Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 13 (12): 2282-2287, 2013
ISSN 1812-5654 / DOI: 10.3923/jas.2013.2282-2287

Research on the Effect Evaluation of the TPEs' Energy-saving and Emission Reduction Based on Entropy-weight and Extension Model

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Abstract: Aiming at the problem of different standards for energy-saving and emission-reducing in TPEs (thermal power enterprises). The author establishes the evaluation index system of energy saving and emission reduction in TPEs. Method of entropy-weighted extentic matter-element model was employed to evaluate effect of energy-saving and emission-reducing for ten TPEs. This study gets overall evaluation and order-arrangement of ten TPEs. It provides references for how to appraise the effect of energy-saving and emission-reducing effectively for TPEs. The results show that the evaluation index system and entropy-weighted extentic matter-element model are feasible and reasonable. The effect of energy-saving and emission-reducing among TPEs is comparable, it increases efficiency of energy-saving and emission-reducing examination.

Key words: Evaluation system, energy-saving and emission reduction, extension model, entropy

INTRODUCTION

As the primarily secondary energy resources, electric power plays an important role in modern economy life. TPEs can free air exhaust pernicious substance mainly is flue dust, oxynitride and sulfur dioxide during coal combustion. In 2010, electricity coal consumption is over 50% of the total coal. The emission of sulfur dioxide, smoke dust, ash and industrial water use accounts for 53, 25, 70 and 40%, respectively of the total quantity in china. Therefore, the power industry is the key areas of the country to implement energy-saving emission reduction. Many internal and external scholars have made a lot of researches on energy saving and emission reduction. By reading and researching related literatures of energy saving and emission reduction (Zhu and Bi, 2007; Ye, 2010; Sugihara *et al*., 2008; Gutierrez-Guerra *et al*., 2009; Lu, 2008; Zhang, 2010). The content of research is presented in three parts: (1) Research on energy saving and emission reduction policies. (2) The research on energy-saving and emission reduction technology. (3) The research of energy-saving and emission reduction evaluation. The literatures of study shows that how to establish a set of scientific and reasonable evaluation index system of energy saving and emission reduction is few. It is asymmetric that current enterprise energy conservation receives the value degree. The scientific and rational assessment on the effect of energy saving and emission reduction in TPEs could find shortcoming.

It makes the TPEs of energy-saving and emission reduction work simple and effective. This study establishes a set of suitable the evaluation index system of energy saving and emission reduction in TPEs, while using entropy-weighted extentic matter-element model to evaluate the effect of energy saving and emission reduction for TPEs.

ESTABLISH IN EVALUATION INDEX SYSTEM

Obeying the choosing principle (Du, 2006), the evaluation index of the effect of the TPE's energy-saving and emission reduction. Based on the present situation and problem of the TPEs' energy-saving and emission reduction. It adopts delphi method, method of frequency analysis and references the evaluation standard of other enterprises' energy-saving and emission reduction (Lv and Hong, 2012). Finally, it determines the evaluation index of the effect of TPEs' energy-saving and emission reduction.

The evaluation index system of the effect of the TPEs' energy-saving and emission reduction see the below Fig. 1.

ENTROPY-WEIGHTED EXTENTIC MATTER-ELEMENT MODEL

Establishing improved extension model: The evaluation of extension model has following steps (Lv and Hong, 2012).

