ENERGY CONSUMPTION INTENSITY IN CHINA STEEL SUPPLY CHAIN

Mohammadreza Haidary,
Department of Industrial Engineering,
Kerman Branch, Islamic Azad University,
Kerman, Iran.

Seyed Hamed Moosavirad
Department of Industrial Engineering,
Faculty of Engineering, Shahid Bahonar
University of Kerman, Kerman, Iran.
*Corresponding Author Email:
hamedmoosavirad@gmail.com

ABSTRACT

Nowadays, energy plays as a critical role in the industrial world. One of the main industries that consume a huge amount of energy is steel industry. As a result, steel industrial managers need to measure the energy consumption in steel supply chain before controlling energy usage. So, the objective of this paper is to investigate the energy of the steel industry in China at the macroeconomic level. The World Input Output Databases have been applied for gathering the requirement data. Mining industry, Water, Gas and Electricity suppliers industry and Machining industry are found as the main Chinese suppliers of China steel industry. Then, by forming the supply chain of the steel industry, the suppliers' energy consumption is compared with each other. It is concluded that in a two echelon supply chain of China steel industry, almost a quarter of the total energy consumption is related to the suppliers and the remaining belongs to steel industry itself. The relationship between the suppliers will be considered in future research to be compared with the results of this paper.

Keywords: Energy consumption intensity, input-output analysis, steel industry, Green supply chain, supplier selection.

1. INTRODUCTION

In the recent decade, the concept of Green in supply chain management (SCM) introduces a new path for SCM researchers and industrial managers. In this research era, few review papers have been published so far (Kannan, 2013; Yeh and Chaung, 2011; Seuring, 2013; Brandenburg, *et al*., 2014; Fahiminia et al., 2016). SCM focuses on supplying the raw materials, designing and manufacturing the product, product selling and transportation while Green Supply Chain Management (GSCM) also includes the environmental aspects of SCM and product recycling (Ahi and Searcy, 2013; Sarkis, 2012).

As the industry and transportation are the main consumers of the non-renewable energy resources, they are the largest producer of CO_2 emissions (Halldórsson and Svanberg, 2013). To deal with this issue, SCM structure provides opportunities to control and optimize the energy consumptions of industries (Halldórsson and Svanberg, 2013) which are the new and important challenges for the industries' managers and researchers. In macro levels, steel industry is the fundamental provider of the other industries' infrastructures and also a pioneer power due to its huge financial transactions with other industries (Noferesaty, *et al*., 2012). The energy consumption in steel industry is 8% of total world energy consumption (Harada and Tanaka, 2011; Niknejad, 2012). However, there is lack of research about the energy consumption of the steel industry suppliers.

Therefore, the objective of this paper is to investigate the energy consumption intensity of the three main suppliers of steel industry at macro level in China as one of the main industries in the world. The rest of paper is organized as follows: First, a brief literature review is presented in Section 2. The methodology of study based on Life Cycle Assessment (LCA) is then described in Section 3. In Section 4, based on the secondary data from the World Input-Output Database (WIOD) and using LCA methodology, the energy consumption intensity of the main suppliers of steel industry in China is analyzed at the macroeconomic level. Finally, Section 5 summarizes the main conclusions and the suggestions for future research.

2. LITERATURE REVIEW

From the product's life cycle perspective, GSCM includes the stages such as supplying the raw materials, designing and manufacturing the product, product selling, transportation, product usage, and product recycling (Ahi and Searcy, 2013; Sarkis, 2012). In other words, GSCM integrates the environmental thinking into supply chain management (SCM) (Chin et al. 2015). By using the green technology in supply chain management, the company can reduce the environmental negative effects and accomplish the optimized usage of resources and energy (Niknejad, 2012).

