A Decomposition Method of Carbon Emission Reduction Targets for Office Parks of Power Grid Companies Considering Equity and Efficiency

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Abstract: In order to realize the goal of "carbon peak and carbon neutral", power grid companies need to decompose carbon emission reduction targets at the park level. In this paper, the park-level indicators are selected based on the principles of fairness, efficiency, feasibility and sustainability, and the carbon emission reduction target decomposition index system of office park of power grid company is constructed. Then, the expert assignment and entropy weighting method are integrated to get the comprehensive weights to realize the preliminary decomposition of carbon emission reduction targets, and then the carbon emission reduction potential factor is introduced to optimize the initial target value of carbon emission reduction, which results in the final value of carbon emission reduction targets of each park. Finally, taking 2020 as the base year, under the constraint of China's carbon peaking in 2030, the effectiveness and scientificity of the decomposition method of the carbon emission reduction targets of office parks were verified by using arithmetic examples according to the decomposition model. The study can provide theoretical basis and decision-making guidance for the realization of the carbon emission reduction target at the park level.

Keywords: carbon emissions, target decomposition, office park, sustainability, Carbon reduction potential factor

1 Introduction

In recent years, scholars at home and abroad have conducted in-depth discussions on the principles and methods of allocating the total amount of carbon emissions, and the relevant research has gradually matured. Chen Wenying et al. (2005)[1] proposed the allocation method of "two convergence" of carbon emission credits from the perspective of future globalization, and used this method to provide a mathematical basis for China's greenhouse gas emission reduction negotiations. Yang Lingling et al. (2010)[2] studied the allocation of carbon emission credits within the electric power industry, and proposed two types of credit allocation parameter models (power generation capacity allocation model and power generation type allocation model) for carbon emission credits of the electric power industry. Du Shaofu et al. (2009) [3] discussed and established a production optimization model for enterprises from the perspective

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of minimizing the purification and treatment cost of the allowed emission credits to derive the optimal production strategy with emission limits. Huang Huang (2020)[4], Tian Yun and Chen Chi-bo (2020)[5] explored the marginal abatement cost of the allocation result and the national carbon emission reduction incentive and penalty scheme on this basis, respectively. Zheng Liqun (2012)[6] and Miao Zhuang et al. (2012)[7] improved the traditional DEA model and used the ZSG-DEA model to decompose the national total carbon emission target regionally. Hahn (1984) [8] pointed out that in an imperfectly competitive environment, the initial allocation of emission rights will have an impact on the efficiency of trading. The allocation methods of emission rights mainly include free allocation, fixed-price sale and auction, among which, although free issuance or fixed-price sale is more convenient, the initial allocation amount or issuance price is difficult to determine; while auction is more flexible, and the auction price can also act as a signal to show the marginal cost of pollution control of enterprises (Cramton & Kerr, 2002)[9].

Aiming at the appealing problems and the current situation, this paper proposes a decomposition method for the carbon emission reduction target of the park.

2 Decomposition indicator system construction

At present, the principle of carbon emission limit is mainly divided into two kinds, one is the principle of per capita emission convergence representing the interests of developed regions, which ignores the interests of developing regions and lacks fairness; the other is the principle of historical responsibility based on per capita cumulative amount. Developing regions believe that developed regions have emitted the vast majority of CO_2 in their history before they have entered into the developed region's level, so in terms of historical responsibility, developed regions should play an important role in reducing the national CO_2 level. developed regions should make a major contribution in reducing national CO_2 emissions.

Nowadays, if the development of developing regions is hindered or slowed down in order to slow down the global warming problem, this is a lack of fairness to the developing regions, so it is necessary to maintain fairness in the allocation of national carbon emission allowances to ensure the economic development of the developing regions. This paper introduces the principles of feasibility and sustainability and establishes a decomposition index system for the carbon emission reduction targets of parks under the traditional principles of fairness and efficiency, taking into account the enforceability of the emission reduction policies of parks in different regions as well as the sustainable green development of the parks in the future,as shown in Figure 1.