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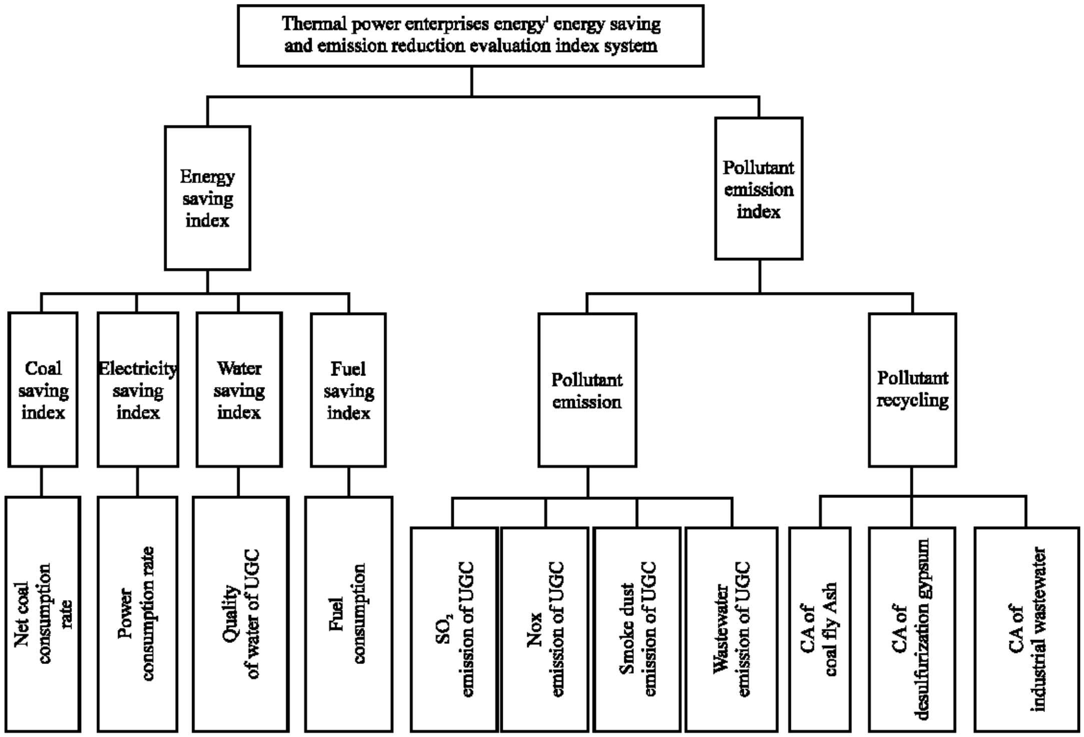

Fig. 1: TPE's energy-saving and emission reduction evaluation index system

Determining the matter-element to be evaluated: Matter-element is composed of three things N, characteristics C and values V to represent ordered triples. Note R = (N, C, V). Because a thing often has more features, it describes $c_1, c_2,\cdots, c_n$ of n eigenvalues and $v_1, v_2,\cdots, v_n$ of magnitudes of thing N.

Expressed as:

$$R = \begin{bmatrix} N, & c_1, & v_1 \\ & c_2, & v_2 \\ & \vdots & \vdots \\ & c_n, & v_n \end{bmatrix}$$

R is called n-dimensional.matter-element, abbreviated, R = (N, C, V), among them:

$$C = \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_4 \end{bmatrix}, V = \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_4 \end{bmatrix}$$

So, the analysis of the data is represented matter-element R_0 for the thing to be evaluated.

Namely:

$$R_0 = \begin{bmatrix} P_0, & c_1, & v_1 \\ & c_2, & v_2 \\ & \vdots & \vdots \\ & c_n, & v_n \end{bmatrix}$$

R_0 is called the thing to be evaluated.ci represents the i-th feature of the thing to be evaluated.vi represents the value of the i-th feature.

Determining classical field: Classical field is each grade of thing on the range of data taken of corresponding feature:

$$R_{0j} = (P_{0j}, C_i, X_{0ji}) = \begin{bmatrix} P_{0j}, & c_1, & x_{0j1} \\ & c_2, & x_{0j2} \\ & \vdots & \vdots \\ & c_n, & x_{0jn} \end{bmatrix} = \begin{bmatrix} P_{0j} & c_1 & (a_{0j1}, b_{0j1}) \\ & c_2 & (a_{0j2}, b_{0j2}) \\ & \vdots & \vdots \\ & c_n & (a_{0jn}, b_{0jn}) \end{bmatrix}$$

where, R_{0j} is matter-element model of the j-th level of things. P_{0j} is the j-th level of the division of things. (j = 1, 2···m,); c_i is the j-th feature of the level of P_{0j}; X_{0ij} is P_{0j} about range of c_i, namely classical field. The intuitive meaning of classical field is the basic intervals of things that each attribute changes. The range of X_{0ij} is interval (aoij, boij).Written as Xoij = (aoij, boij), (i = 1, 2,···,n).

