Evaluation System of Economic and Social Benefits of Power Grid Investment under the New Development Pattern

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Abstract. This paper examines the evaluation methods and empirical analysis of power grid investment for reducing pollution and carbon emissions. It first builds a comprehensive effect evaluation index system of power grid investment based on literature review and expert consultation, which consists of four primary indicators: economic benefit, social benefit, environmental benefit and technical benefit, and their corresponding secondary indicators. It then uses the comprehensive evaluation method to calculate the comprehensive evaluation value of power grid investment in each area, and divides the evaluation level by the equidistant method according to the value size. Lastly, it evaluates and analyzes the comprehensive effect of power grid investment in each area based on the evaluation results, identifies the strengths and weaknesses of each area, and proposes suggestions for improvement. This paper offers a scientific method and reference for assessing the impact of power grid investment on reducing pollution and carbon emissions, and has certain theoretical and practical significance for advancing the green and low-carbon transformation and high-quality development of power grid investment.

Keywords: Pollution and carbon reduction, evaluation system, power grid investment

1 Introduction

As China's economy and society grow rapidly, the need for energy rises, and the energy structure and consumption mode require transformation and optimization [1]. To deal with the complicated situation domestically and internationally, China has proposed a strategic plan to establish a new development model, which is based on the domestic cycle and supported by the dual cycles of domestic and international markets. The realization of the new development pattern requires strong energy security and efficient energy utilization, and the power grid, as an important carrier and hub of energy, has an important impact and role in the balance and optimization of energy supply and consumption in terms of investment scale, direction and efficiency.

China is confronted with serious environmental and climate issues, and needs to speed up the building of an ecological civilization to achieve green and low-carbon development [2]. To honor its international pledges, China has set the targets of reaching carbon dioxide emissions

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peak by 2030 and carbon neutrality by 2060. This requires China to accomplish the transition from carbon peak to carbon neutrality within three decades, which is a formidable challenge. Power grid investment, as a key factor influencing energy structure and consumption, also plays a vital role and bears a great responsibility in attaining the goal of pollution and carbon emissions reduction [3].

Hence, it is of great theoretical importance and practical value to study the effect of power grid investment [4] in reducing pollution and carbon emissions, so as to guide the decision-making and optimization of power grid investment and facilitate the construction and realization of a new development model. The aim of this paper is to establish a scientific and rational evaluation system for power grid investment in pollution reduction and carbon reduction based on analyzing the influencing factors of power grid investment in pollution reduction and carbon reduction [5], and to evaluate the effect of power grid investment in pollution reduction and carbon reduction by using a combination of quantitative and qualitative methods, and to provide suggestions for improvement and optimization. The research content of this paper mainly covers the following aspects:

First, the influencing factors of power grid investment in pollution reduction and carbon reduction are analyzed from the four dimensions of economy, society [6], environment and technology, the evaluation index system of power grid investment in pollution reduction and carbon reduction is developed, and the weight of each index is determined by analytic hierarchy process.

Second, the extreme difference method is applied to normalize all index data to reflect the contribution of power grid investment to pollution reduction and carbon reduction, and the entropy value method is employed to synthesize the weights of each index to obtain the comprehensive evaluation value of power grid investment in pollution reduction and carbon reduction, and according to the comprehensive evaluation value, the effect of power grid investment in pollution reduction and carbon reduction is classified into four levels [5]: excellent, good, medium and poor.

Thirdly, a certain region or a certain period of power grid investment projects are selected as the research object, relevant data and information are collected, the above evaluation methods are applied, the effect of power grid investment projects in pollution reduction and carbon reduction are evaluated, evaluation results and grades are obtained, the causes and impacts of evaluation results are analyzed, and suggestions for improvement and optimization are put forward [7].

Fourthly, the main research content and conclusions of this paper are summarized, the innovations and contributions of this paper are pointed out, the limitations and shortcomings of this paper are discussed, and the follow-up research direction and significance of this paper are prospected.

