Life Cycle Thinking for Industrial Symbiosis: Case Study in China's Iron/Steel Industrial Park Using SFA and Value Chain Analysis

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1. Introduction

Industrial symbiosis (IS) provided specific opportunities for industrial parks to enhance the eco-efficiency through the co-operation between co-located firms, with the exchange of materials, energy and/or by-products in a mutually beneficial way (Chertow, 1998, 2000, 2007). Especially from the perspective of life cycle, the IS could contribute to the mitigation of environmental pollutants in the up-stream, manufacturing process and down -stream.

Iron and steel industry could be a hub for the local industrial network, given its manufacturing features (Li et al., 2010). As an energy intensive industry, it particularly related to the carbon mitigation strategy. A mitigation strategy for the iron and steel industry can be promoted in two geographical levels: inside companies and in industrial parks. Industrial parks are a new urban system with high intensity of industries and populations that have remarkably influenced regional economic growth, technological innovation, and environmental quality. It is one form of the realization of the concept of IS.

A useful way to investigate the carbon mitigation effects in an industrial park was to trace the carbon flows from up-stream to the down-stream. Based on this, in this study, we aimed to conduct a substance flow analysis and assisted with value chain analysis to investigate the carbon mitigation effects of IS in a life cycle perspective, in a typical iron/steel industrial park (ISIP) in China. We particular focused on the carbon mitigation from power purchase, waste heat utilization and waste management.

2. Methodology

We applied SFA to study and simulate the carbon flows in the industrial parks before and after the implication of industrial symbiosis technologies.

Shown as Figure 1, the geographical scale of the system was an iron/steel-centered industrial area with materials and energy flow features. The iron/steel plant was connected with other plants in the form of waste/by-product exchange. The core of the system was the manufacturing process of iron and steel industry.

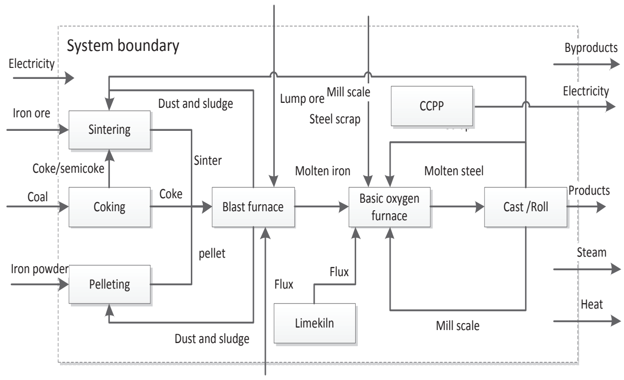

Figure 1 System boundary of SFA

Based on the methodology proposed by the World Resource Institute (WRI)(WRI, 2010) and the World Business Council for Sustainable Development (WBCSD) (WBCSD, 2005), in this study, we calculated the carbon emissions in terms of direct and indirect ones accord to the features of iron/steel manufacturing.

$$C_0 = C_1 + C_2 - C_3 \quad (1)$$

$$C_1 = (\Sigma C^{O}_{Di} + \Sigma C^{O}_{Fi}) \times 44/12 \quad (2)$$

$$C_2 = \Sigma P^{I}_{Pi} \times F_{Pi} \quad (3)$$

$$C_3 = \Sigma P^{O}_{Pi} \times F_{Pi} \quad (4)$$

Where, C_0 was the net carbon dioxide emissions; C_1 was the direct emissions, C_2 was the input of indirect carbon flows; C_3 was the carbon deduction by products and/or by-products utilization. In equation (1) to (4), where the capital letter C refers to the amount of carbon. The capital letter P refers to the by-products. F_{pi} is the equivalence carbon dioxide emission factor. The superscripts I and O are using to distinguish the input flow and output flow. The subscript i refers to different flows. The subscript letters D, F, FC and P refer to direct carbon emission, fugitive emission, fix carbon in products and carbon free products (indirect carbon flow) respectively.

3. Case study

The case study is in a typical ISIP in northern China. The production of crude is 10 million tons annually.