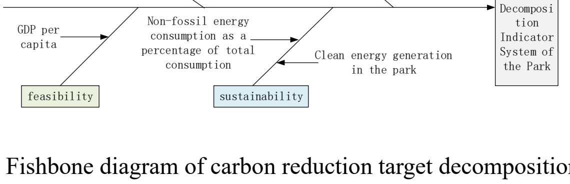

Figure 1. Fishbone diagram of carbon reduction target decomposition system

2.1 Equity indicators

The per capita CO_2 emissions of the parks(A1) and the total annual historical CO_2 emissions of the parks(A2) embody the principle of fairness, and the fairness of the initial allocation of CO_2 reduction targets should include two aspects. First, allocating emission rights based on per capita consumption demand to ensure the fairness of per capita emissions in each park, per capita CO_2 emissions represent fairness, parks with more per capita CO_2 emissions should accordingly take on more emission reduction tasks, as a positive indicator; second, taking regional economic development into account, giving more emission rights to developing regions to support their gradual growth, the total annual historical CO_2 emissions of parks reflect the The total annual historical CO_2 emissions of the parks reflect the polluter pays principle, and the parks with high emission history should take more responsibility for emission reduction, which is a positive indicator.

2.2 Efficiency indicators

Carbon emissions per unit of GDP(B1) reflect the principle of efficiency, so as to maximize the cost-effectiveness of the economy, the higher the emission efficiency of the region of the more inefficient use of energy resources, need to bear more responsibility for a positive indicator. That is, in the limited space of CO_2 emissions, as far as possible to create the maximum economic output. This paper argues that the principle of efficiency is that under the same total amount of carbon emission resources, the initial regional allocation mechanism can maximize the economic output of the whole country, and the essence of efficiency is that carbon emission resources should flow to more efficient regions.

2.3 Feasibility indicators

GDP per capita(C1) reflects the principle of feasibility, which is mainly considered from the perspective of the enforceability of the emission reduction policy. Policy feasibility means that the distribution plan can be accepted by each local government. Since the current downward pressure on China's economy has increased and the focus of local governments is still on economic growth, GDP per capita, which reflects the financial capacity of the region, is used as the local distribution index for policy feasibility, which is a positive indicator.

2.4 Sustainability indicators

The proportion of non-fossil energy consumption to total consumption(D1) and clean energy generation in the parks(D2) reflect the principle of sustainability. Sustainability is mainly considered from the aspects of the parks' consumption and generation of renewable energy power, and the proportion of non-fossil energy consumption to total consumption can reflect to a certain extent the degree of acceptance of renewable energy power in the parks, and the higher the degree of acceptance, the smaller the space of carbon emission reduction obtained, as a The higher the degree of acceptance, the smaller the space for carbon emission reduction, which is a negative indicator to encourage the consumption of renewable energy power. The power generation capacity of clean energy in the parks reflects the utilization of clean energy resources in the parks, and the larger the power generation capacity is, the smaller the potential for emission reduction is, and the smaller the space for carbon emission reduction is, which is a negative indicator, so that the development of renewable power generation in the parks can be guided and encouraged through policies.

3 Decomposition Modeling of Carbon Emission Reduction Targets

In view of the traditional single-assignment method, there are problems of unscientific calculation of weights and the inability to take into account the evaluation will of decision makers and the information characteristics of indicator data. This paper adopts the comprehensive weighting method, which can effectively integrate the expert weights and objective weights, so that it can not only reflect the experience of experts, but also reflect the data law. After obtaining the comprehensive weights, we can initially decompose the carbon emission reduction target, considering that the potential of carbon emission reduction in different parks may be different, and introduce the carbon emission reduction potential factor according to the characteristics of the index values of the parks, so as to further optimize the results of the target decomposition to get the final decomposition of carbon emission reduction target, and the specific model solving process is shown in Figure 2.

