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Constructing an energy efficiency benchmarking system for coal production

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HIGHLIGHTS

- Contributed to overall coal industry energy efficiency research by focusing on coal mining production.
- Constructed an energy efficiency indicator system to benchmark coal production.
- Created an energy efficiency benchmarking methodology and defined the benchmark standard.
- Analyzed the potential for energy efficiency improvements in China's coal production.

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ABSTRACT

Coal mining not only produces, but also consumes a large amount of energy. Coal production has an extremely high energy efficiency potential, and benchmarking is critical to discover this potential. To address problems such as ambiguity of coal production (e.g. underground mining), benchmarking range and absence of both indicators and standards for energy efficiency benchmarking, this paper makes use of product-based and process-based benchmarking. These two techniques are used to construct a benchmarking system for coal production with high energy efficiency, and improve the standards used at the eight coal mines owned by the Yankuang Group. Comparison and analysis of benchmarking in enterprises indicates that energy use during raw coal production could be reduced by 22.77%. Across China energy savings from coal production could reach 15.98–32.98 Mtce, with an equivalent 42–87 Mt of CO_2 emissions saved. Lastly, this paper provides measures to improve coal production energy efficiency.

1. Introduction

1.1. Current energy efficiency in the coal industry

Research on energy efficiency in the coal industry (coal mining, processing, utilization) primarily focuses on coal processing and utilization, including power generation, chemicals, metal smelting other key industries. For example, Zhang et al. [1] and Bhatt [2] researched the energy efficiency of coal-fired electric power plants; Man et al. [3] designed a coke-oven gas assisted coal to olefins process for high energy efficiency; Zhang et al. [4] proposed improving energy efficiency of cyclone circuits in coal beneficiation plants; Santosh et al. [5] researched clean coal technology to improve environmental quality and energy efficiency.

However, the literature rarely analyzes energy consumption in the coal mining sector, but rather focuses on coal mining in terms of economic benefit. Although there is no documented amount of energy consumed by the global coal mining industry, according to Chinese data it is estimated that energy consumption reached 100 Mtce (million tons of coal equivalent) per year. Some studies show that coal mining has high energy-saving potential: Zhao et al. [6] found that coal mining and washing is one of the fastest ways to increase TFEE (total-factor energy efficiency), meaning a higher level of energy efficiency per unit of economic output. Also, the US Department of Energy (DOE) energy bandwidth analysis shows that the US mining industry consumes about 365 billion kW h/year and that there is potential to reduce the annual energy consumption to 169 billion kW h, which is about 46% of current annual energy consumption [7]. Therefore, research on energy efficiency of coal mining is significant for the entire coal life cycle.

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1.2. Research on energy efficiency benchmarking

In a given industry, energy benchmarking is defined as a process of measuring energy performance of an individual plant or sector against a common metric that represents "standard" or "optimal" performance of that plant or sector [8]. It is useful for understanding energy use patterns, identifying inefficiencies in energy use, estimating the potential for energy conservation, and designing policies to improve energy economy [9]. Energy management is widely used in a variety of industries, as listed in Table 1, which lists energy efficiency benchmarking management by industry type.

With regards to energy intensive industries, previous studies have proposed energy efficiency benchmarking systems on oil and gas chemistry [10], steel industry [11] and cement industry [12]. However, very few studies focused on energy efficiency benchmarking for coal mining, likely due to the complexity of coal production technology and lack of international attention. Though the first process-based coal mine standards were established in 1992 [13], in the past two decades, there has been nearly no research on major energy consumption indicators of coal mine energy efficiency, nor were there any case studies available that describe the status of energy efficiency in coal mining. We have researched on the Science Direct and ISI Web of Knowledge database for the keywords "coal production", "coal mining", "energy efficiency" and "benchmark" from the year 2000 to 2015, but we do not find relevant literatures. Coal production energy efficiency benchmarking is crucial in studying coal energy consumption and therefore, a new benchmarking methodology and a set of energy consumption grade standards need to be established.