As to the scenarios design, we designed two scenarios:

- Business as usual (BAU scenario): there is no waste heat utilization and IS;

- IS scenario: the technology of CO_2 capture by slag carbonization (CCSC) was applied. It would utilize the waste heat and slag to produce construction material.

4. Results and discussion

The SFA simulation results were showed in Figure 2 and Figure 3. It was noted that compared with BAU scenario, the net carbon emissions reduced from 1928.92 to 1706.03 $kgCO_2$/t steel. The carbon mitigation embodied into the power purchase was not reduced, but the carbon embodied into the waste heat was greatly reduced. Also more carbon was embodied into the products, thus the net emission was reduced (Figure 4).

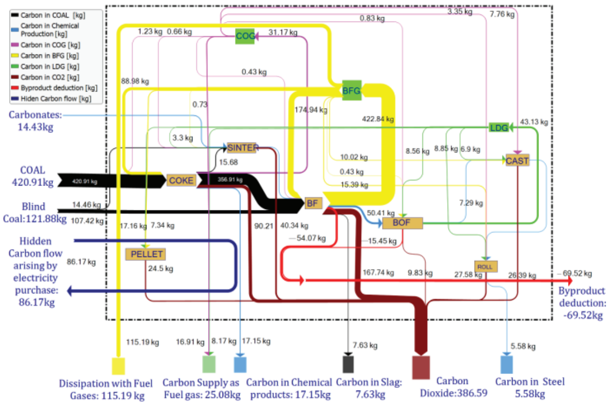

Figure 2 The Carbon flow chart of BAU scenario

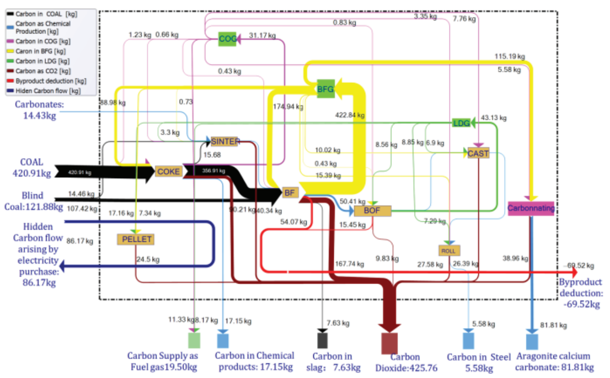

Figure 3 Carbon Flow analysis for CCSC technology

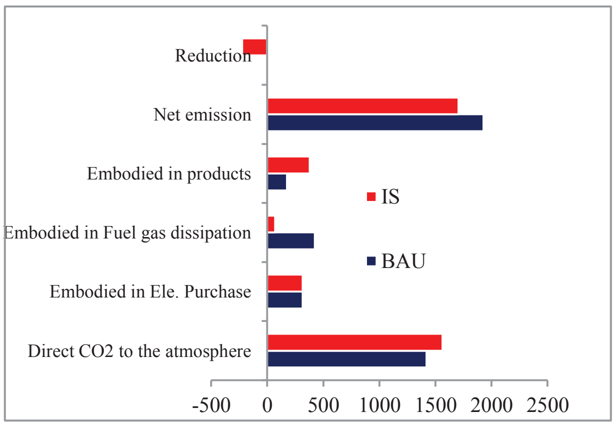

Figure 4 Comparison of carbon emissions

Unit: kg CO_2/t steel

Furthermore, from the perspective of value chain analysis, as the IS could embody the carbon elements which was in the waste before into the products, thus the added value of the industrial chain was increased, which contribute to the decrease of the cost of carbon mitigation.

5. Conclusion

The results of SFA noted that IS could help to reduce the carbon emissions inside the industrial parks, in terms of direct and indirect one. A further analysis based on the VCA showed that IS could also help to reduce the reduction cost, as it could increase the added value of industrial chains.

Our results highlighted that apart from energy efficiency measures, industrial symbiosis provided extra reduction opportunities through the secondary energy utilization, exchange of waste and or by-products. A life cycle thinking of IS contributes to a better path of fight to climate change.

Acknowledgement

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