Determining sectional field: Sectional field is the range of each index in the evaluation system. It is the comprehensive range of classical field:

$$R_p = (P, C_i, V_{pi}) = \begin{bmatrix} P, & c_1, & x_{p1} \\ & c_2, & x_{p2} \\ & \vdots & \vdots \\ & c_n, & x_{pn} \end{bmatrix} = \begin{bmatrix} P & c_1, & (a_{p1}, b_{p1}) \\ & c_2, & (a_{p2}, b_{p2}) \\ & \vdots & \vdots \\ & c_n & (a_{pn}, b_{pn}) \end{bmatrix}$$

where, R_p represents the matter-element model of classical field of thing assessment degree. p represents all levels. x_{pi} is all value assignment range of index c_i (a_{pi}, b_{pi}). Namely sectional field is denoted by x_{pi}= (a_{pi}, b_{pi}).

Improved extension model: R_0 element is standardized in classical field matrix (Hu *et al*., 2003). Namely the magnitude of each classical field is divided by the value of the right endpoint T_q. Getting new classical field matter-element matrix.

The content is summarized as follows:

$$R'_{oj}=(N',C,V')=\begin{bmatrix} N' & c_1 & \langle a_{oj1}/b_{p1}, b_{oj1}/b_{p1}\rangle \\ & c_2 & \langle a_{oj1}/b_{p2}, b_{oj2}/b_{p2}\rangle \\ & \vdots & \vdots \\ & c_n & \langle a_{oj1}/b_{pn}, b_{ojn}/b_{pn}\rangle \end{bmatrix}$$

In type: N' is classical and limited matter element that is standardized, V' is magnitude that is standardized. Similarly, the magnitude of evaluated matter-element is divided by the value of the right endpoint T_q. It can get the new evaluated matter element.

Namely:

$$R_p'=\begin{bmatrix} P', & c_1, & \langle v_1/b_{p1}\rangle \\ & c_2, & \langle v_2/b_{p2}\rangle \\ & \vdots & \vdots \\ & c_n, & \langle v_n/b_{pn}\rangle \end{bmatrix}$$

Entropy method determines index weights: Index weights that reflect important degree of influential factors are quantized coefficient. Different weight will lead to different evaluation results. In this study, the entropy weight is used to determine weight. It is an objective weighting method that is not affected by subjective factors in a full sense. Moreover it reduces the influence that extreme value acts on synthetic evaluation. It is more reliable and efficient than the principal components analysis method and the analytic hierarchy process. The detailed steps as follows.

- **Data normalization:** During the circumstance that has m pieces of evaluation indexes and n evaluated objects. The obtained original data matrix as:

$$X=\begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix} \quad (1)$$

According to the nature of indicators, they will be divided into two categories indicators. One is the bigger and better indicator; the other is smaller and better indicator.

For bigger and better indicator, has:

$$v_{ij}=\frac{x_{ij}-\min(x_j)}{\max(x_j)-\min(x_j)} \quad (2)$$

For smaller and better indicator, has:

$$v_i=\frac{\max(x_j)-x_{ij}}{\max(x_j)-\min(x_j)} \quad (3)$$

The above matrix is standardized, get R = $(r_{ij})_{m,n}$.

In type: Normalized values; max (x_j),min (x_j), It is the maximum and minimum of the J indicators respectively. After standardized $0\le v_i\le 1$.

- **Defining entropy:** Expression:

$$H_i=-k\sum_{j=1}^{n} f_{ij}\ln f_{ij} \quad (4)$$

$$i = (1, 2,\cdots m)\ (j = 1, 2,\cdots, n)$$

where, H_i is the entropy of evaluation parameters:

$$f_{ij}= r_{ij}\Big/\sum_{j=1}^{n} r_{ij}$$

among them, n represents the number of evaluation object:

$$k=\frac{1}{\ln n}$$

when f_{ij}= 0, making $f_{ij}\ln f_{ij}$ = 0.

- Seeking entropy:

$$\omega_i=\frac{1-H_i}{\sum_{i=1}^{m}(1-H_i)} \quad (5)$$

where, ω_i is the entropy of evaluation indicator, namely weight coefficient. m represents the number of evaluation object.

