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ESTIMATING THE ENERGY CONSUMPTION AND AIR POLLUTANTS EMISSIONS FROM IRON AND STEEL INDISTRY IN CHINA USING AIM/ENDUSE MODEL

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ABSTRACT

Iron and steel industry (ISI) is an important pollutant emission source in China. This research estimated the energy consumption, CO_2, air pollutants and heavy metal emissions from ISI in different regions of China based on the different resource endowments and development strategies. AIM/Enduse model was applied to analyze the application ratio of 16 advanced technologies in 9 scenarios. Different EAF ratio and emission factor of electricity were estimated in different scenarios. Results show that although the crude steel demand will decrease in the future, the application ratio of advanced technologies will be increases of varying degrees. EAF will keep increasing to the maximum limitation in CM2 and CM4 scenario. Correspondingly, electricity consumption will increase 9.7% and 34.1% in these two scenarios comparing with BaU in 2050, while, coal used for coking will decrease. Higher EAF ratio and low electricity emission factor will decrease CO_2 and air pollutants emission. However, more Hg, Cd and Cr will be emitted with the increasing EAF ratio.

Keywords: iron and steel industry, technological assessment, AIM/Enduse, China,

1. INTRODUCTION

The iron and steel industry (ISI) in China has been growing rapidly in line with the popularity of continuous casting technology and huge increases in infrastructure construction demand [1]. Whereas, the energy efficiency of existing steel plants in China is still lower than other major steel-producing countries due to the widespread presence of outdated facilities [2]. Consequently, the energy consumption of the ISI increased more than 3 times from 2000 to 2013, and 1687.2 million tons of CO_2 were emitted in 2013 [3, 4]. Therefore, controlling greenhouse gas (GHG) emissions is essential for China's efforts to address global climate change and promoting industrial transformation and upgrading.

The Chinese government issued a series of policies to curb severe environmental pollution problems and promote industrial upgrades in ISI. For instance, blast furnaces (BF) with capacities under 400 m^3 and basic oxygen furnaces (BOF) and electric arc furnaces (EAF) under 30 tons will be eliminated as mentioned in the latest Five-year plan. National emission standard for ISI is also becoming more stringent for promoting the ultra-low emissions regulation. Many researchers analyzed the emission reduction potential by various measures. For example, through technology upgrading, 12,139 PJ fuel and 416 TWh electricity will be saved from 2010 to 2030 [5]; 13% of energy will be reduced if increase the Electric Arc Furnace (EAF) ratio to 35% in 2030 [6]. Moreover, carbon capture and storage (CCS) technology [7], carbon policies are also considered [8]. However, these current researches did not analyze specific technologies, Moreover, they only considered whole China as the research area without consider the regional differences in resource endowment.

To solve these issues, this research will estimate the energy consumption and gas emissions from China's ISI until 2050 in detail. 16 advanced technologies will be introduced, and production structure will be changed by increasing EAF ratio. The originalities of this research are (1) separating China as three regions based on different level of policy implementation; (2) applying AIM/End-use model to evaluates the promotion process of each technology; (3) considering the emission reduction effect from electricity generation sectors.

2. METHODOLOGY

2.1 Introduction of AIM/Enduse model

Asian-Pacific Integrated Model (AIM)/Enduse used in this research is a bottom-up modeling tool. It calculates energy consumption and GHG emissions on the basis of simulating material and energy flow during each production technology processes [9, 10].

Selection of technologies takes place in a linear optimization framework where system cost is minimized in each year under several constraints like satisfaction of service demands, availability of energy and materials supplies, existing device stock, maximum allowable quantity of devices, and emissions (eq 1).

Total Cost = Initial investment cost (￥) + Operating and maintenance cost (￥/year) + Energy cost (￥/year) + Payment for energy tax (￥/year) + Payment for emission tax (￥/year) (1)

2.2 Parameter setting

China are separated into three regions based on the different schedule of ultra-low emission transformation of IS enterprises (Tab.1). Domestic crude steel demand in China until 2050 is estimated our former research by using a crude steel demand model [11, 12] (Fig. 1). Crude steel demand in each region are estimated by AIM/LPS_ED[ISI] model [13]. Energy consumption by ISI in China in 2015 is downscaled to each province based on regional energy balance table, and then calculate the CO_2 and air pollutants emissions based on IPCC 2006 report. Totally 16 advanced technologies are estimated including 10 energy-saving technologies and updating the furnace to increase their energy efficiency. Nine scenarios are setting in this research, including business as usual (BaU), moderate and rapid growth of EAF, decrease emission factor of electricity, and carbon capture storage (CCS) [Tab. 2].

