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: CO₂ emissions of coking, sintering, iron-making, steel-making and deep processing sectors respectively are 407.5, 1964.4, 1765.5, 124.0, 1279.0kt; CO₂ emissions of 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]. CO₂ emissions of iron-steel industry has reached 15% of the country's total emissions [2][1], 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 3200m³ 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 360m² sintering machine, a 265m² sintering machine, two 210m² sintering machine, a 180m² sintering machine, two 2000 m³ blast furnaces, two 3200 m³ 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 (CO₂), methane (CH₄) and nitrous oxide (N₂O) [5] [6]. This methodology mainly aims at CO₂ emissions related to iron-steel production, because the global warming climate change is dominated by CO₂. 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:

\[ E_1 = E'_1 + E''_1 \]  (1)

Indirect emissions—net emissions from purchased electricity and heat

\[ E_i = E'_i + E''_i \]  (2)

1) Direct emissions

a) Fossil fuel combustion

\[ E'_i = (P_{n} - P_{m}) \times E_i \]  (7)

where, \( E'_i \) : indirect CO2 emissions from net purchased electricity(\( tCO2 \)); \( P_{n} \) : purchased electricity(MW); \( P_{m} \) : electricity for outside(MW); \( E_i \) : CO2 emission factor of area electricity consumption(\( tCO2/\)MW).

b) Electricity indirect emissions

\[ E'_i = (P_{n} - P_{m}) \times E_i \]  (7)

where, \( E'_i \) : indirect CO2 emissions from net purchased electricity(\( tCO2 \)); \( P_{n} \) : purchased electricity(MW); \( P_{m} \) : electricity for outside(MW); \( E_i \) : CO2 emission factor of area electricity consumption(\( tCO2/\)MW).

c) Heat indirect emissions

\[ E''_i = (H_{n} - H_{m}) \times E_{HF} \]  (8)

where, \( E''_i \) : indirect CO2 emissions from net purchased heat(\( tCO2 \)); \( H_{n} \) : purchased heat(GJ); \( H_{m} \) : heat for outside(GJ); \( E_{HF} \) : CO2 emission factor of area heat consumption(\( tCO2/GJ \)).

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.

\[ U_i = \sqrt{\sum_{i=1}^{n} (U_{1} \times \mu_{1})^2 + \sum_{i=1}^{n} (U_{2} \times \mu_{2})^2 + \ldots + \sum_{i=1}^{n} (U_{m} \times \mu_{m})^2} \]

\[ U_i = \sqrt{\sum_{i=1}^{n} U_{i}^2} \]  (9)

where, \( U_{i} \) : uncertainty of the sum or difference of n estimated values(\( \% \)); \( U_{j1}, U_{j2}, \ldots, U_{jn} \) : uncertainty of n added or subtracted estimated values (\( \% \)); \( \mu_{1}, \mu_{2}, \ldots, \mu_{m} \) : n added or subtracted estimated values.

\[ U_i = \sqrt{\sum_{i=1}^{n} U_{i}^2} \]  (10)

where, \( U_{i} \) : uncertainty of the product of n estimated values(\( \% \)); \( U_{i1}, U_{i2}, \ldots, U_{in} \) : 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 CO₂ emissions from fuel combustion and production processes of every link in 2012, and calculate indirect CO₂ emissions from purchased electricity and heat. In the end, calculate CO₂ 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**