Calculation and grading of correlation degree:

- Calculating distance to distance:

$$\rho(v_i, X_{Pi})=\left|v_i-\frac{1}{2}(a_{Pi}+b_{Pi})\right|-\frac{1}{2}(b_{Pi}-a_{Pi}) \quad (6)$$

$$\rho(v_i, X_{0ji})=\left|v_i-\frac{1}{2}(a_{0ji}+b_{0ji})\right|-\frac{1}{2}(b_{0ji}-a_{0ji}) \quad (7)$$

where, $\rho(v_i, X_{pi})$ and $\rho(v_i, X_{0ji})$ represent proximity between point v_i and interval X_{pi} and X_{0ji}.

- **Calculating copula function:**

$$K_j(v_i) = \frac{\rho(v_i, X_{0ji})}{\rho(v_i, X_{pi}) - \rho(v_i, X_{0ji})} \tag{8}$$

where, $K_j(v_i)$ represents the i-th calculation indicator of matter-element to be evaluated.

c_i represents incidence degree of the j-th degree.

- **Comprehensive evaluation:**

$$K_j(P_0) = \sum_{i=1}^{n} \omega_{ij} K_j(v_i) \tag{9}$$

where, ω_{ij} represents the weight of each evaluation.

$K_j(P_o)$ represents evaluation object P_o that is about incidence degree of the j-th degree. As $K_j = \max K_j$, then judging P_0 belongs to the class J. Getting the final evaluation result of the object to be evaluated $K_j = \max K_j (P_o)$

CASE STUDY

TPEs consume large amounts of coal resources during electricity generation progress. Using a lot of fossil fuels generate economic benefits, and at the same time causing serious environmental problems. Energy saving and emission reduction decrease is an important way to enhance economic benefits and solve environmental pollution problems. Therefore, calculating correctly the effect of energy-saving and emission reduction of TPEs. Thereby improving each indicator of energy-saving and emission reduction about TPEs. It is beneficial to increase exploitation efficiency of coal, reduce environment pollution and improve TPEs' competition capability. This study intends to select ten TPEs to evaluate the effect of energy-saving and emission reduction. The subsystem of energy consumption and the subsystem of pollutants emission reduction are evaluated through entropy-weighted matter-element model.

Determining matter-element to be element:

$$R_0 = (N,C,V) = \begin{pmatrix} N, & c_1 & v_1 \\ & c_2 & v_2 \\ & c_3 & v_3 \\ & c_4 & v_4 \\ & c_5 & v_5 \\ & c_6 & v_6 \\ & c_7 & v_7 \\ & c_8 & v_8 \\ & c_9 & v_9 \\ & c_{10} & v_{10} \\ & c_{11} & v_{11} \end{pmatrix}$$

where, R_0 represents the TPEs to be evaluated, c_1 represents net coal consumption rate; c_2 represents power consumption rate; c_3 represents quantity of water of unit generating capacity; c_4 represents fuel consumption; c_5 represents SO_2 emission of unit generating capacity; c_6 represents NO_x emission of unit generating capacity; c_7 represents smoke dust emission of unit generating capacity; c_8 represents wastewater emission of unit generating capacity; c_9 represents comprehensive application of coal fly ash; c_{10} represents comprehensive utilization of desulfurization gypsum; c_{11} represents utilization of industrial wastewater.

Processing indicator data: Getting the subsystem of energy consumption and the subsystem of pollutants emission reduction through actual investigation and expert interview, sectional field:

$$R_p = \begin{bmatrix} \text{TPEs } E_1, & \text{Net Coal Consumption rate,} & (295, \ 370) \\ & \text{Power Consumption Rate,} & (4.95, \ 8.1) \\ & \text{Quantity Of Water Of UGC,} & (0.4, \ 0.8) \\ & \text{Fuel Consumption,} & (8500, 9500) \\ & SO_2 \text{ Emission Of UGC,} & (1, \ 11) \\ & N_{ox} \text{ Emission Of UGC} & (1.3, \ 10) \\ & \text{Smoke Dust Emission Of UGC} & (0.9, \ 5.9) \\ & \text{Wastewater Emission Of UGC} & (0.57, \ 1.8) \\ & \text{CA Of Coal Fly Ash} & (60, \ 100) \\ & \text{CA Of Desulfurization Gypsum} & (90, \ 100) \\ & \text{CA Of Industrial Wastewater} & (80, \ 100) \end{bmatrix}$$