The traditional method is based on estimates of energy efficiency, which can be expressed as the ratio of energy consumed in coal mining and preparation and the total energy produced. This method is too simple, however, to reflect energy efficiency in coal production, and does not capture the disparity in conditions from different regions of China. Only two provinces have established provincial coal production standards, and they have shown great disparity even in the same year. Shandong's standard limits the comprehensive energy efficiency from 5.00 kgce/t to 14.53 kgce/t for different mines in 2012 [14], and Liaoning's provincial standard limits it to 12.4 kgce/t for existing mines in 2012 [15].

1.3. The structure of world coal production

World coal production in 2012 was 7.8645 billion tons. China has always been a major player in global coal production and consumption. Coal production in China has increased significantly from 917.4 Mtoe (million tons of oil equivalent) in 2003 to 1840 Mtoe in 2013, with an annual growth rate of 7.2% [23]. China's share of world coal production rose from 35.7% in 2003 to 47.4% in 2013 (Fig. 1). It is predicted that coal will continue to play a leading role in the energy structure of China for a long period [24].

The mining industry is one of the major energy-consuming sectors. It not only generates energy, but also consumes a large amount of power and contributes to greenhouse gas emissions (GHG). Sahoo et al. [19] estimated that energy consumption in the global mining industry accounts for 3% of all global energy consumption across all industries. The total energy consumption in mining sector in China was 211.9 Mtce in 2012 [25], accounting for 8.4% of the total energy consumption, which is much higher than the global average. Specifically for coal mining, the total energy consumed during coal mining increased from 40 Mtce in 2005 to over 60 Mtce in 2012, accounting for 2.4% of all industries in China[1].

[1] Unpublished data from China Coal Processing & Utilization Association.

Table 1
Energy efficiency benchmarking management application areas.

Areas	Research focus
Industrial energy benchmarking	Introduces industrial energy benchmarking and existing programs and practices. Also provides a general description of industrial energy benchmarking [9]
Products across countries	Presents a method (mapping & benchmarking) to compare the energy efficiency of products across countries [16]
17 industry sectors	Estimates the best practice technology (BPT) energy use of 17 industry sectors based on energy benchmark curves or energy indicators prepared at country-level [17]
Building	A total of twelve methods for benchmarking building energy consumption are reviewed. It is found that many simple methods can achieve satisfactory performance [18]
Mining industry	Estimates the minimum energy consumption of total mining industries including coal, metal and minerals using statistical data. Benchmarking analysis is useful to estimate the energy saving potential [19]
Electricity production	Conducts a study on the potential for reducing global energy-related CO_2 emissions from electricity production through simple benchmarking [20]
Copper and gold	Provides a baseline for energy in current gold and copper operations internationally [21]
Enterprise energy-efficiency potential	Builds a process lifecycle model of enterprise energy efficiency benchmarking and models for indicators of energy efficiency potential to provide the foundation for benchmarking options [22]

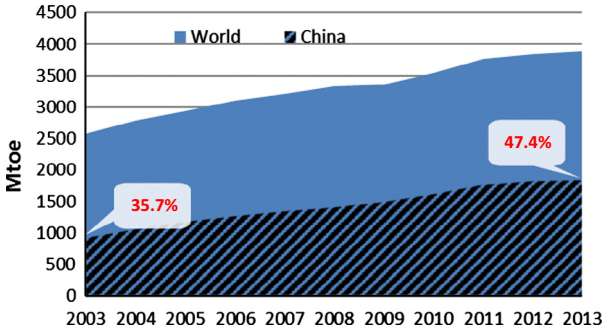

Fig. 1. Production of coal in China as a proportion of global coal production. *Source:* BP statistical review of world energy 2014.

1.4. China's energy efficiency status quo

During the first three years of the Twelfth Five Year Plan, Chinese coal companies installed advanced energy-saving technology and equipment, eliminated obsolete processes and products, and adopted new fuel and electricity saving methods during the coal production process, which saved 4.3 Mtce. This is only 1% of energy consumption saved. This unsatisfactory result may be due to the following reasons: lack of appropriate energy-efficiency techniques and poor auditing of mining processes like ventilation, hoisting and drainage. In addition there is also a lack of energy-saving management policies and no technological development.

1.5. Paper structure

This paper uses energy efficiency benchmarking to explore potential energy efficiency measures during coal mining, and pioneers the establishment of a comprehensive benchmarking system for coal mining energy efficiency. Three aspects of issues must be