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Prospective on energy related carbon emissions peak integrating optimized intelligent algorithm with dry process technique application for China's cement industry

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ABSTRACT

Global climate change is a significant environmental problem. A major trigger of climate change is the excess carbon emissions. Based on 44 scenarios in the second generation of new dry cement technology systems, this paper establishes IPSO-BP model to forecast the carbon emissions peak of China's cement industry for 2016–2050 years. The results indicate that China's cement industry only implements capacity reduction plans and the second generation of new dry cement technology systems, so that carbon emissions can reach the peak before 2030. It is up to 19 years ahead of the carbon emissions peak of the basic scenario and the carbon emissions peak is reduced by 38 Mt. Moreover, this paper analyzes the technical combination of the earliest carbon emissions and the lowest carbon emissions. As for the earliest carbon emissions technical combination, China's cement industry carbon emissions will peak at 789.95 Mt in 2021. According to the lowest carbon emissions technical combination, China's cement industry carbon emissions will peak at 742.37 Mt in 2025. Accordingly, the conclusions will be helpful for making carbon emissions reduction policies for China's cement industry.

1. Introduction

Since the industrial revolution was carried out in the last century, fossil fuels have been abundant exploited and utilized. Excess Greenhouse gas emissions have resulted in a series of environmental problems such as global warming, extreme weather and environmental degradation. As a major greenhouse gas, the contribution rate of carbon dioxide (CO_2) is 63% [1]. Therefore, controlling carbon dioxide emissions (hereinafter referred to as carbon emissions) plays an important role in settling the problem of climate change.

The core content of “Paris Climate Conference 2015” was controlling carbon emissions. At the meeting, the “Paris Climate Agreement” was adopted by196 parties. After the meeting, in order to curb the growth of carbon emissions, the goal of global average temperature rising less than 2 °C was set, which was generally considered as a global challenge [2].

With the rapid growth of China's economy, the contradiction between the carrying capacity of the ecological environment and economic growth has become increasingly remarkable [3]. Global carbon project websites demonstrate that the total amount of global carbon emissions have reached 362 million tons in 2015, and China accounted for over 28.77%, which more than the sum of the United States and the European Union [4]. As a result of rapid economic growth, China has become the largest carbon dioxide emitter [5]. As an immense carbon-emitting country; China's government adopted a series of positive measures.

In order to achieve the reduction objective and accelerate the procedure of the resource-saving society, China's government should adapt to the new perspective of solving environmental problems, so as to manage resources in an adaptive and multilateral way [6]. Intended Nationally Determined Contributions (INDC) was released by China's government, which set out the action goal coping with climate change: the carbon intensity in 2030 will descend by 60%–65%. According to “the 13th five-year plan on controlling greenhouse gas emission”, carbon intensity will decline by 18% and the total amount of carbon emissions will be effectively controlled in 2020 [7].

Building materials industries are the quintessential carbon-

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intensive industries, mainly including cement, gypsum, brick, stone, glass, ceramics, which are the major sources of carbon emissions in many countries [8–10]. Among them, cement is a crucial building material. China is the largest cement production and consumption country, the cement production accounts for over 39% of the world cement production [11]. Cement industry plays an important role in China's economic development. On the other hand, cement production has also given rise to critical environmental pollution in China, especially in terms of carbon emissions. The relevant data demonstrate that the dust pollution of the backward cement plant accounts for nearly 6–8% of the total carbon emissions [12]. From 1990 to 2011, carbon emissions of China's cement industry have grown to 11.3% of China's total carbon emissions [13], and it also accounted for 60.6% of the global cement carbon emissions [14]. The related contents in “China cement production standard specification” [15] indicate that the objective of China's cement industry is to stockpile energy, reduce carbon emissions, develop advanced production technology and technical equipment and promote cleaner production. China's cement association issued the “cement industry planning in 13th five-year”, which formulated clear targets for reducing carbon emissions and cutting excessive industrial capacity of cement industry: cement clinker capacity is reduced by nearly 4 million tons, and 60% of the production lines use the second generation of new dry cement technology systems by 2020 [16].

As a high energy consuming industry, cement industry has a high contribution rate of carbon emissions. If the cement industry's carbon emissions peak time is advanced and peak value is reduced, the effect of carbon emission reduction in China will be greatly improved. Therefore, it is of great significance to research the carbon emissions of the cement industry.

