Analysis of GHG Emission Verification of The Iron-steel Industry

Case study of an iron-steel company in hebei province

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***Abstract*—The iron-steel industry is a resource and energy intensive industry and results to abundant GHG emissions because of a mass of fossil fuel consumption. In recent years, air quality in North China becomes worse and worse. In order to analyze the GHG emissions of the iron-steel industry, we made the survey in a typical iron-steel enterprise in Hebei province. According to the verification: CO_2 emissions of coking, sintering, iron-making, steel-making and deep processing sectors respectively are 407.5, 1964.4, 1765.5, 124.0, 1279.0kt; CO_2 emissions of production processing and electricity (including heating) are 562.0 and 211.0kt respectively and totally 12817.2kt for the whole production line. The uncertainty of the activity data is about ±3.54%, so it belongs to the high precision level. The research can help the iron-steel companies verify the GHG emissions in each process and find out emissions reduction potential.**

Keywords-energy intensive industry; verification of GHG emission; energy conservation and emissions reduction; uncertainty analysis; emissions reduction potential

I. INTRODUCTION

Iron-steel industry consumes the most resources and energy, and becomes the key industry of energy conservation and emission reduction in China's industrial sector. Coal is the main energy consumption for China's iron-steel industry, accounting for 68% of the industry's total energy consumption [1] [2]. Compared with 2010, the energy consumption of unit industrial production reduces 18% by 2015.According to estimates, the iron-steel industry accounts for about 23% of total industrial energy consumption and about 16% of the total energy consumption of China [1]. CO_2 emissions of iron- steel industry has reached 15% of the country's total emissions [2] [3], and accounts for 51% of the total emissions of global iron-steel industry [4]. Judging from the national steel production, the output of steel production in Hebei Province has ranked first in the country for 13 years.

II. RESEARCH BACKGROUND

A. Introduction of the Research Company and Major Energy Consuming Equipment

The main products of this company are divided into four categories, respectively are plate, bar, wire and type. The steel plate has 20000kt production capacity every year. The 3200m^3 blast furnace in Southern District is the most advanced blast furnace system, of which the PCI rate and coke ratio are in the advanced level. Main energy consuming equipment of the company are four 36-hole coke ovens, two 65-hole coke ovens, a 360m^2 sintering machine, a 265m^2 sintering machine, two 210m^2 sintering machine, a 180m^2 sintering machine, two 2000 m^3 blast furnaces, two 3200 m^3 blast furnaces, four 55t converters, three 150t converters, a medium-sized production line, two bar production lines, two high-line production lines, two hot-plate production lines. In order to take full advantage of secondary energy, this research company adopts coke dry quenching (CDQ) power generation, sintering waste heat power generation technology, blast furnace top gas recovery turbine unit (TRT), three gas (coke oven, blast furnace and converter gas) power generation technology.

B. Research Content

Purpose of the research is to find out the energy consumption and emissions status of iron- steel production companies. The content of this research includes the consumption of coal, purchased electricity, refined oil products and natural gas. Meanwhile, comprehensive energy consumption, annual total yield, total industrial output value, industrial added value, and energy consumption of per ton steel, comprehensive energy consumption per ten-thousand-ton output value and comprehensive energy consumption per ten-thousand-ton industrial added value are also the contents of this research.

III. GHG EMISSION VERIFICATION METHODOLOGY

A. *Applicable Conditions of MRV Methodology*

The methodology is applicable to enterprises that are engaged in producing iron and steel. Steel production process always emits carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) [5] [6].This methodology mainly aims at CO_2 emissions related to iron-steel production, because the global warming climate change is dominated by CO_2. It is suitable for coking, sintering, iron-making, steel-making and deep processing segments.

B. Determine the Boundary

Boundary is divided into organizational boundary, emission boundary and time boundary [7]. Organizational

boundary refers to iron-steel production companies that have independent legal status and have the ability to settle accounts independently. Emission boundary is divided into direct emission boundary and indirect emission boundary [8]. Direct emission comes from energy activities and industrial processes of iron-steel companies. The emission caused by consumption of purchased electricity and heat is addressed as indirect emission. In general, year is the statistical period of time boundary.

