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Analysis of Carbon Performance of Thermal Power Enterprises

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Abstract— *This article introduces the current situation of carbon performance, carbon emission management policies, and carbon performance evaluation of thermal power enterprises. It explains the reasons for choosing evaluation based on carbon resource value flow, analyzes the carbon resource value flow process of thermal power enterprises, and determines the carbon performance evaluation method.*

Keywords— *Thermal power enterprise, Carbon performance evaluation, Entropy weighting-TOPSIS method.*

I. INTRODUCTION

Performance is a management concept that reflects the utilization effect after the resource input in the production process. It describes the external effects and internal efforts by calculating the efficiency at various stages such as input, process, output, and circulation. Carbon performance is used to measure the efficiency and effectiveness of CO2 activity input and output. In this study, it specifically refers to the environmental damage and beneficial economic effects caused during the carbon circulation process. Carbon performance evaluation is mainly used to measure whether implementing low-carbon strategies achieve expected goals, or whether they have improved compared to previous years. Carbon performance belongs to carbon management accounting. It can provide clear information, discover shortcomings, and be conducive to targeted rectification by responsible personnel. Carbon performance evaluation is a comprehensive evaluation process that evaluates the efforts made by enterprises in maximizing energy utilization and economic value from both environmental performance and financial performance perspectives.

II. OVERVIEW OF THERMAL POWER ENTERPRISES IN CHINA

Thermal power enterprise refers to an enterprise that uses combustible fuels (such as coal) as fuel to produce electricity in a factory. Thermal power enterprises have always been one of the main sources of social power supply, and the electricity they produce meets various social needs. In recent years, affected by the upgrading of the economic structure and the rise in energy prices, thermal power plants have also been actively upgrading their technology and are committed to energy conservation and emissions reduction.

Since 2020, facing the impact of the epidemic and the complex domestic and international environment, the power industry has actively promoted resumption of work and production, and provided strong power guarantee for social production and life. As shown in Figure 1, China's thermal power generation has shown a slight downward trend in recent years. Under the background of "dual carbon", thermal power enterprises responded to the national call and increased the proportion of clean power generation capacity. According to the research of Pan Ch et al. (2023) [2], the carbon emissions intensity of electricity production is continuously improving.

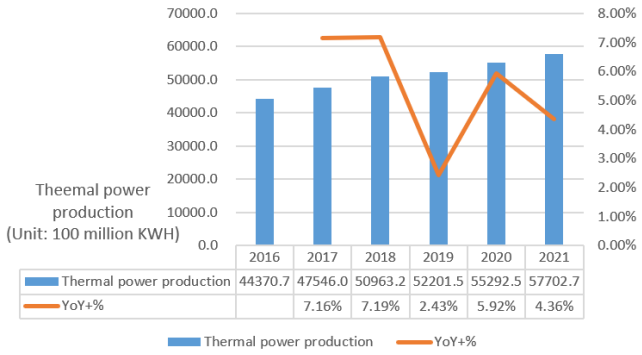

Figure 1. Thermal power production from 2016 to 2021
Data source: China Statistical Yearbook 2021

Recently, the China Electricity Council released the "China Electricity Industry Annual Development Report 2022". In terms of green development of electricity, the national supply standard coal consumption of thermal power plants with a capacity of 6,000 kilowatts or above is 301.5 grams/kilowatt-hour, which is 2.01 grams/kilowatt-hour lower than the previous year; the carbon dioxide emissions per unit of thermal power generation in China is about 828 grams/kilowatt-hour, which is a reduction of 21.0% compared to 2005. It can be seen that the thermal power enterprises have significantly reduced emissions. However, with the increasing emphasis on carbon emissions by the country and policy pressures, thermal power enterprises must formulate more effective low-carbon strategies, and establish carbon performance evaluation systems to achieve high-quality development.

III. CARBON EMISSION MANAGEMENT POLICIES FOR THERMAL POWER ENTERPRISES

In the context of high carbon emissions and increasingly tight energy supply, the government has issued a series of policies for thermal power enterprises to promote energy conservation and emission reduction. This paper summarizes the policies promulgated by the government between 2012 and

2021 on carbon emission management of thermal power enterprises, as shown in Table 1 below.

TABLE 1. Summary of carbon emission management policies of thermal power enterprises from 2012 to 2021

Time	Name of policy	Content of policy
2012	*Guidelines for Cleaner Production Evaluation of Coal-fired Power Generation Enterprises*	It stipulated the evaluation benchmark and calculation method of assessment score for clean production evaluation index of coal-fired power generation enterprises
2013	*Guidelines for Environmental Compliance of Coal-fired Thermal Power Enterprises*	It stipulated environmental access conditions for the coal-burning thermal power industry, limited pollutant emission targets, and set liability for environmental violations
2015	*Work Plan for Comprehensive Implementation of Ultra-low Emissions and Energy-saving Transformation of Coal-fired Power Plants.*	By 2020, eligible coal-fired units should be upgraded to ultra-low emissions, with the average power supply coal consumption below 310g/KWH
2016	*Work Plan for Controlling Greenhouse Gas Emissions during the 13th Five-Year Plan Period*	Carbon dioxide emissions per unit power supply of large power generation groups shall be controlled within 550 grams of carbon dioxide/KWH
2016	*The 13th Five-Year Plan for Electric Power Development (2016-2020)*	The average coal consumption of newly built coal-fired power generation units was lower than 300 grams of standard coal/KWH, and the carbon dioxide emission intensity of coal-fired units dropped to 865 grams/KWH
2017	*Construction Plan of National Carbon Emission Trading Market (Power Generation Industry)*	Control and reduce carbon emissions through market mechanisms
2017	*Technical Policy on Pollution Prevention and Control of Thermal Power Plants*	To guide the thermal power industry in formulating pollution prevention and control plans and selecting emission technologies, and provide technical support for the pollution prevention and control work of enterprises
2020	*Measures for the Administration of Carbon Emission Trading (Trial Implementation)*	The unified carbon emission trading market has officially started its first implementation cycle, and companies in the power sector are the first to be included in the emissions control list
2021	*The 14th Five-Year Industrial Green Development Plan*	continue to adopt cleaner production technologies, establish a green and low-carbon basic data platform, and improve the green and low-carbon standard system.