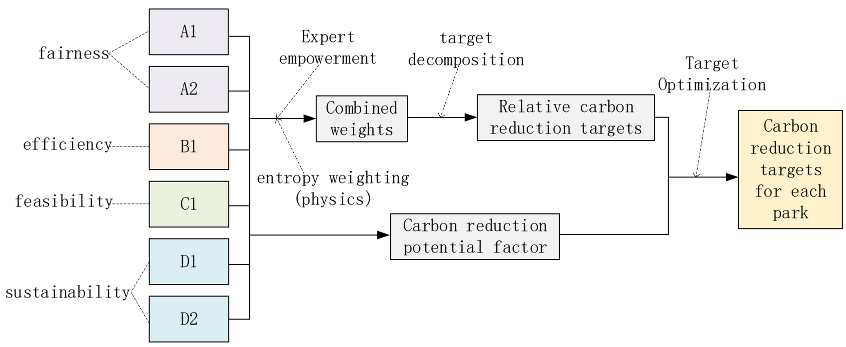

Figure 2. Carbon Emission Reduction Park Decomposition Model Framework Diagram

3.1 Determination of indicator weights

First, industry-related s authoritative experts are invited to score n indicators on a percentage basis, and then a weighted average is carried out to obtain the expert-assigned weights of each indicator, which is expressed as follows:

$$r_j = \frac{\sum_{i=1}^{s} a_i}{100 \cdot s} \cdot 100\% \quad (k = 1, 2, \ldots\ldots, n) \tag{1}$$

Where: r_j denotes the expert-assigned weight of the jth indicator, and a_i denotes the score of the ith expert for the indicator.

Secondly, the entropy weight method was used for objective weighting, and since the unit of measurement of each indicator was not uniform, the preprocessing and dimensionless processing of the data of each indicator was needed to eliminate the influence of the scale. Firstly, the natural logarithm of the data of n indicators of m regions is taken to eliminate the problem of large size difference, and then the data are standardized by using the method of very large and very small values. The formula for the indicators is as follows:

$$x'_{ij}=\frac{x_{ij}-\min\{x_{1j},\cdots x_{nj}\}}{\max\{x_{1j},\cdots x_{nj}\}-\min\{x_{1j},\cdots x_{nj}\}}\text{（Positive indicators）}$$
$$x'_{ij}=\frac{\max\{x_{1j},\cdots x_{nj}\}-x_{ij}}{\max\{x_{1j},\cdots x_{nj}\}-\min\{x_{1j},\cdots x_{nj}\}}\text{（Negative indicators）} \quad (2)$$

Where x'_{ij} is the value of the i-park indicator j after dimensionless processing, x_{ij} is the value of the i-park indicator j after taking the logarithm, $\max\{x_{1j},\cdots x_{nj}\}$ is the maximum value of the i-park indicator j after taking the logarithm, and $\min\{x_{1j},\cdots x_{nj}\}$ is the minimum value of the i-park indicator j after taking the logarithm.

Then calculate the probability size of each park on the indicator p_{ij}:

$$p_{ij}=\frac{x'_{ij}}{\sum_i x'_{ij}} \quad (3)$$

The information entropy of the indicator is then calculated e_j:

$$e_j=-k\sum_i p_{ij}\times\ln(p_{ij}) \quad (4)$$

Where k = 1/ln(m) and m is the number of parks.

The entropy weight w_j of the indicator is then determined:

$$w_j=(1-e_j)/\sum_j(1-e_j) \quad (5)$$

As the expert assignment has a greater advantage than the objective assignment in determining the weights according to the intention of the decision maker, but the objectivity is relatively poor and the subjectivity is relatively strong; while the use of objective assignment has an objective advantage, but it does not reflect the extent to which the participating decision makers attach importance to the different indicators, and there will be a certain amount of weighting and a degree of opposite to the actual indicators. Aiming at the advantages and disadvantages of subjective and objective assignment methods, we also strive to control the subjective randomness within a certain range and realize the neutralization in subjective and objective assignment. The objective aspect makes the indicator assignment fair, realizes the inner unity of subjectivity and objectivity, and the evaluation results are real, scientific and credible. Therefore, when assigning weights to the indicators, the inherent statistical laws and authoritative values between the indicator data should be considered. In this paper, the combined assignment method combining expert assignment and objective assignment is adopted to make up for the shortcomings brought by single assignment. The obtained comprehensive weight is:

$$q_j=\frac{\sqrt{r_j w_j}}{\sum_{j=1}^{n}\sqrt{r_j w_j}} \quad (6)$$

3.2 Breakdown of carbon reduction targets

The relative size of the carbon emission reduction target of each park is obtained by calculating the weight of each indicator determined by the above method, and the specific calculation formula is as follows:

$$c_i = \sum_j q_j \frac{x'_{ij}}{\sum_i x'_{ij}} \tag{7}$$

Where c_i is the relative target of carbon emission reduction in park i and q_j is the combined weight of indicator j.

The carbon reduction potential factor of the park is then determined based on the values of the indicators:

$$\beta_i = \sqrt[5]{EP_i \times EH_i \times EG_i \times GP_i \times EN_i \times EQ_i} \tag{8}$$

$$EN_i = \{ \begin{matrix} (0.25 - NP_i) / \min NP_i ; NP_i < 0.25 \\ 1; NP_i \geq 0.25 \end{matrix} \tag{9}$$

Where EP_i is the per capita CO_2 emissions of park i, EH_i is the total annual historical CO_2 emissions of park i, EG_i is the carbon emissions per unit of GDP of park i, GPi is the per capita GDP of park i, EN_i is the proportion of non-fossil energy consumption to the total consumption of park i, and EQ_i is the power generation capacity of clean energy in park i. China's 2030 non-fossil energy target is to account for 25% of primary energy consumption, so this paper chooses the proportion of non-fossil energy to energy consumption as a parameter for consideration.

Finally, the carbon emission reduction targets of each park are calculated by combining the relative carbon emission reduction targets and carbon emission reduction potential factors determined above:

$$C_i = \beta_i \times c_i \tag{10}$$

4 Calculus Analysis

In order to verify the practicability of the carbon emission reduction target decomposition method of the parks proposed in this paper, five (A, B, C, D, E) office parks of power grid companies in a certain region are selected to verify the method of this paper, with 2020 as the base year and 2030 as the planning year. The subjective weights invite S experts to carry out empowerment, the objective weights are calculated according to the entropy weighting method, and then the comprehensive weights of each index are obtained, and the specific calculation results are shown in Table 1.

Table 1. Weighting Table of Carbon Emission Reduction Indicators in the Park

norm	A1	A2	B1	C1	D1	D2
Subjective weights	0.226	0.221	0.144	0.095	0.172	0.142
Objective weights	0.249	0.148	0.135	0.112	0.178	0.178
Combined weights	0.238	0.182	0.140	0.104	0.176	0.160

As shown in Table 1, per capita CO_2 emissions in the park and total annual historical CO_2 emissions in the park are given higher weights, reflecting the fact that the decomposition of carbon emission reduction targets mainly prioritizes fairness and efficiency, and at the same time, feasibility and sustainability are also reflected in the empowerment of specific indicators, which is in line with the initial intention of the grid company to pursue the concept of low-carbon, green and economically efficient operation and construction, fully reflecting the rationality and scientificity of the park carbon reduction target system. This fully reflects the rationality and scientificity of the carbon emission reduction index system of the park. Based on the baseline value and weight calculation results of each indicator of each park in 2020, the relative value of carbon emission reduction target of each park can be obtained, and then the relative value of carbon emission reduction target can be optimized by the carbon emission reduction potential factor of each park, and finally the carbon emission reduction target of each park can be obtained as shown in Fig. 3, so as to realize the decomposition of carbon emission reduction target.