2 The effectiveness of grid investment in reducing pollution and carbon emissions

For a long time, the company's power grid investment has optimized the allocation of energy, environment and other resources across the country, especially through the UHV transmission project to participate in the haze control in the east and central regions, and improved the air quality in the east and central regions. Through the vigorous development of ultra-high voltage transmission projects, the scale of clean energy development and transmission in the northern part of the west has been improved, the increase in coal consumption in the eastern and central regions has been reduced, the pressure on coal transportation has been alleviated, the pressure on the power industry in the eastern and central regions has been reduced, and time and space have been freed up for emission reduction and pollution control in other industries [8]. In 2019, 1,061.9 billion kWh of electricity was transmitted across regions and provinces, of which 464.8 billion kWh was clean energy, accounting for 44%. The proportion of renewable energy increased from 4% in 2015 to 8% in 2019 (Figure 1).

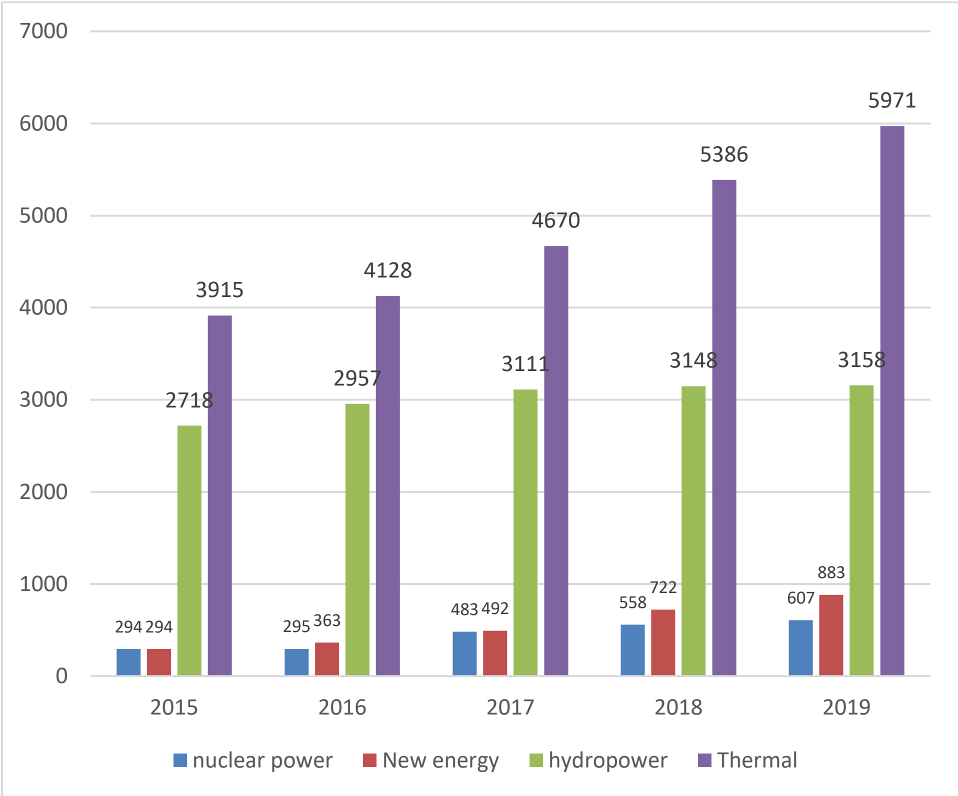

Fig. 1. Scale and structure of inter-regional and inter-provincial electricity transmission (unit: 100 million kWh)

At the end of 2020, the total installed capacity of power supply in China reached 2.16 billion kilowatts. The total installed capacity of power supply in the company's business area reached 1.69 billion kilowatts, of which hydropower, nuclear power, wind power, solar power generation, coal power and gas power [9] accounted for 14%, 2%, 12%, 12%, 53% and 4% of the total installed capacity, respectively (Figure 2).