In view of the importance of energy conservation and emissions reduction in China's cement industry, many scholars have carried out different degrees of research. As an example, Cai et al. [17] collected detailed information of 1574 domestic cement plants, and evaluated the carbon emissions of cement industry. The results illustrated that emissions of state-owned and large enterprises accounted for 59.4% and 61.9%; the average emission of China's cement enterprises was 35 kg $CO_2/T \bullet cl$. Cui and Liu [18] worked out the carbon emission coefficient of cement production process; the results demonstrated that the carbon dioxide emissions from raw materials calcined, coal and electricity individually made up 59%, 26% and 12% of the total amount. Zhang et al. [19] quantitatively evaluated the potential and avoidable cost of carbon dioxide emission of China's cement industry through the application of emission reduction technology. The conclusion was that the industry's carbon emissions reduction could be achieved by improving energy efficiency and alternative energy fuel, and the replacement of clinker would provide a significant cost advantage. The energy consumption and carbon emissions of the cement industry during the period of 2010–2050 were simulated by Li et al. [20]. It concluded that carbon emissions reduction of China's cement industry would mainly depend on the recent improvement of energy efficiency. Shen et al. [21] examined the impact and the development potential of different policies from the power, environment, clean energy and many other aspects. Wang et al. [22] had made clear that technology promotion and industrial structure adjustment are the main measures to reduce carbon dioxide emissions in the industry.

Through the collation of a large number of studies on carbon emissions, this article summarizes the relevant content of the literature on carbon emissions models at home and abroad.

The first method is Long-range Energy Alternatives Planning System (LEAP). Kumar [23] devised different energy scenarios by LEAP model, and carbon emissions were estimated by the lowest cost. The results suggested that under the technology scenario, in 2050, the carbon emissions would decline by 74%. Azam et al. [24] estimated the energy consumption and carbon dioxide emissions of the road transport in Malaysia from 2012 to 2040. Cai et al. [25] took the cement industry as one of the targets, were the one of earlier researchers to quantitatively estimate CO_2 mitigation potential in China. 12 techniques were used in scenario calculation, the conclusion states that two kinds of technology possess the greatest potential for reducing emissions.

The second method is the logarithmic mean Divisia index (LMDI). Wang et al. [26] studied the main driver of CO_2emissions growth by LMDI. Research on carbon emissions in China's cement industry were carried out by Branger, Frederic [27]. Lin and Ouyang [28] dug into the driving factors for the emission growth of China's non-metallic mineral products industry and explored the potential of the non-metallic mineral industry to reduce the emission reduction potential. The results manifests that the adjustment of energy structure, the adjustment of industrial structure and the progress of technology may lead to the decrease of carbon intensity.

The third method is the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) Wen et al. [29] provided beneficial guidance for exploring driving factors of agricultural carbon emissions in Hebei Province, and put forward the corresponding policy proposals for emission reduction. Lixia Yang et al. [30] investigated the mechanism driving emissions by the coaction of natural and socioeconomic factors. Khan et al. [31] Discovering the financial development, income inequality, impact of energy use and per capita GDP on carbon dioxide emissions in three Asian developing countries. Bin Xu et al. [32] applied a quantile regression approach to explore the main driving forces of the difference in carbon emissions under high, medium and low level of development.

The fourth method is the Back Propagation Neural Network (BP neural network). BP neural network is known as a multilayer feed forward neural network that demonstrates better performance in classification and prediction of nonlinear system. Neural network is a classic and widely used model. Many domestic and foreign scholars have conducted in-depth research on neural network, especially the application of optimization algorithms. Fabio et al. [33] indicated that the application of artificial neural networks (ANN) has been extended to model the carbon emissions and ANN is becoming an effective and popular technique alternatively to conventional methods. Jiao et al. [34] proposed a new forecasting method by combining stacked auto-encoders (SAE) and the back propagation (BP) algorithm. Neural networks appear to be a useful approach to deal with nonlinear systems.

In addition, neural networks are widely made use of in the prediction of nonlinear systems. In the study of Anand Mohan Yadavan [35], neural network and response surface methodology (RSM) was used to predict the behavior of coal oil agglomeration in terms of ash rejection (% AR) and combustible matter recovery (% CMR). Qiu et al. [36] used the electric load datasets from Australian Energy Market Operator (AEMO) to evaluate the effectiveness of the proposed incremental DWT-EMD based RVFL network. Islam et al. [37] combined a modified backpropagation neural network with a chaos-search genetic algorithm and simulated annealing algorithm for very short term electrical energy demand prediction in deregulated power industry.

BP neural network is also widely used in forecasting carbon emissions. Dong et al. [38] made use of BP neural network to overcome the weakness of multiple linear regressions (MLR); it can be applied to the prediction of carbon emissions. Jinying Li et al. [39] explored the potential of carbon intensity reduction in Beijing.