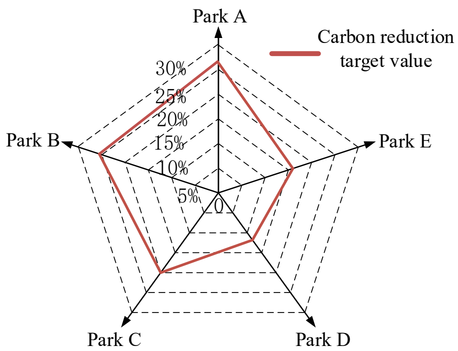

Figure 3. Radar chart of carbon reduction decomposition targets

As can be seen from Figure 3, the carbon emission reduction targets of each park A, B, C, D and E are 26.13%, 25.12%, 20.05%, 12.46% and 16.15%, respectively. Because of the high per capita CO_2 emissions and low utilization rate of clean energy in Parks A and B, the decomposition of the carbon emission reduction targets are relatively high, and the carbon emission reduction targets of Parks D and E are less because of their good clean energy consumption rate and more standardized personnel behavior management carbon reduction measures, and Park C is in the middle of the five parks. Park D and Park E have relatively high carbon reduction targets because of their good clean energy consumption rate and standardized personnel behavior management carbon reduction measures, and Park C is in the middle of the five parks.

5 Conclusions

To address the problem of carbon emission reduction target decomposition in the office park of the power grid company, the carbon emission reduction target decomposition index system of the office park is constructed from four aspects, namely, fairness, efficiency, feasibility, and sustainability; the comprehensive assignment method integrating expert assignment and entropy weight method is proposed, the relative value of carbon emission reduction target of each park is calculated, and the carbon emission reduction potential factor is introduced to realize the optimization of the target value; at last, the effectiveness and reasonableness of the park's carbon emission reduction decomposition index system and the carbon emission reduction decomposition method is validated with the examples, and the following conclusions can be drawn:

1. Construct the carbon emission reduction target decomposition index system of the office park, which fully covers the principles of fairness, efficiency, feasibility and sustainability, embodies the interests of all parties, and has strong operability and popularizability.

2. Adopting subjective and objective combination of empowerment methods, subjective weights using expert empowerment and objective weights using entropy weighting method, which makes the empowerment practical and effective.

3. Introducing carbon emission reduction potential factor to further optimize the carbon emission reduction decomposition target; the direction of future research mainly lies in the selection of indicators, and selecting the relevant indicators that are more in line with the local parks for analysis, so that the decomposition method is more in line with the actual situation of the local parks.

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References

[1] Cheng, W,Wu, Z,He, J. (2005) Two-convergece approach for future global carbon permit allocation. J Tsinghua Univ(Sci&Tech), Vol.45(6): 850–857.

[2] Yang, L,Ma, X. J (2010) Comparision on the Allocation Models of Cabong Emission Premits in Electricity Market. J Shaanxi Electric Power, Vol.38(2): 5–9.

[3] Du, S,Dong, J,Liang, L. J (2009) Optimal Production Policy with Emission Permits and Trading.Chinese Journal of Management Science, Vol.17(3): 81–83.

[4] Huang, H. J (2020) Allocation of China's Total Provincial Carbon Emissions under the Constraint of Carbon Intensity Target in 2030: An Analysis Based on the Perspective of Marginal Emission Reduction Cost Effect. Research World, Vol.07: 25–33.

[5] Tian, Y,Cheng, C. J (2020) Reward and punishment scheme of China’s provincial carbon emission reduction based on the allocation of carbon emission rights. China population，resources and environment, Vol.30(11): 54－62.

[6] Zheng, L. J (2012) Sharing the Carbon Emission Reduction Responsibility across Chinese Provinces: A Zero Sum Gains DEA Model. Resources Science, Vol.34(11): 2087－2096.

[7] Miao, Z,Zhou, P,Li, X. J (2012) China's Carbon Intensity Constraint Efficiency Allocation Research During“12·5”Period—Based on ZSG Environmental Production Technology. economic management, Vol.34(9): 25－36.

[8] Hahn R W. Market power and transferable property rights[J]. The Quarterly Journal of Economics, 1984, 99(4): 753-765.

[9] Cramton P, Kerr S. Tradeable carbon permit auctions: How and why to auction not grandfather[J]. Energy Policy, 2002, 30: 333-345.