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A review of energy use and energy-efficient technologies for the iron and steel industry

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ABSTRACT

The iron and steel sector is energy-intensive, and it consumed 18% of the world's total industry final energy consumption in 2013. At present, according to the statistical data of International Energy Agency (IEA) published in 2012, the iron and steel industry has the technical potential to reduce its current total energy consumption by approximately 20% by applying the best available technology (BAT), and more than half of this technical potential may be obtained in China, where more energy-efficiency technologies/measures should be implemented in the steel plants. So a review of energy-efficiency technologies/measures in steel industry could be helpful for steel plants to improve their energy efficiency. Therefore, this paper presents a list of energy-efficiency technologies and practices applicable to the steel industry, which includes case studies around the world and information of energy savings and cost when available. Also, a brief overview of the steel industry around the world, details and energy use conditions of different steel manufacturing processes, types of energy use and specific energy consumption of steel industry and details of secondary energy are also included in this paper to give readers a clear understanding of the energy use situation of the steel industry.

1. Introduction

The production process for manufacturing steel is energy-intensive and requires a large amount of resources. In 2013, the iron and steel sector accounted for 18% of the world's total industry final energy consumption [1]. The energy efficiency of steel industry has a direct effect on overall energy consumption. As such, improving energy efficiency should be a primary concern for iron and steel plants, especially in times of high energy price volatility.

Industrial energy intensity can be reduced through technological progress [2]. There are many existing researches on steel industry from a technical point of view [3–9], and the energy saving potential of China [10,11] (including Taiwan [12]), the U.S. [13], Germany [14], India [15], and the EU [16,17] has been assessed in scientific papers. Besides the aforementioned studies, several reports and publications on energy issues and energy-efficient technologies and measures [18–33] of the iron and steel industry are also available in the literature. There is no doubt more widely use of best available technology (BAT) would greatly reduce energy intensity. However, at present, the popularity of energy-saving technology in iron and steel industry still needs to be improved.

Global crude steel production grew 96% between 2000 and 2014, an average annual growth rate of 6.9% [34]. Rapid expansion of production capacity has had generally positive effects on the energy efficiency of the industry. New plants tend to be more energy-efficient than old ones, but not all new plants apply the best available technology (BAT). Based on the International Energy Agency (IEA)'s statistical data published in 2012, the iron and steel industry has the technical potential to reduce its energy consumption by approximately 20% of the current total energy consumption of the sector, by applying BAT, and over 65% of this technical potential may be obtained in China [19].

There are various energy-efficiency opportunities that exist in every steel plant, many of which are cost-effective; however, even cost-effective options are not often implemented in steel plants, and part of the reason for this phenomenon is the limited information. On the other hand, BATs are always changing due to continuous radical and incremental innovation. So a review of latest energy-efficiency technologies/measures in steel industry could be helpful for steel plants to improve their energy efficiency.

The work presented in this paper is a unique study for iron and steel industry, as an extensive literature review was conducted in this study to obtain information on the energy use and energy efficiency measures/technologies for the iron and steel industry. This study reviewed case studies from iron and steel plants around the world, and presents

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a long list of 158 iron and steel sector-specific energy-efficiency measures and technologies, including energy savings and cost information, when available; in addition, references about other cross-cutting measures that are in principle applicable across all manufacturing industries are also given in this paper. Most of references used in this paper are from China, Japan and U.S., which are major steel production countries. We hope this study could be useful reference for global policy makers, researchers, and industrial energy users and help create a strong awareness of energy savings in the iron and steel industry.

In addition, the paper also gives an overview of the development and present situation of world crude steel production, steel production routes, breakdown of energy consumption by end use and production process, and major secondary energy to give readers a clear understanding of steel industry.

2. Overview of the iron and steel industry

2.1. Development of the iron and steel industry

Iron, the precursor of steel, fueled the industrial revolution that began in 1750, enabling manufacturing of equipment in factories and rail transport. Modern steelmaking was developed 150 years ago with the invention of the Bessemer process, resulting in affordable mass production of steel (an iron alloy). This development set off a second industrial revolution and sustained economic growth [35].