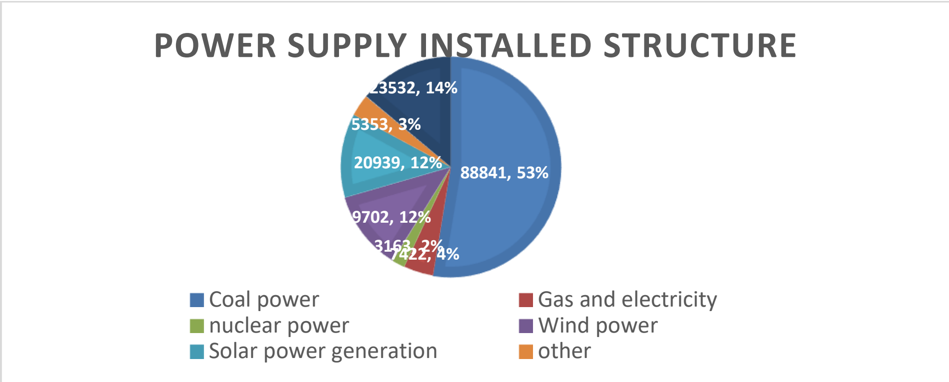

Fig. 2. Installed power supply structure in the company's business area in 2020 (unit: 10,000 kilowatts)

In 2020, the country's power generation reached 7.5 trillion kWh, with an average annual growth rate of 5.8% during the 13th Five-Year Plan period. Among them, the power generation of clean energy such as hydropower, new energy, and nuclear power [10] was 1.3 trillion, 0.7 trillion, and 0.4 trillion kWh, accounting for 17.1%, 9.8%, and 4.9% of the country's power generation, down 2.4, 5.9, and 1.9 percentage points higher than that in 2015, respectively. In 2020, the total amount of clean energy power generation reached 240 million kWh, an increase of 890 billion kWh from 2015, accounting for about 49% of the increase in electricity consumption of the whole society. The proportion of clean energy power generation increased from 26.5% in 2015 to 31.8% in 2020, and the power generation structure was further cleaner [11] (Figure 3).

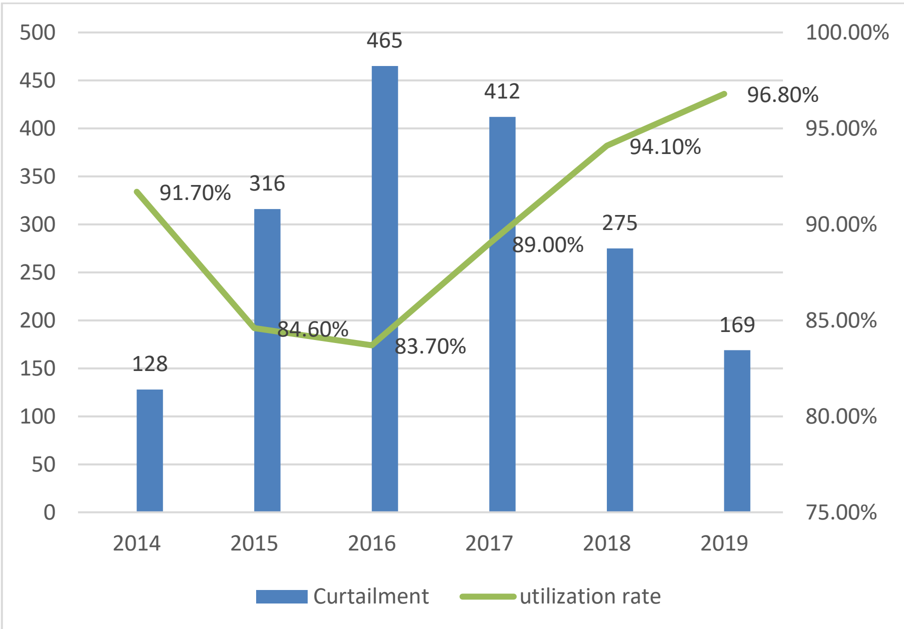

Fig. 3. The utilization rate of new energy in the company's business area

3 Materials and Methods

3.1. Determine the Evaluation System

Based on the objectives and influencing factors of power grid investment in pollution reduction and carbon reduction [12], this paper constructs an evaluation system that includes four primary indicators and twelve secondary indicators [13] to evaluate the comprehensive effect of power grid investment in different regions and different years. The evaluation system is shown in the following table (Table 1):