C. Quantitative Calculation of GHG

Direct emissions include: fossil fuel combustion emission in coking, sintering, iron-making, steel-making and deep processing sectors; the emission comes from high-temperature decomposition of dolomite, limestone and electrode consumption; the emission is caused by carbon acts as a reducing agent as well as be oxidized in iron-making and steel-making processes. Indirect emissions mainly refer to the consumption of purchased electricity and heat.

Direct emissions—emissions from fossil fuel combustion and industrial processes:

$$E_d = E_f + E_p \tag{1}$$

Indirect emissions—net emissions from purchased electricity and heat

$$E_i = E_e + E_h \tag{2}$$

1) Direct emissions

a) Fossil fuel combustion

b) Electricity indirect emissions

$$E_e = (P_{in} - P_{out}) \times EF_e \tag{7}$$

where, E_e: indirect CO_2 emissions from net purchased electricity(tCO_2); P_{in} : purchased electricity(MWh); P_{out} : electricity for outside(MWh); EF_e: CO_2 emission factor of area electricity consumption(tCO_2/MWh).

c) Heat indirect emissions

$$E_h = (H_{in} - H_{out}) \times EF_h \tag{8}$$

where, E_h: indirect CO_2 emissions from net purchased heat(tCO_2); H_{in} : purchased heat(GJ); H_{out} : heat for outside(GJ); : CO_2 emission factor of area heat consumption(tCO_2/GJ).

D. Leak

The main sources of the leak include transport of mining raw materials, outsourcing service of some products and CO2 emissions caused by staff travel and other conditions. When this methodology is applied to calculate GHG emissions, the amount of leak depends on the actual emissions proportion of total emissions of business activities.

E. Uncertainty Analysis

Error propagation is applied to quantize the uncertainty, as shown in Formula 9 and Formula 10.

$$U_c = \frac{\sqrt{(U_{s1}\times\mu_{s1})^2 + (U_{s2}\times\mu_{s2})^2 + \ldots + (U_{sn}\times\mu_{sn})^2}}{|\mu_{s1} + \mu_{s2} + \ldots + \mu_{sn}|} = \frac{\sqrt{\sum_{n=1}^{N}(U_{sn}\times\mu_{sn})^2}}{|\sum_{n=1}^{N}\mu_{sn}|} \tag{9}$$

where, U_c: uncertainty of the sum or difference of n estimated values(%); U_{s1}、U_{s2}、...U_{sn}: uncertainty of n added or subtracted estimated values (%); μ_{s1}、μ_{s2}、…μ_{sn}: n added or subtracted estimated values.

$$U_c' = \sqrt{U_{s1}'^2 + U_{s2}'^2 + \ldots + U_{sn}'^2} = \sqrt{\sum_{n=1}^{N} U_{sn}'^2} \tag{10}$$

where, U_c': uncertainty of the product of n estimated values(%); U_{s1}'、U_{s2}'、…U_{sn}': uncertainty of n multiplied estimated values(%).

F. The Development of Monitoring Plans

Monitoring plans should include:

Basic information of iron-steel companies, such as the name, reporting year, steel industry code, organization code, legal representative, business address, mailing address, contacts and so on.

The emissions boundary of iron-steel companies.

Instruction of calculation methods includes selection of calculation methods, the level of activity data used in calculation, relevant emission factors and other parameters.

Uncertainty that may be present and measures that should be taken.

IV. Samples Of The Verification

A. Identify the Main Emission Sources and Boundaries

The main emission source is various kinds of fixed or mobile combustion equipment, such as Coke ovens, sinter machines, blast furnaces, converters, continuous casting machines and industrial boilers. Time boundary is 2012. Direct emission boundaries include: fossil fuel combustion in coking, sintering, iron-making, steel-making and deep processing sectors; high-temperature decomposition of carbon flux and electrode consumption in industrial processes; carbon content changes in iron-making and steel-making processes.

