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Potential of energy savings and CO_2 emission reduction in China's iron and steel industry

Ruying An[a,b,c], Biying Yu[a,b,c,d,*], Ru Li[a,b,c], Yi-Ming Wei[a,b,c,d]

[a] Center for Energy and Environmental Policy Research, Beijing Institute of Technology, Beijing 100081, China
[b] School of Management and Economics, Beijing Institute of Technology, Beijing 100081, China
[c] Beijing Key Lab of Energy Economics and Environmental Management, Beijing 100081, China
[d] Sustainable Development Research Institute for Economy and Society of Beijing, Beijing 100081, China

HIGHLIGHTS

- Analyze potential of energy and CO_2 reductions in China's iron and steel industry.
- A National Energy Technology—Iron and Steel (NET-IS) model is developed.
- Potential CO_2 emission reductions could achieve 818.3 $MtCO_2$ during 2015–2030.
- Promoting low-carbon technologies is the most effective way for emissions reduction.
- Emission abatement cost would be 1740 CNY/CO_2 in 2030 in iron and steel industry.

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ABSTRACT

The iron and steel industry plays an important role in mitigating global climate change. As the largest steel producer and consumer, China bears the primary responsibility for energy savings and CO_2 emission reduction in the iron and steel industry. In this study, taking China as the empirical context, we analyze the effectiveness of the following four strategies on the potential of energy savings and emission reduction: phasing out backward production capacity in accordance with the current major policies, adjusting the production structure to increase electric arc furnace steelmaking, promoting low-carbon technologies, and switching to clean fuels. Under the principle of cost minimization, the mitigation potential of different strategies until 2030 and the technological development paths for reducing energy and CO_2 emissions in China's iron and steel industry are identified via an established National Energy Technology model. The results show that promoting low-carbon technologies is the most effective strategy for energy savings and emission reduction alongside cost minimization. Compared with existing policies, these strategies could lead to a cumulative reduction of 818.3 $MtCO_2$ (4.1%) during the period 2015–2030. Therefore, policy makers should provide financial or administrative support to promote the development of specific production and low-carbon technologies such as non-blast furnace iron-making and endless strip production.

1. Introduction

The IPCC fifth assessment report has clearly pointed out that climate change is caused by anthropogenic greenhouse gas emissions, and poses a threat to human society and natural ecosystems [1]. Therefore, effective adaptation and mitigation measures are necessary. To address climate change, key sectors such as industry, transportation, construction, and agriculture need low-carbon transformation. As one of the most resource-intensive industries, the iron and steel industry is a major sector of greenhouse gas emissions accounting for about 7% of total global CO_2 emissions [2]. In 2016, world total crude steel output was 1.63 billion tons, while China's crude steel production reached 808.4 million tons, accounting for 49.6% of global output (Fig. 1). The apparent consumption of finished steel reached 1.52 billion tons globally, with China accounting for about 45.0% in 2016 [3]. At present, China has become the world's largest steel producer and consumer [4]. Furthermore, energy consumption in China's iron and steel industry is dominated by coal and coke which accounts for 89.18% of energy consumption in the iron and steel industry [5]. This makes the iron and steel industry the main CO_2 emitters in China, contributing

* Corresponding author at: Center for Energy and Environmental Policy Research, Beijing Institute of Technology, Beijing 100081, China.
E-mail addresses: yubiying_bj@bit.edu.cn (B. Yu), wei@bit.edu.cn (Y.-M. Wei).

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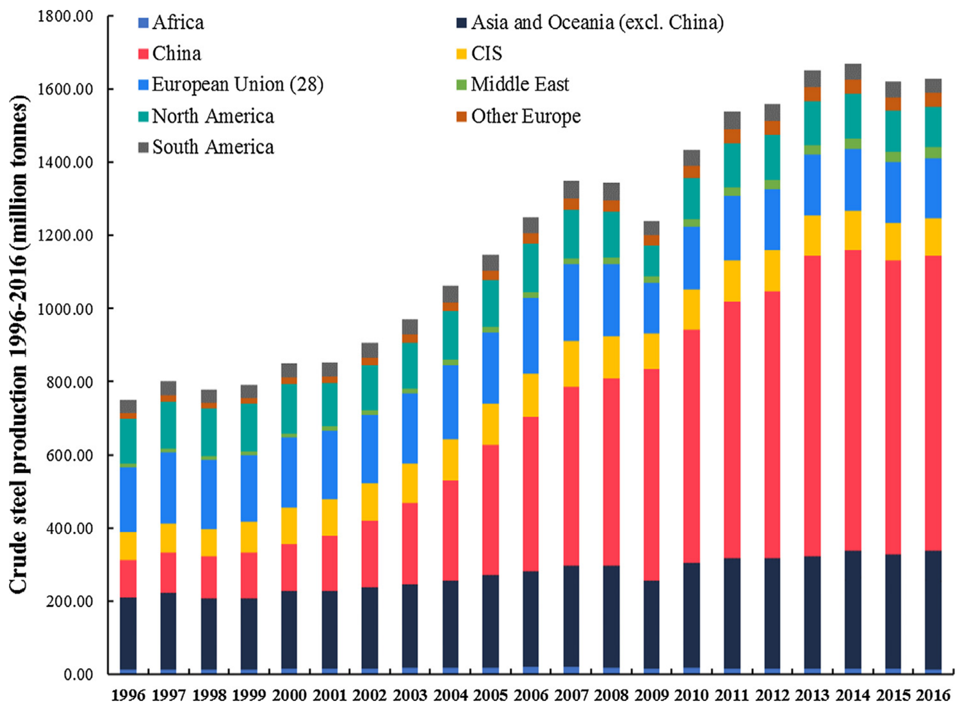

