textile production of 79.29 million tons in 2012, representing approximately 56.3% of global production. The textile industry is also a high energy consumption sector in China, after the ferrous metal smelting industry, the chemical manufacturing industry, the non-metallic mineral manufacturing industry, the hydroelectric power industry, the mining industry, petroleum processing and the coking industry. The "twelfth five-year GHG emission control program" issued by the State Council emphasizes GHG emission reduction in the textile industry (Wang and Xu, 2011). Thus, it is highly necessary to analyze the GHG emissions of the textile industry and to seek potential energy saving measures.

There are a number of related studies concerning GHG emissions in the textile industry, particularly focusing on specific products and production processes. In terms of GHG emission accounting, certain large cloth production companies such as Levi Strauss Co. and Continental Clothing Co. have calculated the life cycle carbon footprint of shirts, jackets, T-shirts and other clothing styles (Mahler et al., 2012; Norbert, 2009). Li et al. (2011) measured the life cycle carbon footprint of black cotton products and indicated

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that the proportion of carbon emission raw materials is the highest (64.54%), the carbon emissions resulted from wastewater discharge and energy consumption account for 34.33%. Germany's Systain International Environmental Consulting Firm calculated the life cycle GHG emissions of three types of clothing for Germany's Otto Group (BASF, 2009). Researchers have conducted influence factor analysis for GHG emissions in the textile industry. For instance, Wang et al. (2011) established a factorization model of China's textile industry using the LMDI (Logarithmic Mean Division Index) method. His results show that the expansion in industrial scale was the main reason for the increase in GHG emissions from the textile industry. Zhao (2012) analyzed the carbon footprint of the textile supply chain and declared that electricity consumption and thermal energy consumption are the main sources of GHG emissions. Regarding the research on GHG emission reduction measures for the textile industry, Li et al. (2013) mainly discussed the accounting boundary setting methodology for the carbon footprint calculation. Yao (2014) explored calculation methods for the carbon footprint of cotton fiber based on Publicly Available Specification (PAS) 2050 and proposed carbon emission reduction measures for textile production at the raw materials stage. Zabaniotou and Andreou (2010) analyzed energy consumption in the cotton ginning process of Greek National textile and discussed the feasibility of applying alternative energy options in the ginning process. Hong et al. (2010) conducted an investigation regarding textile enterprises' energy consumption efficiency, energy consumption structure and utilization in Taiwan and proposed several energy saving strategies. Bevilacqua et al. (2010) calculated the carbon footprint of a Merino wool sweater based on the Life Cycle Assessment (LCA) theory and indicated that strengthening industry clusters could effectively reduce the carbon footprint of textile products caused by transportation. Ma and Lu (2015) estimated the factors influencing carbon emissions of the textile and garment industry and found the main influencing factor is the GDP of the textile industry and the energy consumption per unit of GDP. M.H. Wang et al. (2015) and Z.Z. Wang et al. (2015) calculated the CO2 emission of China's textile industrial. His results show that the carbon intensity of China's textile industry is decreasing.

The literature review finds that there are several related studies concerning the carbon footprint calculation and GHG emission reduction for the textile industry; however, most of them targeted specific textile products or typical enterprises. Few studies have been conducted to investigate the GHG emissions of the China's textile industry. The only three studies calculating the GHG emission in China's textile industry (M.H. Wang et al., 2015; Z.Z. Wang et al., 2015; Wang and Wu, 2011) have the limitation of lacking updated data, and consider limited energy sources. In order to overcome these research gaps, this study will conduct a comprehensive analysis of the GHG emissions in China's textile industry and analyze its emission characteristics. Emission predictions will also be conducted to foresee the GHG emission under an optimal technology scenario in the near future. Suggestions for reducing the GHG emissions of China's textile industry will be proposed based upon our findings.

2. Methodology

To calculate GHG emissions for the textile industry, it is critical to first establish a defined boundary. The boundary definition in our study refers to "The Greenhouse Gas Protocol – A Corporate Accounting and Reporting Standard" (Bhatia and Ranganathan, 2004). In this report, GHG emissions are divided into direct emissions and indirect emissions. Direct GHG emissions are from sources owned or controlled by textile industry companies, termed Scope 1 (see Table 1). The energy-related GHG emission sources and the non-energy related GHG emissions of Scope 1 are emissions in the industrial process caused by chemical reaction, such as nitrous oxide (N_2O), methane (CH_4) from the chemical treatment of chemical products, and wastewater treatment. Because the non-energy related GHG emissions contribute less than 1% of the total GHG emissions, they are not included in our study (Tong et al., 2012).

Indirect GHG emissions are caused by company activities but occur from sources owned or controlled by other companies in the textile industry. Indirect emissions can be further divided into Scope 2 and Scope 3. Scope 2 emissions are emissions from the generation of purchased electricity, heat, steam and other energy consumption. Scope 3 emissions are a consequence of textile industry activities but occur from sources not owned or controlled by textile industry companies (refer to Table 1). Because scope 3 carbon emission behavior is very different and the energy consumption proportion is limited, our research solely considers the energy-related GHG emissions of scope 1 and scope 2. Furthermore, because of statistical data limitations, the indirect energy-related GHG emissions of scope 2 solely include GHG emissions from purchased electricity.

2.1. GHG emission calculation

2.1.1. Direct GHG emissions

The energy-related GHG emissions of the textile industry can be estimated by referring to the "IPCC national GHG inventory guidelines"(Institute for Global Environmental Strategies, 2006) and the "GHG protocol tool for energy consumption in China" (Song and Yang, 2011). Although the textile industry's energy-related GHG emissions are generated in various chemical processes, the carbon content of different fuels and materials are very different. Therefore, the three types of GHG emissions, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), are investigated by converting them into carbon dioxide equivalents (CO_2e). The carbon footprint of the textile industry is indicated by its global warming potential (*GWP*), which means the global warming effect from a per unit mass of certain GHG emissions in a fixed period (Reisinger et al., 2011). The total direct energy-related GHG emissions within the textile industry's boundary are estimated based upon energy consumption and emission factors (EF) (Tian et al., 2013; Yue et al., 2015). The following equation presents the calculation method:

$$C_{\text{total-direct}} = \sum_{i} E_i EF_i O_i \tag{1}$$

Where $C_{\text{total-direct}}$ represents the total direct energy-related GHG emissions (in million tons, t), subscript i represents energy fuel type i; E_i represents the energy consumption (in million tons, t) of fuel type i; EF_i represents the Emission Factors (EF) of fuel type i; and O_i represents the oxidation rate of fuel type i. According to China Statistics Yearbook (NBS, 2015) and China Energy Statistics Yearbook (NBS, 2001–2015), there are eight types of energy resources for the textile industry: coal, coke, crude oil, gasoline, kerosene, diesel oil, fuel oil and natural gas. Their emission factors are shown in Table 2 (Tian et al., 2013).

2.1.2. Indirect GHG emission

Indirect energy-related GHG emissions in China's textile industry mainly originate from electricity consumption. Because of different technology levels and energy structure mixes in different periods and regions, the emission factors for electricity generation change significantly over time and across regions. In this study, total energy-related GHG emissions are calculated by applying the following equation:

$$C_{\text{electricity}} = \Sigma EF_e^k \times Pe \times Ps_k / Ps_{\text{total}} \tag{2}$$