<table>
<thead>
<tr>
<th>Link</th>
<th>Fuel type</th>
<th>Net consumption</th>
<th>Unit</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coking</td>
<td>Coke oven gas</td>
<td>21,6905</td>
<td>10⁴m³</td>
<td></td>
</tr>
<tr>
<td>Sintering</td>
<td>Coke</td>
<td>42,3214</td>
<td>10⁴t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blast furnace gas</td>
<td>396,168.579</td>
<td>10⁴m³</td>
<td></td>
</tr>
<tr>
<td>Iron-making</td>
<td>Anthracite</td>
<td>63,0956</td>
<td>10⁴t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coke</td>
<td>76,4548</td>
<td>10⁴t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coke oven gas</td>
<td>288,7852</td>
<td>10⁴t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total blast furnace gas byproduct of iron-making</td>
<td>13,99608.5019</td>
<td>10⁴m³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blast furnace gas consumption of iron-making unit</td>
<td>538,096.6083</td>
<td>10⁴m³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total converter gas byproduct of steel-making unit</td>
<td>973,554.307</td>
<td>10⁴m³</td>
<td>Statistics</td>
</tr>
<tr>
<td>Steel-making</td>
<td>Coke oven gas</td>
<td>2,212,5466</td>
<td>10⁴m³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blast furnace gas converter gas</td>
<td>90,6639</td>
<td>10⁴m³</td>
<td></td>
</tr>
<tr>
<td>Deep processing</td>
<td>Coke oven gas</td>
<td>2,157,4039</td>
<td>10⁴m³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blast furnace gas</td>
<td>66,309.1495</td>
<td>10⁴m³</td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>Steam coal</td>
<td>0.0477</td>
<td>10⁴t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Petrol</td>
<td>0.0016</td>
<td>10⁴t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diesel</td>
<td>0.3636</td>
<td>10⁴t</td>
<td></td>
</tr>
<tr>
<td>Loss</td>
<td>Blast furnace gas converter gas</td>
<td>500,385.71</td>
<td>10⁴t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coke oven gas</td>
<td>0.0382</td>
<td>10⁴t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diesel</td>
<td>0.0182</td>
<td>10⁴t</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>Coke oven gas</td>
<td>26,415.2486</td>
<td>10⁴m³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blast furnace gas converter gas</td>
<td>640,545.3719</td>
<td>10⁴m³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coke oven gas</td>
<td>53,810.8850</td>
<td>10⁴m³</td>
<td></td>
</tr>
<tr>
<td>Production processes</td>
<td>Limestone consumption</td>
<td>82,7700</td>
<td>10⁴t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dolomite consumption</td>
<td>58,8900</td>
<td>10⁴t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electrode consumption</td>
<td>5,500</td>
<td>10⁴t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Purchased nickel-iron alloy consumption</td>
<td>0.0000</td>
<td>10⁴t</td>
<td></td>
</tr>
</tbody>
</table>

#### 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 CO₂ emission formula.

#### 4) The summary of CO₂ emissions of the company

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

<table>
<thead>
<tr>
<th>Link</th>
<th>CO₂ emissions</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coking</td>
<td>Coke oven gas</td>
<td>40.754</td>
</tr>
<tr>
<td></td>
<td>Anthracite</td>
<td>41.727</td>
</tr>
<tr>
<td>Sintering</td>
<td>Coke</td>
<td>121.10</td>
</tr>
<tr>
<td></td>
<td>Blast furnace gas</td>
<td>33.599</td>
</tr>
<tr>
<td></td>
<td>Subtotal</td>
<td>196.43</td>
</tr>
<tr>
<td>Iron-making</td>
<td>Anthracite</td>
<td>121.38</td>
</tr>
<tr>
<td></td>
<td>Steam coal</td>
<td>106.09</td>
</tr>
<tr>
<td></td>
<td>Coke</td>
<td>826.39</td>
</tr>
<tr>
<td></td>
<td>Coke oven gas</td>
<td>0.5792</td>
</tr>
<tr>
<td>Steel-making</td>
<td>Total blast furnace gas byproduct of iron-making</td>
<td>1187.0</td>
</tr>
<tr>
<td></td>
<td>Blast furnace gas</td>
<td>456.36</td>
</tr>
<tr>
<td></td>
<td>Total converter gas byproduct of steel-making unit</td>
<td>147.24</td>
</tr>
<tr>
<td></td>
<td>Converter gas consumption of iron-making unit</td>
<td>0.0000</td>
</tr>
<tr>
<td>Deep processing</td>
<td>Subtotal</td>
<td>176.55</td>
</tr>
<tr>
<td>Steel-making</td>
<td>Coke oven gas</td>
<td>1.6865</td>
</tr>
<tr>
<td></td>
<td>Blast furnace gas</td>
<td>0.0769</td>
</tr>
<tr>
<td></td>
<td>Converter gas</td>
<td>10.635</td>
</tr>
<tr>
<td></td>
<td>Subtotal</td>
<td>12.398</td>
</tr>
<tr>
<td>Deep processing</td>
<td>Coke oven gas</td>
<td>16.444</td>
</tr>
<tr>
<td></td>
<td>Blast furnace gas</td>
<td>56.237</td>
</tr>
<tr>
<td></td>
<td>Converter gas</td>
<td>5.252</td>
</tr>
<tr>
<td></td>
<td>Subtotal</td>
<td>127.90</td>
</tr>
</tbody>
</table>
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. According to the actual situation, the results are shown in Table 3. The uncertainty of the total emissions is ± 3.54%. According to the verification of the company, CO₂ emissions of coking, sintering, iron-making, steel-making and deep processing sectors respectively are 407.5, 1964.4, 1765.5, 124.0, 1279.0kt; CO₂ 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.

### D. Uncertainty Analysis

The error propagation method is applied to quantify the uncertainty, as shown in Formula 9 and Formula 10. According to the verification of the company, CO₂ emissions of coking, sintering, iron-making, steel-making and deep processing sectors respectively are 407.5, 1964.4, 1765.5, 124.0, 1279.0kt; CO₂ 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.

#### 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.

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#### 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.

### REFERENCES