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Potential assessment of optimizing energy structure in the city of carbon intensity target

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HIGHLIGHTS

- Establish the low-carbon city development model.
- GMI (1, 1) model is adopted to predict the carbon intensity development trends.
- Multiple Regression Forecast of the Primary Energy Consumption.
- The energy structure optimization is an effective measure to decrease the carbon intensity.

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ABSTRACT

Optimizing energy structure to reduce carbon intensity is an effective way to build the low-carbon city development model. To assess the contribution potential of energy structure optimization in order to achieve the carbon intensity target in Hangzhou City, the component data prediction, scenario prediction, GMI (1, 1) model and other multidisciplinary approaches were adopted to predict the carbon intensity trends in the above said City from 2014 to 2020. This contribution potential is evaluated based on 9 kinds of combined scenarios. The results show that: 1. Under the same economic growth rate, with the increase in energy structure adjustment range, the carbon intensity "decline range" becomes larger, and the higher is the "contribution potential" of energy structure optimization to achieve the carbon intensity target. 2. Within the same range of energy structure optimization, the economic growth rate is lower, the carbon intensity "decline range" is smaller, and the "contribution potential" of energy structure optimization is higher for the same carbon intensity objective. By optimizing energy structure and industrial structures adjustment, the technology upgrading for carbon emissions and the scientific and technological level of the systematic industrial policies are more conducive to supporting the realization of low-carbon city.

1. Introduction

With the dramatic global energy consumption, the carbon dioxide emissions caused by global climate change have been drawing more and more people's attention. Therefore, the need to reduce carbon dioxide emissions in ensuring stable economic development under the premise of energy consumption has become the focus of the far and wide world to make researches and discussions [1,2]. With the signing of the "Paris Agreement", China agreed to stop the increase in carbon dioxide emissions around 2030 or before. According to the plan of this vision agreement, the ambition is to make the ratio of the Chinese fossil fuel energy fall to about 80% by then. As a largest developing country, China will assume greater responsibility in the reduction of carbon emissions. The World Energy Outlook released by the U.S. Energy Information Administration (EIA) in 2008 said that from 2004 to 2030, the Chinese coal consumption will rise by 3.2% annually [3–5]. However, the coal-dominated energy consumption structure has brought serious environmental pollution problems. According to the statistics of the year of 2008, millions of tons of emissions were counted in China and results have shown the total carbon dioxide emissions of 6896 M tones, 23.212 M tones for sulfur dioxide emissions, soot emissions were counted to be 90.16 M tones, and industrial dust emissions being 4.849 M tones respectively. Thereafter, results also showed that energy consumption was dominated by coal. Although proportions of coal in the total Chinese energy consumption dropped to 68.7% from a peak value of 76% in 2008, but still

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occupy the absolute position and shows an upward trend in recent years share [6]. The Chinese oil and gas energy, especially natural gas, its proportion varied widely compared to that in the developed countries. The energy technology, processing and utilization efficiency are lower than those of OECD countries. The air pollutant emissions and energy consumption per unit energy intensity are relatively high. Therefore, energy consumption structure has an important theoretical and practical significance to the Chinese energy conservation and emissions reduction.