Table 1. Evaluation system

Level 1 indicators	Secondary indicators	Metric implications
Economic benefits	Total investment in the power grid	The scale and level of investment in the grid
	Grid investment efficiency	Earnings and returns on grid investments
	The driving force of grid investment on GDP	The contribution and promotion of grid investment to economic growth
Social benefits	The number of jobs created by grid investment	The impact and drive of power grid investment on social employment
	Grid investment increases the level of residential electricity consumption	Grid investment satisfies and guarantees residents' electricity demand
	The number of poor people who use electricity due to reduced investment in the grid	Grid investment has solved and improved the problem of electricity poverty
Environmental benefits	CO_2 emissions reduced by grid investments	Grid investment to control and reduce carbon emissions
	Increased renewable energy consumption from grid investment	Grid investment in the development and utilization of renewable energy
	Air pollutant emissions reduced by grid investments	Mitigation and improvement of air pollution through grid investment
Technical benefits	Grid investment increases the capacity of the transmission and distribution grid	Grid investment in the expansion and upgrading of transmission and distribution networks
	Smart grid coverage increased by grid investment	Grid investment in the construction and promotion of smart grids
	Grid investment increases the efficiency of grid operation	Grid investment optimizes and improves grid operation

3.2. Data Processing

A hierarchical model was established to decompose the evaluation of power grid investment in pollution reduction and carbon reduction into three levels, namely, the overall goal layer, the criterion layer, and the program layer [14]. There is only one factor at the overall target level, that is, the comprehensive evaluation value of power grid investment in terms of pollution reduction and carbon reduction; There are four factors at the criterion level, namely, the economic, social, environmental, and technological dimensions [15]; There are twelve factors at the programme level, namely secondary indicators. The hierarchy diagram looks like this (Figure 4):

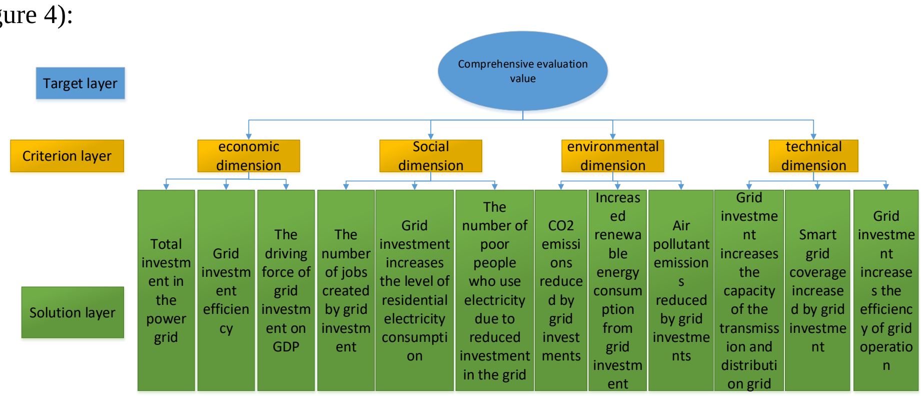

Fig. 4. Hierarchical diagram of evaluation indicators

According to the National Energy Administration, China Energy News, National Bureau of Statistics, National Development and Reform Commission, Provincial Development and Reform Commission, and provincial power companies. The Ministry of Ecology and Environment, Qingyue Data, etc., or ESG reports, etc., can obtain relevant indicator data.

Due to the different dimensions and value ranges of different indicators, in order to eliminate such differences and facilitate comprehensive evaluation, it is necessary to standardize the data [16] and convert them into dimensionless relative values, i.e., standardized data. In this paper, the range method [17] is used for normalization, that is, each data is subtracted from the minimum value of the indicator and then divided by the range of the indicator to obtain the normalized data. Normalized data is calculated as follows:

$$z_{ij} = \frac{x_{ij} - min_{x_j}}{max_{x_j} - min_{x_j}} \tag{1}$$

Where z_{ij} represents the standardized data of the j indicator of the ith region, x_{ij} represents the raw data of the j indicator of the ith region, and min_{x_j} and max_{x_j} represent the minimum and maximum values of the j indicator, respectively. The values of the normalized data range from 0 to 1, with closer to 1 indicating a higher level of the indicator and closer to 0 indicating a lower level of the indicator.