Indirect emission boundaries mainly refer to GHG emission caused by the consumption of purchased electricity and heat.

B. Quantitative Calculation

Table 1 shows the relevant activity levels and sources of this company. According to GHG calculation formulas, calculate direct CO_2 emissions from fuel combustion and production processes of every link in 2012, and calculate indirect CO_2 emissions from purchased electricity and heat. In the end, calculate CO_2 emissions of the company in 2012, as shown in Table 2.

2) The activity levels and sources of the reporting entity

TABLE I. THE ACTIVITY LEVELS AND SOURCES OF THE REPORTING ENTITY

Link	Fuel type	Net consumption	Unit	Source
Coking	Coke oven gas	53466.068	10^4m^3	Statistics
Sintering	Anthracite	21.6905	10^4t	
	Coke	42.3214	10^4t	
	Blast furnace gas	39616.8579	10^4m^3	
Iron-making	Anthracite	63.0956	10^4t	
	Steam coal	76.4548	10^4t	
	Coke	288.7852	10^4t	
	Coke oven gas	759.8922	10^4m^3	
	Total blast furnace gas byproduct of iron-making	1399608.5019	10^4m^3	
	Blast furnace gas consumption of iron-making unit	538096.6083	10^4m^3	
	Total converter gas byproduct of steel-making	97355.4307	10^4m^3	
	Converter gas consumption of iron-making unit	0	10^4m^3	
Steel-making	Coke oven gas	2212.5466	10^4m^3	
	Blast furnace gas	90.6639	10^4m^3	
	converter gas	7032.1886		
Deep processing	Coke oven gas	21574.0395	10^4m^3	
	Blast furnace gas	66309.1495	10^4m^3	
	Converter gas	36512.3571	10^4m^3	
Transport	Steam coal	0.0477	10^4t	
	Petrol	0.0016	10^4t	
	Diesel	0.3636	10^4t	
Loss	Blast furnace gas	5003.8571	10^4m^3	
Others	Petrol	0.0382	10^4t	
	Diesel	0.0182	10^4t	
	Coke oven gas	26415.2486	10^4m^3	
	Blast furnace gas	640545.3719	10^4m^3	
	Converter gas	53810.8850	10^4m^3	
	Name	**Value**	**Unit**	**Source**
Production processes	Limestone consumption	82.7700	10^4t	Statistics
	Dolomite consumption	58.8900	10^4t	
	Electrode consumption	0.5500	10^4t	
	Purchased nickel-iron alloy consumption	2.0000	10^4t	
	Purchased ferrochrome consumption	7.0000	10^4t	
	Purchased ferromolybdenum consumption	3.0000	10^4t	
	Crude steel production	784	10^4t	
Purchased electricity and heat	Purchased electricity	184502.4365	10^4Kwh	
	Output electricity	115685.4753	10^4Kwh	
	Purchased heat	0	10^4t	
	Output heat	12.3351	10^4t	

3) Emission factors and sources in each link of the company

All parameters including carbon emission factors refer to the national development and reform commission for verification of numerical calculation in the CO_2 emission formula.

4) The summary of CO2 emissions of the company

TABLE II. THE SUMMARY OF CO2 EMISSIONS OF THE COMPANY IN 2012

Link		CO_2 emissions	Unit
Coking	Coke oven gas	40.7540	10^4t
Sintering	Anthracite	41.7278	
	Coke	121.1081	
	Blast furnace gas	33.5996	
	Subtotal	196.4355	
Iron-making	Anthracite	121.3821	
	Steam coal	106.0982	
	Coke	826.3952	
	Coke oven gas	0.5792	
	Total blast furnace gas byproduct of iron-making	1187.0264	
	Blast furnace gas consumption of iron-making unit	456.3668	
	Total converter gas byproduct of steel-making	147.2407	
	Converter gas consumption of iron-making unit	0.0000	
	Subtotal	176.5544	
Steel-making	Coke oven gas	1.6865	
	Blast furnace gas	0.0769	
	Converter gas	10.6355	
	Subtotal	12.3989	
Deep processing	Coke oven gas	16.4446	
	Blast furnace gas	56.2377	
	Converter gas	55.2214	
	Subtotal	127.90	