Timilsina and Camarero related the energy efficiency with the productivity to point out the whole production process from the increase in production efficiency to reduce energy consumption, thus revealing an internal relationship between productivity and energy efficiency [7,8]. Deng and He analyzed the development history of industrial energy efficiency management, and studied the effects of different efficiency management policies on national energy consumption [9,10]. Zhou and Cui analyzed the impacts of energy efficiency of the manufacturing industry equipment, conceived energy-saving policies and environment development, and instituted the lowest energy consumption standard [11,12]. Based on a large amount of data from industrial enterprises, Castelo and Ekins adopted the Panel Data Econometrics and measurement methods and results prompted the decrease in the Chinese energy consumption intensity factor which is rising relative price of energy, energy research and development expenses, Chinese enterprise property right and industrial reforms, etc. [13,14]. Choi and Zhou adopted the Input-Output Method to study the causes of the Chinese energy consumption per unit output decline [15,16]. On conclusion, they found that energy consumption efficiency improvement was mainly induced by the changes in technology sector, and also by some increasing imports of energy-intensive products. However, completing the structural changes will enhance energy consumption to boost up. Klepper and Morris premeditated the improvement in the energy consumption efficiency conditions for the industrial sector in China [17,18]. Studies suggest that the industrial restructuring effect was negative in the improvement of the Chinese industrial sector's energy efficiency, and the improvement of the entire industrial sector energy efficiency should result from each sub-sector's improvement so far. Enkvist and Baker recommended that the technological progress is undoubtedly an effective way of reducing energy intensity and improving efficiency, but the return effect also occurs simultaneously due to the economic growth stimulation and generate effect of returns [19,20]. Therefore, it will be taken advantage of alternative means to regulate the price of energy and other factors, and prompting more consumers to select other alternatives than energy, so can we accurately achieve energy saving perspectives. Naucle and Fleiter analyzed the relationship between GDP and energy, employment and CPI growth rate in the consumer price index [21,22]. The research put forward a suggestion that energy consumption has no direct or inherent causal relationship with GDP growth. Zhou and Yuan adopted the regression analysis to analyze the regional Chinese energy consumption efficiency characteristics and found that the spatial dependence is obvious between the provincial energy consumption efficiency and regional economic development, with spatial differences being more obvious [23,24]. Li included the knowledge stock into the production function, and adopted constant returns to scale the super-efficiency DEA model to estimate the Chinese provincial total factor energy efficiency (TFEE), and perform the market segmentation perspective inspection based on the provincial TFEE factors of influence [25]. Studies showed that the TFEE of the area is relatively low even though this area is relatively quoted with abundant energy resources. The deepest reason is that the market segmentation distorts the resources allocation, hinders the formation of regional industrial economies of scale, which results in the loss of TFEE.

Combining the existing relevant studies, the relationship between energy consumption and low-carbon cities was explored from different perspectives. These studies have an important inspiration and guidance to further explore the carbon intensity drivers, but hadn't explored how to achieve the low-carbon city target from the perspective of optimized energy structure. Main features are:

(1) At the time of the Chinese energy intensity decomposition, most scholars studied from the industrial level, and from the industrial sector stage there are no further investigations on the decomposition efficiency in industrial energy intensity, and no exploration on the efficiency and structural factors' effects on the energy intensity change has yet appeared.
(2) When studying the regional differences in energy efficiency, most of scholars adopted the data envelopment analysis (DEA) method, and few of them used the panel data analysis to assess the regional differences in energy consumption efficiency. The researches on the convergence between regional and economic differences in energy efficiency have not yet appeared.
(3) There is no literature about researches on the influencing factors that affect the industrial level of energy efficiency from the industrial economy transformation perspective. The study on Chinese "stock" and "incremental" reforms has a great significance on the functional mechanisms, methods and improving ways of industrial energy efficiency, through carrying out the work of energy-saving and emissions reduction.

Optimizing energy structure can not only achieve the coordinated energy industry development and ensure energy security, but also can directly and effectively reduce carbon intensity. As a matter of fact, it becomes naturally one of a series of countermeasures to be considered in the achievement of the carbon intensity targets. About how to achieve such targets through optimizing energy structure, there are two theoretical problems to be solved, i.e., Can optimizing the energy structure significantly reduce the carbon intensity? How much energy structure optimization can achieve the carbon intensity targets? Therefore, in-depth study on these two issues would be of great help to smoothly realize the carbon intensity targets in Hangzhou City.

In this paper, the component data prediction with comprehensive application, scenarios simulation, GM (1, 1) model and other multidisciplinary methods are adopted to assess the energy structure optimization and contribution potential to achieve the carbon intensity targets in Hangzhou City. Based on the primary energy consumption demand forecast in Hangzhou from 2014 to 2020 and adopting the combination of models, the Markov chain model was employed to predict the trend of variations in energy consumption structure. The contribution potential of energy structure optimization for achieving the carbon intensity targets in Hangzhou City is evaluated based on points and nine kinds of combined scenarios projected to be assessed in 2020. Based on the answers to the above mentioned theoretical problems, the theoretical support can be provided to the relevant departments in Hangzhou City for decision-making.

2. Predicting Hangzhou primary energy consumption and its variables

2.1. Data sources

Since the atmospheric CO_2 mainly comes from fossil fuels combustion, this paper adopts formula (1) to calculate the Chinese energy consumption for CO_2 emissions C (10,000 t) over the years