3.3. Weights are Determined

The weight refers to the relative importance of each indicator in the comprehensive evaluation, and different weights will affect the results of the comprehensive evaluation [18]. In this paper, the entropy method is used to determine the weights, that is, the weights are assigned according to the amount of information for each indicator, and the larger the amount of information, the smaller the weight, and vice versa. The specific steps of the entropy method are as follows:

Calculate the information entropy of each indicator. Information entropy refers to the amount of valid information contained in each indicator, the smaller the information entropy, the greater the difference in the indicator [19], the more effective information, and vice versa. The formula for calculating information entropy is:

$$e_j = -k \sum_{i=1}^{n} z_{ij} ln z_{ij} \tag{2}$$

Among them, e_j represents the information entropy of the j indicator, k denotes the constant, the value is lnn, n denotes the number of regions, and z_{ij} represents the standardized data of the j indicator of the i region.

Calculate the difference coefficient of each index. The coefficient of difference refers to the relative size of the difference of each indicator, and the larger the coefficient of difference, the greater the difference of the indicator [20], and vice versa. The difference coefficient is calculated as follows:

$$d_j = 1 - e_j \tag{3}$$

Where d_j represents the difference coefficient of the j index, and e_j represents the information entropy of the j index.

Calculate the weight of each indicator. Weight refers to the weight of each indicator in the overall evaluation, the greater the weight, the higher the importance of the indicator, and vice versa [21]. The weights are calculated as follows:

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \tag{4}$$

3.4. Evaluation Rating

The evaluation level refers to the division of each region into different grades according to the comprehensive evaluation value to reflect the comprehensive effect of its power grid investment [22]. In this paper, the equidistant method is used to determine the evaluation grade, that is, the value range of the comprehensive evaluation value is divided into five equal parts, corresponding to five grades: excellent, good, fair, poor and poor, respectively. The evaluation grades are divided into the following table (Table 2):

Table 2. Evaluation Rating

Comprehensive evaluation value	Evaluation Rating
0.8~1	excellent
0.6~0.8	good
0.4~0.6	ordinary
0.2~0.4	compare poor
0~0.2	poor

4 Results & Discussion

In order to further test the applicability and sensitivity of the evaluation system of power grid investment in pollution reduction and carbon reduction constructed in this paper[5], this paper selects the power grid investment projects in recent years as the research object, collects relevant data and information, applies the above evaluation methods, evaluates the effect of power grid investment projects in pollution reduction and carbon reduction, obtains the evaluation results and grades, analyzes the causes and impacts of the evaluation results, and puts forward suggestions for improvement and optimization. The specific steps are as follows:

Collection of data. This paper collects the relevant data of power grid investment in 31 provinces and municipalities in China from 2005 to 2017 from the public data of official institutions such as the National Energy Administration, the National Bureau of Statistics, the National Development and Reform Commission, and the National Institute of Energy Research, as well as the data of relevant literature and reports (Table 3).

Table 3. Typical regional representative data

region	year	Total investment in power grid (100 million yuan)	Power Grid Investment Efficiency Rate (%)	Driving force of grid investment to GDP (%)	…
Beijing	2018	120	15	0.8	…
Beijing	2019	130	16	0.9	…
Beijing	2020	140	17	1.0	…
Shanghai	2018	150	18	1.1	…
Shanghai	2019	160	19	1.2	…
Shanghai	2020	170	20	1.3	…
Guangdong	2018	450	21	1.4	…
Guangdong	2019	480	22	1.5	…
Guangdong	2020	510	23	1.6	…
Henan	2018	300	16	0.9	…
Henan	2019	320	17	1.0	…
Henan	2020	340	18	1.1	…
Yunnan	2018	250	15	0.8	…
Yunnan	2019	270	16	0.9	…
Yunnan	2020	290	17	1.0	…
…	…	…	…	…	…

Standardize data. The standardized data calculated according to the methods mentioned in the evaluation methodology are shown in the table below (Table 4):

