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China's coke industry: Recent policies, technology shift, and implication for energy and the environment

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HIGHLIGHTS

- ► With 60% of world coke output, China's coke making has big energy/pollution issues.
- ► Actions were taken to improve energy and environmental performance of coke plants.
- ► China's coke industry is experiencing an unprecedented technology shift.
- ► Another shift, focusing on technologies of energy and emission saving, is needed.
- ► More measurement studies on coking emissions are needed given the importance.

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ABSTRACT

China is the largest coke producer in the world, accounting for over 60% of the world coke production, which makes the coke industry in China a significant coal consumer and air pollutant emitter. Recently, China has taken a series of measures to improve energy efficiency and reduce emissions from the coke industry, including eliminating old and low energy-efficiency coking technologies, promoting advanced technologies, and strengthening energy and environmental requirements on coking processes. As a consequence, China's coke industry is experiencing an unprecedented technology shift, which was characterized by the elimination of old, inefficient, and polluting indigenous ovens and small machinery ones within 10 years. This study examines the policies and the prompt technology shift in China's coke industry, as well as the associated energy and environmental effects, and discusses the implications with respect to the development of the coke industry in China towards a more efficient and clean future. As China sets stricter requirements on energy efficiency and the ambient environment, a more significant change focusing on technologies of energy saving and emission reduction is urgently needed at present. Those mature technologies, including coke dry quenching, coke oven gas recycle, fine particle removal, etc., should be enforced in the near future.

1. Introduction

Coke is an important raw material in the iron and steel industry. China is the largest coke producer in the world, accounting for more than 60% of the world coke production in 2010 (National Bureau of Statistics of China, 1996–2011). Fig. 1 presents the coke production in eight leading coke producers in the world. As shown, while the coke production of other major coke producers remained unchanged or even decreased recently, China's coke production increased dramatically from 122 million metric tons (MMTs) in 2000 to 428 MMTs in 2011 (National Bureau of Statistics of China, 1996–2011; China Iron and Steel Association, 2009).

The coke industry is the third largest coal consumer in China after power generation and manufacturing industry, and it is the most important coal chemical industry in China, representing more than 70% of non-fuel uses of coal. Not surprisingly, the coke industry is a significant polluting source in China. Coking processes were estimated to contribute 5.5% to $PM_{2.5}$ (particulate matters with diameters of 2.5 μm or less), 15% to total black carbon (BC) emissions, and > 16% to polycyclic aromatic hydrocarbons (PAH) emissions in China during 2003 and 2005

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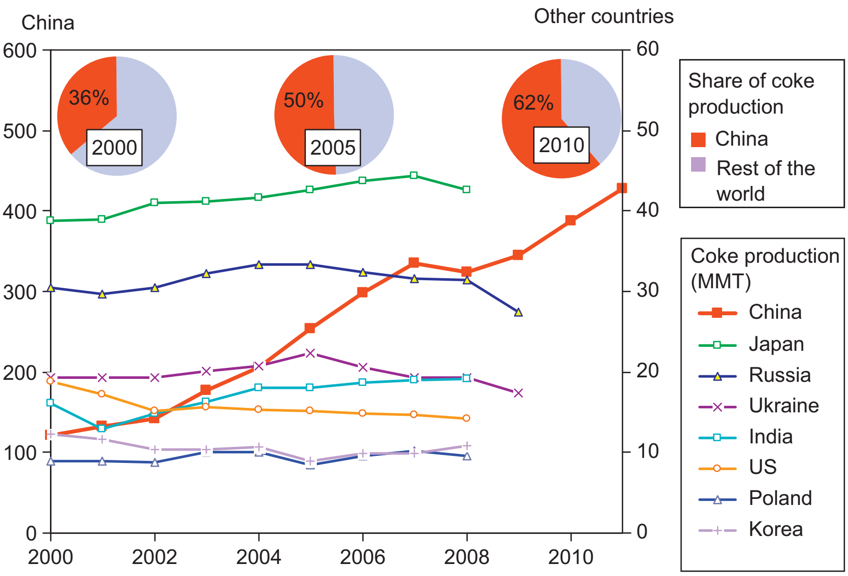

Fig. 1. Coke production in eight leading coke producers in the world.