By summarizing relevant documents issued by the government, the determination to control pollution and reduce emission of thermal power enterprises is clearly demonstrated. The establishment of the carbon performance evaluation system of thermal power enterprises can objectively reflect the real situation of the carbon performance of enterprises and better meet the national strategic decision-making. Therefore, in order to obtain more economic benefits, enterprises will actively fulfill their social responsibilities and conduct carbon performance management.

IV. CURRENT SITUATION OF CARBON PERFORMANCE EVALUATION FOR THERMAL POWER ENTERPRISES

The country has not yet issued a standard carbon performance evaluation method, and the carbon performance evaluation system designed by enterprises is also good and bad. Many enterprises only disclose relevant carbon information in related reports such as social responsibility reports and environmental reports, unable to adapt to the country's low-carbon development strategy, can not play the role of management, evaluation, supervision and promotion. The quality of information disclosed by some enterprises is poor, or there are only empty qualitative descriptions, or the space is too small to provide valuable information for information users. Therefore, the construction of carbon performance evaluation methods has become a research hotspot for scholars.

At present, there are mainly the following methods for carbon performance evaluation.

TABLE 2. Comparison of carbon performance evaluation methods

Method of evaluation	Content	Advantages	Disadvantages
Balanced scorecard	Capture key carbon information from financial, low-carbon, customer, business process and other dimensions	Both financial performance and non-financial performance were considered	It is highly targeted, and different enterprises need to build evaluation systems one by one due to different strategy implementation
DEA model	Data envelopment model, the ratio of inputs to outputs	It does not need a unified unit and is suitable for comparison between enterprises of different sizes.	Input and output indicators are difficult to define in a comprehensive and scientific way
SE-SBM model	Slack variables are introduced based on the traditional DEA method	The bias caused by the radial Angle is eliminated on the DEA model.	The formula is complex, difficult to calculate and difficult to understand.
3E triangle model	The evaluation model is constructed from the three dimensions of energy, economy and environment.	It emphasizes the mutual coordination and balance among the three dimensions	The weight setting lacks scientific nature, and the evaluation grade is highly subjective.
Life cycle approach	It calculates the sum of carbon dioxide emitted by enterprises in the whole process from raw material acquisition, production and processing, product sale, value play to waste.	The calculation process is detailed, accurate and targeted to enterprises.	It is difficult to obtain raw data, and enterprises cannot control carbon emissions in all links.

V. Applicability Analysis of Carbon Performance Evaluation Based on Carbon Resource Value Flow

Value flow analysis belongs to environmental management accounting, mainly for cost accounting and resource utilization efficiency. Centering on the "3R" principle in circular economy, the production process emphasizes that from resource input to resource recycling, and then to the final value output, it should chase to create the maximum benefit with the least consumption, which meets the essential requirements of improving carbon performance.

A. Entropy weight method

The entropy weight method is used to determine the weight of indicators. In the entropy weight method, the information entropy of each index is measured as the ability and value of the index to reflect the problem, and the random uncertainty of the index and the amount of decision-making information are described through the information entropy of the index. At the same time, the correlation and synergy between the indicators are quantified as the ratio of the entropy value of each indicator to the total entropy value by calculating the joint entropy method, so as to obtain the weight of each indicator. It can improve the accuracy and reliability of indicator weight estimation. Applying this method in the carbon performance evaluation system can provide data basis for the development of TOPSIS method and the subsequent calculation of comprehensive performance evaluation value, so as to objectively and effectively evaluate the performance of enterprises.

B. TOPSIS method

The TOPSIS method is suitable for multi-objective decision-making. It selects the evaluation index based on the evaluation object, determines the positive and negative ideal solutions, and calculates the distance between each scheme and the ideal solution. If the evaluation object is the closest to the optimal solution and the farthest from the worst solution, the scheme is the best; otherwise, it is relatively poor. The TOPSIS method has less restrictions on indicators, simple calculation and flexible application, which breaks the limitation of the traditional evaluation model to formulate standard values.

VI. Discussion

The carbon performance evaluation methods mentioned in Table 2 do not consider the impact of the whole process of carbon resources in the production process, and cannot identify the key links and weak links. This can be solved based on carbon resource value flow analysis. Based on the theoretical basis of circular economy, combined with the production process and relying on the value flow analysis, the circulation of carbon resources is divided into three subsystems of carbon input, carbon cycle and carbon output, and the evaluation index system of circular economy is constructed. The entropy weight method is used to determine the index weight objectively, and the TOPSIS method is used to calculate the carbon performance evaluation value and rank the advantages and disadvantages. The combination of the two methods can identify the key links affecting carbon performance, and the calculation results are more scientific, comparable horizontally and vertically, and applicable to the whole industry.

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