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Evaluation and empirical research on the energy efficiency of 20 mining cities in Eastern and Central China

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ABSTRACT

The gap of energy efficiency of eastern and central mining cities in China continues to expand, getting more attention from relevant departments. In this work, 20 mining cities in Eastern and Central China from 2010 to 2014 have been selected as research samples using data envelopment analysis (DEA). Research results show that the level of energy efficiency in mining cities is still low. China is in an extensive economic growth mode with high input, high consumption, low output and low efficiency. Mining cities in China have a huge potential to conserve energy and reduce emissions. China should optimize industrial structures, strengthen scientific and technological input and innovation, as well as implement energy-saving emissions reductions, and increase investment in environmental protection and ideological propaganda.

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1. Introduction

A mining city is generally developed from its rich mineral resources. Depending on its local resources, the main development of a mining city is usually from raw materials or raw energy output. By the virtue of the local, excellent natural mineral resource, mining cities are then developed and constructed by the government to be a single city. Mining cities are an important mineral supply base for the process of modernization, which makes an important contribution to the support and promotion of the economic development of the country. Due to the limitations of mining cities, it is inevitable that these cities will grow to be developed but ultimately decline.

In the 1930s, Innis, a famous Canadian geologist and economist, did pioneering research on resource-based cities and towns in his paper titled "Raw materials production in Canada." In this paper, he described the impact of resource production on local community development and the problems it brings. After researching the sense of belonging in coal town residents, he found about half of the residents were still willing to stay in the area despite of economic decline and large population relocation [1]. Gill AM studied the social interaction of mining cities [2]. They found that social units in the community should have a strong level of interaction; that is, they should have good cooperation between different units

in the area and have more interactive ideas in planning work, to promote the development of the resource-based community. During this period, the research mainly focused on social and psychological aspects, including the application of geography, economic geography, urban planning science and regional development theory, behavioral and social science theory, and the influence of resource type in the lonely life of residents and determination of community instability factors. However, research on the development process of a single resource city has not considered the decline and transformation of resource-based cities in the process of resource depletion.

Since the mid-1980s, the application of economic structure adjustments, sustainable development theory and market segmentation theory have developed quickly. This is largely because old industrial areas have encountered a series of difficulties, including resource depletion and structural decline, bankruptcy in the resource mining industry, and losses in resource processing industry, which have caused a series of issues, including unemployment, economic decline, and social disorder. At that time, the focus of research changed from individual empirical research to the combination of empirical and normative research. Bradbury and other scholars explained the industrial rise and decline of resource-based cities and, in the process, manifested social and economic characteristics with the internationalization theory, the dual structure theory and the attachment theory [3]. For example, after an empirical study about the resource-based cities of Canada and Australia, suggestions for the development of resource-based cities

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were put forward. Research of population characteristics of resource-based cities in the Canadian Quebec-Labrador region was conducted from the angle of population migration [4]. It noted that the mining industry had a strong cyclicity and the development cycle of mining towns had a profound impact.

By the end of the twentieth century, many scholars had carried out comprehensive studies on the sustainable development of resource-based cities [5]. The studies first were on economic transformation in foreign resource-based cities, commonly known as the decline in the region's economic revitalization or structural problems in its economic revitalization. There were many topics that merit study in this area for empirical research and qualitative description [6].

With the depletion of resources and the impact of the resource market, there has been a large shrinking phenomena in resource type cities. In 2007, a forum on "shrinking cities" was held at the University of California, Berkeley, at which some scholars published their views on resource-based cities. After researching cooperation and contradiction between the mineral company and the community in Cerro de San Pedro, which is in San Luis Potosí in Central Mexico, he found that a contradiction between stakeholders because of a lack of negotiations for land use among the companies, communities, non-governmental organizations and the government. They also lacked plans for the development and rehabilitation of resource-based cities. Thus, social organizations and groups played a key role in the process of urban development. More attention needs to be paid to these issues, such as the residents' health, quality of life, and social, economic and environmental urban renaissance [7]. Hendryx did a social survey in coal mine communities when resource-based cities began to enter into a recession. He found that environmental pollution caused by coal mining made local people more likely to suffer from chronic heart disease, respiratory disease and kidney disease [8].