		37	
Transport	Steam coal	0.0661	
	Petrol	0.0046	
	Diesel	1.1256	
	Subtotal	1.1963	
Loss	Blast furnace gas	4.2438	
Others	Petrol	0.1118	
	Diesel	0.0563	
	Coke oven gas	20.1348	
	Blast furnace gas	543.2550	
	Converter gas	81.3838	
	Subtotal	644.9416	
Industrial processes	Limestone, dolomite	64.1560	10^4t
	Electrode	2.0147	
	Carbon reduction process	-10.0206	
	Subtotal	56.1500	
Purchased electricity and heat	Net purchased electricity and heat	21.1394	
Emissions across the company		1281.7176	

C. The Analysis of Quantitative Results

The company produced 8210kt iron, 7840kt steel and 7550kt steel products. Meanwhile, it caused 12817.176kt CO_2 emissions. It applied waste heat, residual gas and residual pressure power generation technology. So it reduced energy losses and significant emissions of GHG because of efficient use of waste energy and provided themselves with 57% of the electricity.

D. Uncertainty Analysis

The error propagation method is applied to quantify the uncertainty, as shown in Formula 9 and Formula 10. According to the actual situation, the results are shown in Table 3. The uncertainty of the total emissions is ± 3.54%. According to National Greenhouse Gas Inventories reported by Intergovernmental Panel on Climate Change (IPCC) in 2006, it was learned that the uncertainty belongs to the high precision level and the activity data is credible.

TABLE III. THE UNCERTAINTY QUANTITATIVE TABLE

Emission sources	**GHG emissions（10^4tCO_2）**	**Activity data uncertainty（%）**	**Emission factor uncertainty（%）**	**Combination uncertainty（%）**	**Total emissions uncertainty（%）**
Fuel combustion					±3.54%
Petrol	0.1163	±2%	±2%	±2.8%	
Diesel	1.1819	±2%	±2%	±2.8%	
Coke	947.5033	±2%	±2%	±2.8%	
Coal	269.2742	±2%	±3%	±3.6%	
Coke oven gas	79.5990	±1%	±1%	±1.4%	
Blast furnace gas	-93.2466	±1%	±1%	±1.4%	
Converter gas	0.0000	±1%	±1%	±1.4%	
Purchased electricity and heat	21.1394	±3%	±5%	±5.8%	
Iron-steel production process	56.1500	±50%	±5%	±50.2%	

V. CONCLUSION

With the increasing demand for energy-saving plan, the company has taken various energy-saving measures. The comprehensive energy consumption of tons of production declined in nearly 5 years.

The research company applied waste heat, residual gas and residual pressure power to generate electricity. So it reduced energy losses and significant emissions of GHG because of efficient use of waste energy and provided themselves with 57% of the electricity.

According to the verification of the company, CO_2 emissions of coking, sintering, iron-making, steel-making and deep processing sectors respectively are 407.5, 1964.4, 1765.5, 124.0, 1279.0kt; CO_2 emissions of production processing and electricity (including heating) are 562.0 and 211.0kt respectively and totally 12817.2kt for whole production line; the uncertainty of the activity data is about ±3.54% and belongs to the high precision level.

ACKNOWLEDGMENT

This research was supported by the National sci-tech support plan-research on the technology of GHG detection and accounting in China’s main industries, and the Hebei province sci-tech support plan-Evaluation on MRV and low-carbon technologies of iron-steel industrial sectors. We would like to express our gratitude to expert group for their encouragement and kindly help.

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