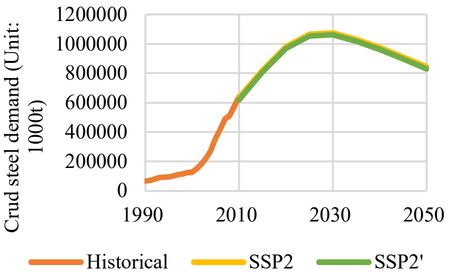

Fig. 1 Future crude steel demand of China

Tab. 1 Three research regions

Code	Provinces
COC	Beijing-Hebei-Tianjin, Shandong, Shanghai, Zhejiang, Jiangsu, Anhui, Shanxi, Shaanxi
MOC	Guangdong, Sichuan, Chongqing, Liaoning, Hubei, Hunan, Xinjiang
ROC	The rest provinces

Tab. 2 Parameters in each scenario

Scenario	Key factors
BaU	Parameters will be constant;
CM1	Emission factor of electricity will reduce 61% in 2050 than 2010;
CM2	EAF ratio will increase to 30%;
CM3	EAF ratio will increase to 30% + Emission factor of electricity will reduce 61% in 2050;
CM4	EAF ratio will increase to 80%;
CM5	EAF ratio will increase to 80% + Emission factor of electricity will reduce 61% in 2050;
CM1-1	Parameters will be constant+CCS
CM4-1	EAF ratio will increase to 80%+CCS
CM5-1	EAF ratio will increase to 80% + Emission factor of electricity will reduce 61% in 2050+CCS;

3. RESULTS AND DISCUSSION

Due to the limited space, this paper will only show the results in COC region as an example.

3.1 Ratio of EAF

Although the crude steel output will decrease after 2030, the ratio of EAF will keep increasing to the maximum limitation in CM2 and CM4 scenario, which are 30% and 80%, respectively.

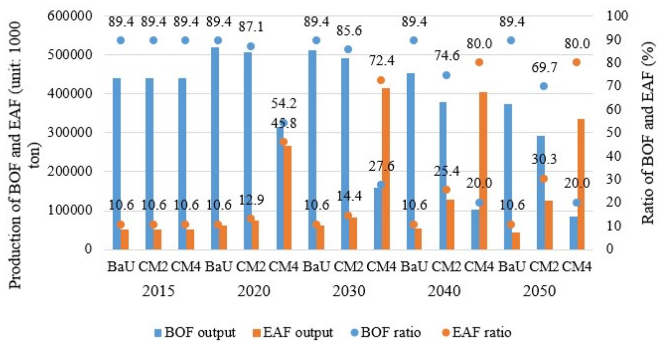

Fig 2. Production (bar chart, left axis) and ratio (scattergram, right axis) of EAF and BOF

3.2 Energy consumption

As the raw material of EAF, electricity consumption will increase 9.7% and 34.1% in CM2 and CM4 scenario comparing with BaU scenario in 2050, respectively, in response to the increasing production of EAF. Mix fuel consumption will also increase 7.4% and 26.3% in 2050, respectively. Whereas, coal used for coking will decrease at most 77.6% in CM4 scenario in 2050 because of the decreasing potential of BOF (Fig. 3).

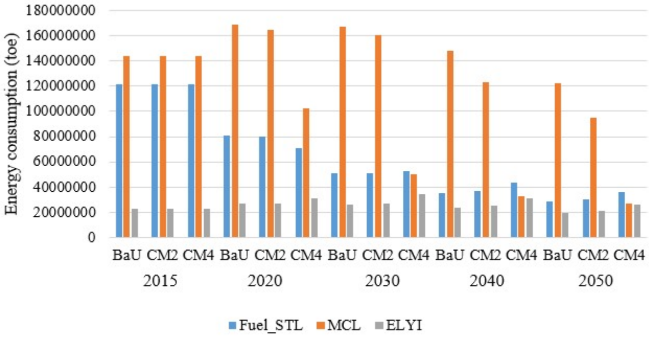

Fig 3. Consumption of Mix fuel (fuel_stl), coal for coking (MCL) and electricity (ELYI) in different scenarioS

3.3 CO_2 and air pollutants emissions reduction by increasing EAF ratio

The EAF ratio has great influence on CO_2 and air pollutants emissions due to its effect on energy structure change. In CM2 scenario, CO_2 emission will decrease 11.1% in 2015 comparing with the emission in BaU scenario. At the same time, emission of CH_4 and PM2.5 will be 16.9% and 18.9% less than BaU in 2050, respectively (Fig. 4). CM4 scenario has more significant emission reduction effect due to the higher EAF ratio than CM2 scenario. CO_2, CH_4 and PM2.5 emission will decrease 38.9%, 59.6% and 76.6% comparing with BaU scenario in 2050, respectively (Fig. 5).