Some scholars focused on GSCM issue in their studies so far. For example, Wu and Barnes (2016) studied on a new model for selecting the green partner in order to form a green supply chain. To cope with this idea, they integrated Multi-objective Programming (MOP) with the Analytic Network Process (ANP). In another article, Kannan *et al*., (2014) have considered the selection of green suppliers based on the methods of GSCM by using fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method, which was applied to a Brazilian electrical company. Based on energy saving level regulation, Xie (2015) studied the decision processes in a green supply chain. He found that energy saving level regulation as well as the supply chain structures have considerable impacts on the performance of supply chain. In addition, it was found that the policy makers need to set a threshold value for the energy saving level as well as considering the decentralized chain (Xie, 2015). Recently, Hong, *et al*., (2016) used a structural path analysis (SPA) based on the multi-regional input–output table for assessing the environmental impact transmission in the entire supply chain of China's construction industry.

One of the important indices is the energy consumption intensity, which indicates the amount of energy consumed for each unit of manufactured product. Steel industry is one of the main energy consumers among other industries. The global production of steel has increased progressively due to the increasing growth of world's population and the progressive growth of global demand for steel as the most important raw material for construction. During the last 12 years, the production of steel has increased by 45%. Energy consumption in this industry is 8% of total world energy consumption (Harada and Tanaka, 2011; Niknejad, 2012). It was reported that the annual production of China's crude steel was almost 639 million tons in 2010 (Hasanbeigi, *et al*., 2013). This amount of production was about 50% of the world's annual steel production. Moreover, it was found that more than 450 terawatt-hours of electricity and more than 14000 petajoule of fuel were consumed for producing this amount of steel (Hasanbeigi, *et al*., 2013). In addition, studies show that the energy efficiency of many iron and steel industries in China is around 61% (He, *et al.*, 2013). In addition, it was found that the energy efficiency of three enterprises among the all studied iron and steel industries in China was below 40%.

Therefore, few studies have been done regarding to the energy consumption intensity in steel industry suppliers. As a result, this article aims to consider the energy consumption of the steel industry suppliers with focus on the two-echelon supply chain of China's steel industry at macroeconomic level.

3. METHODOLOGY

LCA is a technique for assessing environmental impacts associated with all the stages of a product's life from cradle to grave (from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal). This technique has two main approaches for monitoring the environmental impacts of industries. The first approach is process-based which focus on the manufacturing processes (Cabeza, *et al*., 2014; Poudelet, *et al*., 2012). The second approach is input-output analysis which focuses on the Leontief input-output model (Su and Ang, 2015; Miller and Blair, 2009). For addressing the research objective of this paper, the two aforementioned approaches have been integrated by the following stages.

In first stage, the selling volumes for various industries have been obtained by using the secondary data of the WIOD (Timmer, *et al*., 2015). Based on this database, the three main suppliers of China steel industry can be found. In the next stage, by using input-output tables and the total energy consumption, the energy consumption intensity for each industry can be calculated by the ratio of the total energy consumption of each industry to its total selling. Finally, the contribution of each supplier in the consumed energy of China's steel products is obtained.

4. RESULTS AND DISCUSSION

This research used the input-output tables and also the tables of energy consumption in 2009 according to WIOD. This database includes the buying and selling transactions and also the energy consumption for 35 industries in 40 countries.

In the first stage of this research, the three main suppliers of China's steel industry are determined. A part of the prioritizing table for suppliers of China steel industry is shown below:

Table 1: Main suppliers of steel industry in China

Suppliers of steel industry in China	Selling to China's steel industry (million dollars)	Share of each supplier (%)
Mining industry of China	114955	8.7
Water, electricity, and gas supplying industry of China	61277	4.6
Machinery industry of China	41111	3.1
Coal and nuclear fuel industry of China	33256	2.5

Based on Table 1, three industries: (1) mining (2) water, electricity, and gas supplying industry and (3) machinery industry are the main suppliers of China's steel. Accordingly, the two-echelon supply chain of China's steel industry is drawn as below:

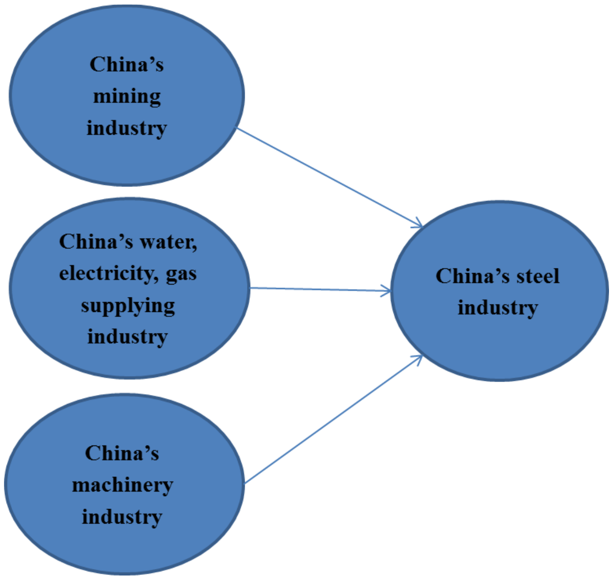

Fig 1: Steel supply chain of China

In the next step, the energy consumption intensity indices for the suppliers of steel industry in China are calculated by the ratio of the total energy consumption of each industry to its total selling. The results are presented in Table 2:

Table 2. Energy consumption intensity of the suppliers of China's steel industry

Suppliers of China's steel industry	Mining industry of China	Water, electricity, and gas supplying industry of China	China's machinery industry
Total energy consumption (terajoule) TJ	3280260	42000000	782030
Total selling(million dollars) $Million\ US\$$	466033	481828	680182
Energy consumption intensity index ($\frac{TJ}{Million\ US\$}$)	7.04	87.17	1.15
Total selling to steel industry(million dollar) $Million\ US\$$	114955	61277	41111
The consumed energy for supplying the raw material of steel industry (terajoule) TJ	809132	5341392	47267

With regard to Table 2 and the fact that China's steel industry directly consumed 17340052 terajoule energy in 2009, the contribution of each main supplier to the indirect consumed energy in two-echelon supply chain of steel industry have been obtained. The results indicate that in two-echelon supply chain of China's steel industry, about 74% of the total consumed energy belongs directly to the steel industry itself, and the remaining portion related to the three main suppliers is about 26%.

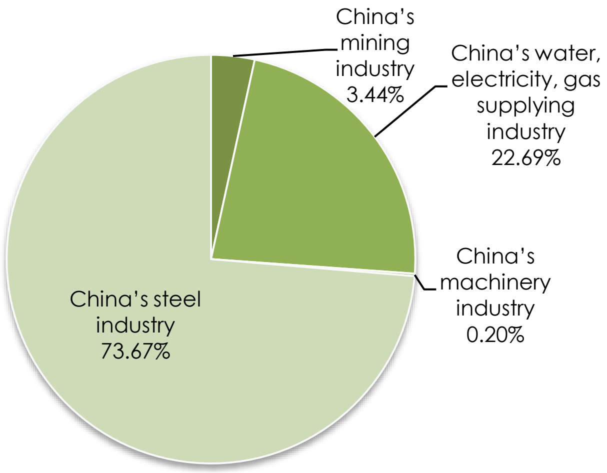

Fig 2: Energy portion of partners in two-echelon supply chain of steel industry in China

5. CONCLUSION

In this paper, three main suppliers of China's steel industry which are mining industry, water, electricity, and gas supplying industry, and machinery industry were identified by using WIOD. Then it was found that the associated energy consumption intensities of these three main suppliers of China's steel industry are 7.03, 87.16, and 1.14 respectively. Results show that in two-echelon supply chain of China's steel industry, about 74% of total consumed energy directly belongs to the steel industry itself, and the portion of the three main suppliers is almost 26%. In other words, it can be concluded that about one fourth of the total consumed energy for steel manufacturing is associated with its suppliers. Consequently, the energy usage of both China's steel industry and its suppliers need to be controlled.

The managers of steel industries in China can implement the proposed method to track the energy footprint of their products in their supply chains as well as in their steel production processes. To enrich the results of this research, other suppliers of China's steel industry such as chemical and service industries can also be considered in future research. Moreover, the research method proposed in this paper can be applied for other supply chains in different countries. Last but not least, the other environmental footprints in the supply chain such as water footprint can be added and analyzed by the presented approach in future research.

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