(Lei et al., 2011; Xu et al., 2006). Coke production, especially small-scale coke production, was considered to create high PAH exposure concentration and increase lung cancer risk in people who work in or live close to coke plants (Zhang et al., 2009a).

In recognition of the significant negative environmental impact of the coke industry, and in order to achieve the national targets of reducing energy consumption per GDP by 20% from 2005 to 2010 and by another 16% from 2010 to 2015, the Chinese government has made tremendous efforts to improve energy efficiency and reduce emissions from coke production during the last decade, including formulating numerous policies to eliminate old, small, low energy-efficiency, and high emission coking technologies, promoting advanced coking technologies, and strengthening energy and environmental requirements on coking processes. As a result of these policies and the rapid growth of coke industry, the coke industry in China has experienced an unprecedented technology shift in a very short period. However, because the coke industry in China is increasing its production significantly, more technical and economic measures are needed to further improve the energy and environmental performance of coking processes.

The purpose of this study is to understand the recent policies and the ensuing technology shift in China's coke industry, as well as the associated energy and environmental effects. We discuss the implication of our findings with respect to the development of the coke industry in China towards a more efficient and clean future.

2. Overview of technologies used in coke industry

Energy efficiencies and emission levels vary significantly across different coking technologies. Countries in the world have different categories for cokemaking technologies, for instance, western countries usually classify coking technologies into by-product ovens, non-recovery ovens, and other advanced ovens. Generally, coke production technologies in China can be classified into five categories: indigenous ovens, modified indigenous ovens, machinery ovens, vertical coke ovens, and heat recovery ovens.

Indigenous ovens are the oldest coke ovens. "Pile" and "kiln" methods are used to make coke with this type of ovens. Indigenous ovens are highly polluting, because the body of the kiln is simply constructed and has no sealing to keep the pollution from escaping (Chen and Polenske, 2006). This type of coking technology has been largely phased out in most countries.

Modified indigenous ovens are similar to the beehive ovens that were widely used in industrialized countries at the beginning of the 20th century. These ovens add simple tar-recovery mechanisms and coke oven gas (COG) recycling to the indigenous design. Modified indigenous ovens discharge the combusted COG into the atmosphere directly, which could produce serious air pollution because the combustion is incomplete (Chen and Polenske, 2006).

Machinery ovens are also named as by-product ovens or conventional slot ovens in other countries. They are able to recover most chemical by-products and COG. All machinery coke ovens essentially have three parts: coking chambers, heating flues and regenerative chambers, and a steel frame. Emissions usually occur in processes of coal crushing, coal pushing, coal feeding, coke quenching, etc. Increasing the height of the coking chamber can reduce emissions by reducing the times of coal pushing, feeding and quenching. It is estimated that coke ovens with coking chamber height of 6 m have 30–40% lower emissions compared to those of 4 m while producing the same amount of product (Wang, 2010). According to the coal feeding system, machinery ovens can be further categorized into top-charged ovens and stamp-charged ovens. The former are charged with ordinary prepared coal (usually 750 kg/m^3) from the top, and the latter are charged with stamped coal cakes (with the size of a little smaller than the coking chamber, usually 950–1150 kg/m^3) from the sides. Stamp-charged ovens have a larger production capacity than top-charged ovens of the same chamber heights, thus have lower emission levels because of the fewer times needed for coal pushing, feeding and quenching.

Vertical coke ovens can improve energy efficiency and reduce emissions by continuous charging. Heat recovery ovens (also named as non-recovery ovens) operate under negative pressure and burn all of volatiles and tar from coal within the chamber to provide heat for the cokemaking process. The share of production of vertical coke ovens and heat recovery ovens in China is very small, less than 6% in 2006 (Xu, 2007).

In order to simplify the calculation of emissions, previous studies usually categorized coke ovens into two groups: (1) indigenous ovens, including indigenous ovens and modified ones and (2) machinery ovens, including all mechanically operated ovens.