

Review of Carbon Reduction Theory and Calculation Methods of Carbon Emissions in China's Iron and Steel Industry

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Abstract: The paper reviews on the carbon reduction theory in Chinese steel industry and introduces three calculation methods of carbon footprint. Provincial Guidelines for Greenhouse Gas Inventories and Accounting Methods and Reporting Guidelines for Greenhouse Gas Emissions in Chinese Steel Producers are calculation methods of greenhouse gas emissions on the enterprise level, established by Chinese government. The calculation method of carbon emissions proposed by Professor Fu Jian-xun, Shanghai University, based on ISO standard, is consistent with that in foreign steel producers. He provided the thought of life cycle analysis and accurately calculated the CO₂ emissions top-down and step by step.

Introduction

As we all know, there has been an improving concern about the environmental pollution and energy consumption. In China, iron and steel industry is often associated with high pollution, high energy consumption and high emissions. In the year of 2015, the whole crude steel production was 1.1235 billion tons, which meant nearly 2.5 billion tons of carbon emissions[1].

In 2014, China and America both issued a joint statement to deal with climate change in Beijing[2]. The carbon emissions were expected to reach the peak and non-fossil energy raised to 20% in the proportion of primary energy in 2030. It means that China should speed up economic restructuring, and change the structure of energy consumption. Because of the common problems as not balanced, much backward production capacity, low energy efficiency, high pollution, high emissions and others, steel industry in our country has been always facing with large international environmental pressure. The steel industry in China has been emphasis on carbon emissions and the focus is to reduce it in steel production process. This paper reviews on the carbon reduction theory and calculation methods of carbon emission in China's steel industry.

Carbon Reduction Theory in Chinese Steel Industry

Carbon reduction work has been carried out in steel industry for a long time. Sheng Gang[3] and Wu Yan-guang constructed of the carbon flow model of coking, sintering, iron making, steel making, rolling and other major processes in steel production process. They established the relationship between carbon sources and carbon-containing products in aspect of matter and energy conservation in production process to provide a theoretical basis for calculating the carbon footprint. Li Ling[4], based on the research status of energy conservation and emission reduction in steel industry, using system dynamics, established the steel demand, energy consumption and CO₂ emissions model in steel industry in China. Based on the source analysis of carbon emission in Chinese steel industry, Zhang Chun-xia[5] et al analyzed the current situation and characteristics of greenhouse gas emissions in domestic and international steel industry, noting that greenhouse gas emissions from the iron and steel industry was mainly CO₂ and was mainly caused by energy consumption. Yin Rui-yu[6] regarded the steel-making process as the driving-interaction network, which interactively formed by the material flow (mainly ferrite flow) and the energy flow (mainly carbon flow). With optimizing the steel-making process based on the material flow and energy flow

analysis, he established low-carbon green manufacturing and ecological development model for steel industry.

Calculation Methods of CO₂ Emissions in domestic Steel Industry

Provincial Greenhouse Gas Directory[7]. Provincial Guidelines for Greenhouse Gas Inventories is divided into fossil fuel combustion, indirect emissions from the net consumption of fossil fuel combustion and indirect emissions from electricity to be calculated.

Total corporate CO₂ emissions:

$$E_{CO_2} = E_{ffc} + E_{ipc} + E_{ec} \quad (1)$$

Where E_{CO_2} —CO₂ emissions for one unit of corporate products, kgCO₂

E_{ffc} —CO₂ emissions from fossil fuel combustion, kgCO₂

E_{ipc} —CO₂ emissions from industrial processes, kgCO₂

E_{ec} —CO₂ emissions from electricity, kgCO₂

$$E_{ffc} = \sum_{i=1} AD_i X E F_i \quad (2)$$

Where E_{ffc} —CO₂ emissions from the net consumption of fossil fuel combustion, kgCO₂

AD_i —Apparent consumption of i fossil fuel, TJ

$E F_i$ —The i fuel emission factor, kg / TJ

$$E_{ffc} = \sum_{i=1} [(AD_i X \eta_{ic} - D_{ic}) X \phi_{io}] \quad (3)$$

Where E_{ffc} —CO₂ emissions from the net consumption of fossil fuel combustion, kgCO₂