Modern iron and steel metallurgy began in the middle of the 19th century and rapidly developed in the 20th century. According to statistical data of the World Steel Association [36], world crude steel production was as high as 28.3 Mt in 1900, maintained at over 100 Mt since 1936, exceeded 200 Mt in 1951, and reached 850 Mt in 2000. In the 21st century, the world crude steel production began increasing further and reached 1670 Mt in 2014 (Fig. 1).

World crude steel production remained relatively constant between 1975 and 2000. Two periods of rapid development in the iron and steel industry occurred after the 1950s, namely, the mid-1950s to the mid-1970s and the late 1990s to the early 21st century. (Table 1).

As technological developments in the iron and steel industry were achieved, energy consumption in this industry has been reduced. However, while the steel industry has reduced its energy consumption per ton of steel produced by 60% over the last 50 years, the field still presents large energy saving potential [39].

2.2. Present situation of the iron and steel industry

The steel industry directly employed over two million people around the world in 2011, along with two million contractors and four million supporting industries. Considering the position of steel as the key product supplied to various industries such as the automotive, construction, transport, power, and machine goods industries, the steel industry remains the source of employment for millions of people (Fig. 2) [35].

In 2014, the world total crude steel production was approximately 1665 million tons, of which China produced 49.4%. The top 10 largest crude steel-producing countries (China, Japan, the U.S., India, South Korea, Russia, Germany, Turkey, Brazil, and Ukraine) produce over 80% of the world crude steel production (Table 2) [40].

More than 1.6 billion tons of steel is manufactured and used every year. Currently, 49.4% of the steel available is produced and used in mainland China. The volume of steel produced will continue to increase, particularly in developing areas, such as Latin America,

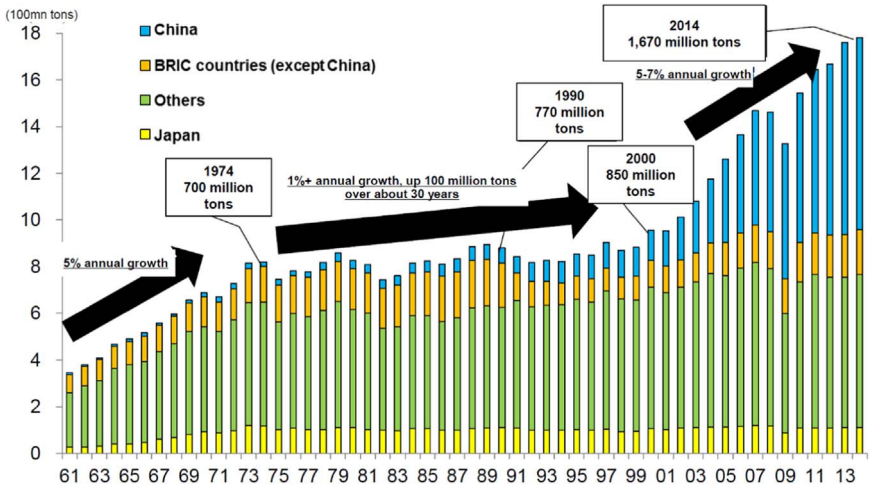

Fig. 1. World crude steel production (1961–2014) [37].

Table 1
Two periods of rapid development in the iron and steel industry [38].

	The first period of rapid development of iron and steel industry	The second period of rapid development of iron and steel industry
Cause	European countries, North America and Japan reconstructed infrastructure and industrialized after the second world war	China and some other developing countries constructed infrastructure and industrialized
Period	from the mid-1950s to the mid-1970s	from the late 1990s, and still continuing
Time of duration	About 20 years	It is expected to continue until the second decade of the 21st century
Increment rate	19 million t/year	60 million t/year
Population involved	About 800 million	About 1.3–1.4 billion
Technical perspective	Independent innovation technology in developed countries, such as converter, continuous casting, computer automation	Applying the mature technology or introduced the advanced technology of developed countries