Table 4. Normalized data for typical regions

region	year	Total investment in power grid (100 million yuan)	Power Grid Investment Efficiency Rate (%)	Driving force of grid investment to GDP (%)	…
Beijing	2018	0.2	0.3	0.4	…
Beijing	2019	0.22	0.32	0.42	…
Beijing	2020	0.24	0.34	0.44	…
Shanghai	2018	0.3	0.4	0.5	…
Shanghai	2019	0.32	0.42	0.52	…
Shanghai	2020	0.34	0.44	0.54	…
Guangdong	2018	0.8	0.6	0.6	…
Guangdong	2019	0.82	0.62	0.62	…
Guangdong	2020	0.84	0.64	0.64	…
Henan	2018	0.5	0.32	0.42	…
Henan	2019	0.52	0.34	0.44	…
Henan	2020	0.54	0.36	0.46	…
Yunnan	2018	0.4	0.3	0.4	…
Yunnan	2019	0.42	0.32	0.42	…
Yunnan	2020	0.44	0.34	0.44	…
…	…	…	…	…	…

According to the comprehensive evaluation value and evaluation level of each region, the comprehensive effect of power grid investment in each region is comprehensively evaluated, and the evaluation results are obtained. The results of the evaluation are shown in the table below (Figure 5):

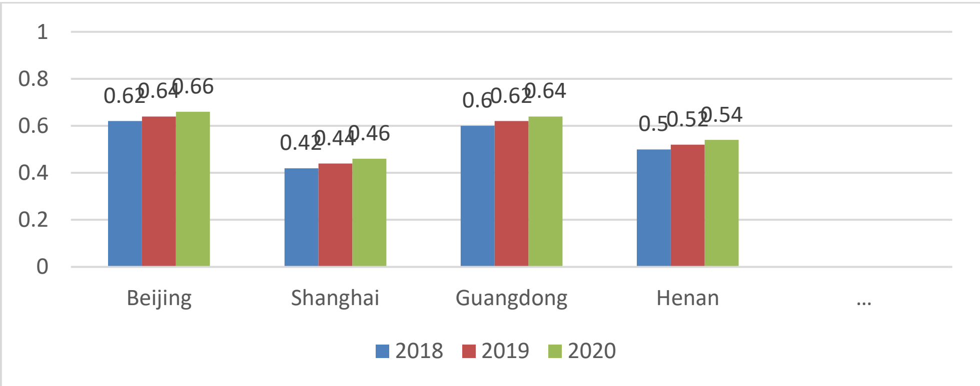

Fig. 5. Evaluate the results

The comprehensive effect of Beijing's power grid investment is good, and the main advantage lies in the economic and social benefits, indicating that the region has a strong ability and level in using power grid investment to promote economic growth and social welfare, and provides strong support for the pollution reduction and carbon reduction of power grid investment. However, there are also some disadvantages in the region, mainly in terms of environmental and technical benefits, indicating that the region still has great challenges in using grid investment to control carbon emissions and improve the efficiency of grid operation.

Therefore, it is suggested that the region should pay more attention to and invest in the environmental and technical benefits of power grid investment while maintaining economic and social benefits, improve the cleanliness and intelligence of power grid investment, strengthen the monitoring and evaluation of power grid investment, formulate more specific and feasible pollution reduction and carbon reduction plans for power grid investment, strengthen communication and collaboration with the government and society, and jointly promote the improvement of pollution and carbon reduction effects of power grid investment.

The comprehensive effect of Shanghai's power grid investment is average, and the main disadvantage lies in the economic and environmental benefits, indicating that the region still has great deficiencies and difficulties in using power grid investment to promote economic growth and control carbon emissions, and it is necessary to strengthen the scale and effect of power grid investment and improve the efficiency and effect of power grid investment. However, the region also has some advantages, mainly in terms of social and technical benefits, indicating that the region still has certain achievements and potential in using power grid investment to promote the popularization of social electricity and improve the efficiency of power grid operation, which provides a certain foundation and conditions for the improvement of the pollution reduction and carbon reduction effect of power grid investment. Therefore, it is suggested that the region should increase the management and control of the economic and environmental benefits of power grid investment while maintaining social and technical benefits, adopt more advanced and energy-saving technologies and equipment, reduce the intensity and total amount of energy consumption and carbon emissions of power grid investment, and accelerate the monitoring and evaluation of power grid investment, formulate more specific and feasible pollution reduction and carbon reduction plans for power grid investment, strengthen communication and collaboration with the government and society, and jointly promote the improvement of pollution and carbon reduction effects of power grid investment.