AD_i —Apparent consumption of i fossil fuel, TJ

η_{ic} —Carbon content for per unit calorific value, kgCO₂/TJ

D_{ic} —Carbon sequestration amount of fuel used for non-energy purposes

ϕ_{io} —Average oxidation rate for burning of i fossil fuel

Carbon sequestration rate refers to a fixed carbon rate when a variety of fossil fuel is used as non-energy material. Since the part of the carbon is not released, it is necessary to be deducted in the calculation of emissions. Carbon oxidation rate refers to the carbon ratio oxidized by a variety of fossil fuel during combustion, characterizing the combustion of fuel. Large amounts of electricity required in steel production process cause indirect greenhouse gas emissions, and this part of emissions is calculated as the following formula:

$$E_{ec} = AD_e \times E F_e \quad (4)$$

Where E_{ec} —CO₂ emissions from electricity, kgCO₂

AD_e —Electricity consumption in steel production process, kWh

$E F_e$ —Greenhouse gas emission factor from electricity, kgCO₂/ kWh

Accounting Methods and Reporting Guidelines for Greenhouse Gas Emissions in Chinese Steel Producers. Accounting Methods and Reporting Guidelines for Greenhouse Gas Emissions in Chinese Steel Producers is more specific than the Provincial Guidelines for Greenhouse Gas Inventories. Input-Output thought[8] is used on the overall level of steel-making to statistic the greenhouse gas emissions in steel production process.

Facilities and services include direct production system, auxiliary production system and ancillary system to service the production. Auxiliary production systems includes power, supplying electricity and water, chemical testing and machine maintenance, warehouse and transportation. Affiliated production system includes command system (factory) and the region to service the

production such as cafeteria, shop bathroom, health stations, etc. The total of CO₂ emissions in steel production producer is calculated as following:

$$E_{CO_2} = E_1 + E_2 + E_3 - R_C \quad (5)$$

Where E_{CO_2} ——Total CO₂ emissions in enterprise,kgCO₂

E_1 ——CO₂ emissions from whole net consumption of fossil fuel combustion, kgCO₂

E_2 ——CO₂ emissions from the industrial processes in enterprise,kgCO₂

E_3 ——CO₂ emissions from the electricity and heat in enterprise,kgCO₂

R_C ——CO₂ emissions from the carbon sequestration products

Emissions from the combustion of fuel arecalculated the same as the Provincial Greenhouse Gas Directory and CO₂ emissions from the industrial processes and carbon sequestration products are calculated as follows:

$$E_2 = P_e \times EF_e + \sum_{i=1}^n P_i \times EF_i + \sum_{i=1}^n M_i \times EF_i \quad (6)$$

Where E_2 ——CO₂ emissions from the industrial processes in enterprise,kgCO₂

P_e, P_i and M_i ——Amount of the electrodes, limestone and dolomite, without sourcing iron and ferroalloy ,kg

EF_e and EF_i ——Carbon emission factors,kgCO₂/kg

$$R_C = \sum_{i=1} AD_C \times EF_C \quad (7)$$

Where R_C ——CO₂ emissions from the carbon sequestration product

AD_C ——Output of the i carbon sequestration product

EF_C ——Carbon emission factor of the i carbon sequestration product

However, for the calculation of greenhouse gas emissions in various departments and processes within the steel industry, the two calculation methods can not get a more detailed report. More importantly, they can't research on changes of carbon footprint caused by the changes of material flow and energy in production process.

Calculation Method of Carbon Emission based on ISO Standards. Professor Fu Jian-xun developed a carbon footprint calculation model based on ISO standard in steel production process and proposed a carbon footprint calculation method with the characteristics of Chinese steel industry and developed proprietary software to calculate the carbon footprint. The calculation process is as follows.

(1) Make the steel production processes and system boundaries (fences),based on the production process in each enterprise.(2) Access the method of segment statistics for technologies and the way from top to bottom in the process section to determine the inventory priorities.(3) Count all of the raw materials and energy consumption items involved in the steel production process in order.(4) Summarize the carbon equivalent of aspects of the main process and auxiliary,based on the carbon equivalent coefficient of each material item and energy item.(5) Consider interface coefficient due to the losses between each receiving process and determine the total output according to the system boundary to convert into CO₂ emissions for per tonne of steel or the total CO₂ emission in steel enterprise.(6) Analysis and evaluate the inventory results and rise up optimization recommendations after the inventory process.

Conclusions

Provincial Guidelines for Greenhouse Gas Inventories and Accounting Methods and Reporting Guidelines for Greenhouse Gas Emissions in Chinese Steel Producers are emission calculation methods of greenhouse gas on the enterprise level, regard less of concrete processes in steel production. The latter is more specific on system boundary and calculation method. The calculation

method for carbon emissions proposed by Shanghai University, based on ISO standard, is consistent with that in steel producers abroad. Professor Fu Jian-xun provided a method to accurately calculate the greenhouse gas emissions of each step and established the management approach to calculate data top-down in steel production process.

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