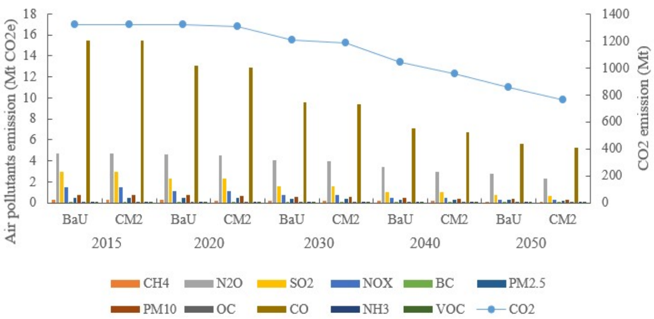

Fig 4. CO_2 (line, right axis) and air pollutants emissions (bar chart, left axis) in BaU and CM2 scenario

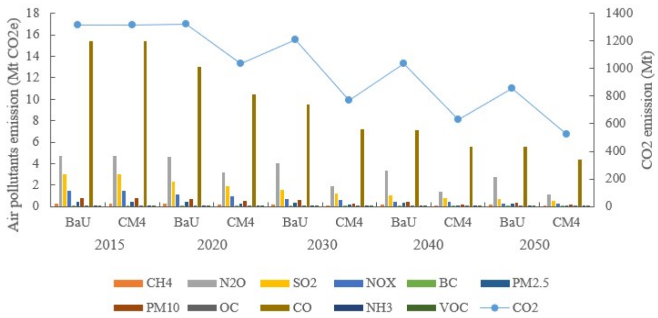

Fig 5. CO_2 (line, right axis) and air pollutant emissions (bar chart, left axis) in BaU and CM4 scenario

3.4 Effect of decreasing emission factor of electricity

Based on the prediction of IEA, the ratio of thermal power will decrease from 79% in 2010 to 43% in 2040. Correspondingly, CO_2 emission will reduce 14.4% in BaU scenario in 2050. With the increasing EAF ratio and electricity consumption, 17.7% and 31.5% CO_2 emission will be decreased in CM2 and CM4 scenario (Fig. 6).

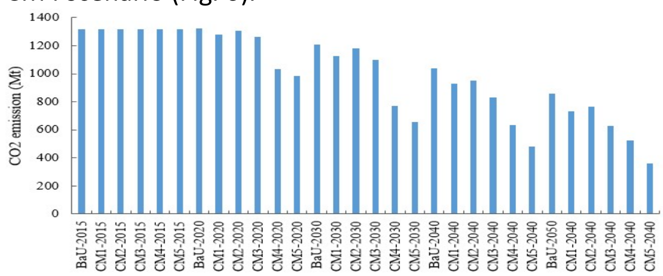

Fig 6. Emission reduction effect of low electricity emission factor

3.5 Emission of heavy metal

Heavy metal emissions from iron and steel industry are estimated based on the emission factors in research of Wang et al. [14]. By increasing the EAF ratio, emission of Hg, Cd and Cr will be more than 1.5 times higher in CM5 than BaU in 2050. Because most of these three heavy metals are emitted from EAF route. Whereas, 2/3 Pb are emitted by BOF route. Therefore, the emission of Pb will be 38% lower in CM5 than BaU in 2050 due to the high EAF ratio.

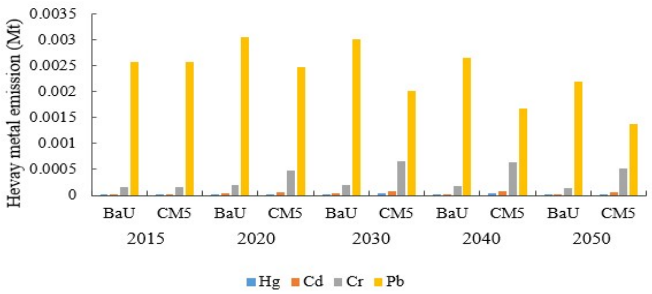

Fig 7. Heavy metal emissions in different scenario and different year

3.6 Application rate of advanced technologies

Advanced technologies will become much popular in the future. Taking Basic Oxygen Gas (BOG) recovery technology as an example, its application rate was 46% in 2015, and will increase to 94% in 2050 in BaU. Whereas, with the BOF ratio decreases, the application rate of BOG will decrease to 80% in CM5 in 2050.

4. CONCLUSION

This research provides a detailed evaluation of the energy consumption and gas emissions in ISI in China using AIM/Enduse model by separating China into three regions based on the different levels of policy implementation. Totally 9 scenarios were analyzed by setting different EAF ratio and CCS technology. As the raw material of EAF, emission factor of electricity was so estimated in this research. Besides, application rate of 10 energy-saving technologies and advanced furnaces were selected freely by the model in each scenario. So that, the annual expenses will be kept to a minimum. Energy consumption, CO_2 and air pollutants emissions and heavy metal emissions from each scenario were calculated to show the mitigation effect of climate change. Results show that the application ratio of advanced technology will increase in BaU and CM2, while, decrease slightly under higher EAF ratio in CM4 scenario. Higher EAF ratio is benefit for energy conservation and emission reduction, However, emission of several kinds of heavy metal would increase which need to arouse our attention.

This paper only takes COC region in China as an example to show part of the results. In the full paper, results in other two regions and more detailed research findings will be presented.

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