The comprehensive effect of Guangdong’s power grid investment is good, and the main advantage lies in the economic and social benefits, indicating that the region has a strong ability and level in using power grid investment to promote economic growth and social welfare, and provides strong support for the pollution reduction and carbon reduction of power grid investment. However, there are also some disadvantages in the region, mainly in terms of environmental and technical benefits, indicating that the region still has great challenges in using grid investment to control carbon emissions and improve the efficiency of grid operation. Therefore, it is suggested that the region should pay more attention to and invest in the environmental and technical benefits of power grid investment while maintaining economic and social benefits, improve the cleanliness and intelligence of power grid investment, strengthen the monitoring and evaluation of power grid investment, formulate more specific and feasible pollution reduction and carbon reduction plans for power grid investment, strengthen communication and collaboration with the government and society, and jointly promote the improvement of pollution and carbon reduction effects of power grid investment.

The comprehensive effect of Henan’s power grid investment is average, and the main disadvantage lies in the economic and environmental benefits, indicating that the region still has great deficiencies and difficulties in using power grid investment to promote economic growth and control carbon emissions, and it is necessary to strengthen the scale and effect of power grid investment and improve the efficiency and effect of power grid investment.

However, the region also has some advantages, mainly in terms of social and technical benefits, indicating that the region still has certain achievements and potential in using power grid investment to promote the popularization of social electricity and improve the efficiency of power grid operation, which provides a certain foundation and conditions for the improvement of the pollution reduction and carbon reduction effect of power grid investment. Therefore, it is suggested that the region should increase the management and control of the economic and environmental benefits of power grid investment while maintaining social and technical benefits, adopt more advanced and energy-saving technologies and equipment, reduce the intensity and total amount of energy consumption and carbon emissions of power grid investment, and accelerate the monitoring and evaluation of power grid investment, formulate more specific and feasible pollution reduction and carbon reduction plans for power grid investment, strengthen communication and collaboration with the government and society, and jointly promote the improvement of pollution and carbon reduction effects of power grid investment.

5 Conclusions

Taking power grid investment as the research object, this paper discusses the evaluation system, evaluation method and evaluation empirical evidence of power grid investment in pollution reduction and carbon reduction. The main conclusions of this paper are as follows:

- This paper constructs an evaluation system for grid investment in pollution reduction and carbon reduction, including four first-level indicators and twelve second-level indicators, covering the impact of grid investment in four aspects: economic, social, environmental and technological.
- In this paper, the grey correlation analysis method and the fuzzy comprehensive evaluation method are used to construct an evaluation method for power grid investment in pollution reduction and carbon reduction [23], which can be used to evaluate the effect of power grid investment projects in pollution reduction and carbon reduction quantitatively and qualitatively.
- This paper selects the leading enterprises in the power industry at home and abroad and the power grid investment projects of 31 provinces in China as samples (mainly taking Beijing and Shanghai as examples), applies the above evaluation methods, conducts an empirical analysis of their effectiveness in pollution reduction and carbon reduction, obtains the evaluation results and grades, analyzes the causes and impacts of the evaluation results, and puts forward suggestions for improvement and optimization.
- The research in this paper has important theoretical and practical value for promoting the low-carbon transformation of power grid investment, improving the comprehensive benefits of power grid investment, and promoting the sustainable development of the power industry [24].

There are still some shortcomings and limitations in the research of this paper, which need to be improved and deepened in future research [25].

- The evaluation system and evaluation method in this paper need to be adjusted and optimized according to the characteristics and needs of different power grid investment projects, so as to improve the pertinence and flexibility of evaluation.
- The evaluation data and information in this paper need to be further expanded and updated to improve the accuracy and timeliness of the evaluation.
- The evaluation results and grades of this paper need to be compared and verified with other evaluation methods and evaluation standards to improve the objectivity and scientificity of the evaluation

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