Fig. 1. Crude steel production around the world from 1996 to 2016.

approximately 15% of national CO_2 emissions [6]. Therefore, the development of the iron and steel industry is facing serious environmental problems [7], and the transition to low-carbon technologies is of great significance for controlling CO_2 emissions and implementing commitments to emission reduction [8].

China's iron and steel industry is driven by domestic demand. With the rapid development of the economy and urbanization, the iron and steel industry has grown vigorously. Alongside the national policy of phasing out backward production capacities and applying new technologies, comprehensive energy consumption per tonne of steel production has dropped substantially in the past few decades [9]. However, the overall energy efficiency of China's iron and steel industry remains relatively low compared with countries with advanced technologies. This is mainly because of China's outdated production equipment, poor energy efficiency among small enterprises, and low secondary energy recovery rate [10]. Therefore, the introduction of advanced technologies and equipment is an effective way to enhance the energy efficiency of the iron and steel industry [11].

Recently, CO_2 emissions in China's iron and steel industry have increased year by year [12]. To achieve energy savings and CO_2 emission reduction in the iron and steel industry, the government has promulgated a series of policies, including the following: (1) eliminating backward production and prohibiting new capacities (e.g., blast furnaces of 400 m^3 and less) [13,14]; (2) developing electric arc furnace (EAF) steelmaking, implementing green upgrading and innovation, and promoting technological innovation [15,16]; (3) popularizing removal or recovery technologies, such as sintering efficient dust removal systems, dry removal of converter flue gas dust, waste heat recovery and others [13]; and (4) establishing strict environmental standards and emissions targets [17,18]. National policies have provided an important guarantee for the sustainable development of the iron and steel sector in China.

Until now, many studies have investigated the potential of CO_2 emission reduction that China's iron and steel industry can achieve by considering some of the above-mentioned policies. However, most of those studies over-simplified the steel production process and lack detailed descriptions of the energy-consuming technology inventory, and thus cannot comprehensively evaluate the impacts of the latest national plans, industrial standards, and international frontiers on the iron and steel industry. The present study aims to provide a more concrete picture on the steel production process and relevant technologies, and to analyze the effectiveness of four energy-saving and CO_2 emission reduction strategies on China's iron and steel industry. These strategies include: following the current policies scenario, which focus on phasing out backward production capacities (business-as-usual [BAU]); adjusting the production structure by further raising the proportion of EAF steelmaking in addition to the BAU scenario (PS); further promoting low-carbon technologies in addition to the PS scenario (LT); and switching to clean fuels by reducing coal consumption in addition to the LT scenario (CF). As can be seen, the CF scenario is a combination of all four strategies. To evaluate the effectiveness of these strategies, we further develop a National Energy Technology-Iron and Steel (NET-IS) model with the objective of cost minimization during the procedure of steel production. The NET-IS model describes the decision-making process for the selection of different production technologies throughout the steel production process, and then calculates and analyzes the corresponding energy use, emissions, and required investment costs for meeting demand. The results provide a more manipulable technology development path that could better instruct policy design and technology deployment for reducing energy consumption and CO_2 emissions in the iron and steel industry.

The layout of the present paper is as follows. In Section 2, we briefly review previous work related to the energy and emissions of the iron and steel industry. In Section 3, we introduce our method, which includes the details, architecture, and equations of the NET-IS model. In Section 4, we analyze the settings for the four scenarios and the parameters established in the NET-IS model. In Section 5, we show the projection results in terms of the CO_2 emissions, costs, energy consumption, and technology path. Finally, in Section 6, we draw conclusions and discuss some policy implications.

2. Literature review

As an important sector of energy consumption and CO_2 emissions, the iron and steel industry has become one of the most popular target sectors for scholars. Many scholars have explored the main drivers of