In the background of a global environment facing a severe crisis and the depletion of fossil energy, and because China is the world's second largest energy consumer after the U.S., the level of Chinese energy efficiency has the world's governmental and public attention. Many scholars have carried out beneficial explorations of China's energy efficiency from different perspectives and have achieved fruitful research results.

The focus of Chinese scholars is mainly on the definition and classification of mining cities, the transformation of mining cities, the problems in the development of mining cities, the transformative ways of mining cities and transformation mechanisms.

After 2010, with some achievements in the transformation of mining cities, research began to shift to urban space planning, industry development and the competitiveness of mining cities [9]. However, study of the evaluation of urban transformation and the problems in the process of transition, especially the criteria for the identification and classification of mining cities in the transition period, has not been perfect [10]. In most research, the objects are mostly based on a national level or on a single typical mining city. The research and comparison of mining cities in a typical region is relatively few [11].

At present, there are 426 mining towns and 99 mining cities in China, 28 of which are in the eastern region, 50 in the central region, and 28 in the western and central region [12]. Mining cities are mainly distributed in the eastern and central regions, and mining cities in the western region are often small.

Mining cities mainly rely on their first industry. With the depletion of resources and national economic transformation and upgrading, if a mining city cannot transform effectively, its decline is inevitable. After the 1990s, due to the failure of economic transformation and the depletion of mineral resources, many companies in Fuxin city suffered a great loss, and bankruptcy affected one company after another. There are also other

cities facing a similar situation because of the failures of their transitions [13].

One of the important measures for maintaining the prosperity of these cities, or even to slow their decline, is to improve their energy efficiency. In this paper, we choose resources cities in Central and Eastern China as the research subjects and then evaluated their energy efficiency and tried to find a reliable path to improve the energy efficiency of mining cities.

Since the United Nations Conference on Environment and Development (UNCED) was held in 1992, sustainable development has been adopted as a fundamental development strategy by many countries, including China. While it has been widely adopted as a goal, it does not, in itself represent ecological benefits. Eco-efficiency, an instrument for sustainability analysis that indicates an empirical relation in economic activities between environmental cost or value and environmental impact, has been proposed as a route to promote such a transformation.

Eco-efficiency plays an important role in expressing how efficient the economic activity is with regard to natural goods and services. Eco-efficiency is measured as the ratio between the (added) values of what has been produced (income, high quality goods and services, jobs, GDP, etc.) and the (added) environmental impacts of the product or service.

The sustained development of mining cities in China has been concerning to many scholars in China and abroad, but there are few studies on the energy efficiency of mining cities [14]. Previous research methods were mainly single factor energy efficiency (also known as energy intensity). It is more intuitive and its calculation is relatively simple, but it is difficult to use to accurately measure the potential energy efficiency [15].

At present, most literature in this field pays attention only to energy utilization or economic efficiency but ignores environmental problems produced in the process of energy utilization, which tends to result in the deviation of energy efficiency measures and misleads economic decision making [16]. In this paper, the use of energy produced in the process of environmental pollution problems is also included in the study. The current industry, industrial waste gas emissions and solid waste are incorporated in the impact on environment research and calculation.

The main purpose of this paper is to study the development of energy cities in different regions of China and analyze the gap between these cities. We collect urban development data and do the corresponding calculations by data envelopment analysis, obtain conclusions, and give suggestions for the next steps by the government.

2. Eco-efficiency measurement framework

A study on energy efficiency in the traditional method is called "single factor energy efficiency", and the most commonly used index is the unit of GDP energy consumption, which is equal to a country or region's total energy consumption to GDP ratio, also known as energy intensity. The outstanding advantages of single factor energy efficiency are that it is intuitive, simple and strong. For a long time, the method has been the mainstay of energy efficiency research. However, the main drawback is that it contains many factors, such as structure, which cannot reflect the energy utilization process input and the interaction between elements, and, as such, cannot reflect the changes in industrial structure, energy structure and changes the input substitution effect on energy intensity, which cannot accurately reflect the potential efficiency of energy utilization technology.

In this paper, a method of data envelopment analysis is used to study the relative efficiency of decision-making units with multiple input and output variables. With data envelopment analysis

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