Standardized according to the following equation:

$$\bar{x}_i = \begin{cases} \dfrac{x_i - \min x}{\max x - \min x} & x_i \text{ is positive indicator} \\ \dfrac{\max x - xi}{\max x - \min x} & x_i \text{ is reverse indicator} \end{cases}$$

where, $\bar{x_i}$ is standardized indicator; x_i is initial value of indicator; $\min x_i$ is minimum value of the same indicator, namely the minimum value of sectional field; $\max x_i$ is maximum value of the same indicator, namely the maximum value of sectional field; Original data of saving-energy and emission reduction indicators from ten TPEs are standardized. The data of the indicators are calculated by matlab. Final result sees Table 1.

Table 1: Processing results of indexes standardized

	TPE									
Index	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}
C_1	0.627	0.187	0.827	0.33	0.73	0.160	0.440	0.67	0.467	0.347
C_2	0.438	0.178	0.787	0.29	0.72	0.356	0.530	0.57	0.469	0.476
C_3	0.750	0.150	0.650	0.20	0.43	0.425	0.850	0.75	0.450	0.525
C_4	0.715	0.270	0.701	0.21	0.60	0.594	0.163	0.48	0.202	0.154
C_5	0.740	0.340	0.870	0.61	0.91	0.460	0.680	0.82	0.180	0.590
C_6	0.839	0.930	0.897	0.97	0.92	0.712	0.058	0.79	0.506	0.885
C_7	0.820	0.780	0.600	0.56	0.88	0.700	0.940	0.98	0.940	1.000
C_8	0.821	0.488	0.772	0.46	0.68	0.244	0.772	0.65	0.715	0.390
C_9	1.000	0.250	1.000	1.00	0.90	0.750	0.880	1.00	0.950	1.000
C_{10}	1.000	0.000	1.000	1.00	0.80	1.000	1.000	1.00	1.000	1.000
C_{11}	0.950	0.650	1.000	0.85	0.90	0.900	1.000	0.95	0.800	0.750

Table 2: Index weights

Index	Weight (w)
C_1	0.1269
C_2	0.0916
C_3	0.1051
C_4	0.1964
C_5	0.0789
C_6	0.0537
C_7	0.0994
C_8	0.0795
C_9	0.0494
C_{10}	0.0472
C_{11}	0.0719

Determining weight: Appling Eq. 1-5. The entropy method was adopted in each index weights coefficient, the weights are calculated by MATLAB.

The results are shown in Table 2.

Determining classical domain and sectional field: Sectional field of each indicator has been determined in the process of standardization. sectional field for:

$$R_p = (P, C, X_p) = \begin{bmatrix} p, & c_1, & (0,1) \\ & c_2, & (0,1) \\ & c_3, & (0,1) \\ & c_4, & (0,1) \\ & c_5, & (0,1) \\ & c_6, & (0,1) \\ & c_7, & (0,1) \\ & c_8, & (0,1) \\ & c_9, & (0,1) \\ & c_{10}, & (0,1) \\ & c_{11}, & (0,1) \end{bmatrix}$$

The intuitive meaning of classical field is basic interval that represents each property variation about thing. Adopting standardization of data range. Each index value are converted to (0, 1). Distributed equally according to level number. Determining classical field of each attribute. The results are shown in Table 3. Among them the Grade "1", "2", "3", "4" which means "bad", "moderate (mod-)", "good", "well".

Calculating correlation and degree: According to the determined weights of Table 3. Appling Eq. 6-9, to calculate, The weights are calculated by MATLAB. The evaluation results obtained as shown in Table 4.

Analysis of evaluation results: We can know from Table 4 thar the effect of ten TPEs'saving-energy and emission reduction is at three different levels. Six TPEs E1, E3, E5, E7, E8 and E10 have the same evaluation degree of the effect of energy-saving and emission reduction. But J^* value is not consistent. And J* value can judge the degree that matter-element to be evaluated biases adjacent level. It can decide advantages and disadvantages about the effect of saving-energy and emission reduction for six TPEs. namely $E_3>E_7>E_1>E_5>E_8>E_{10}$。 Three TPEs E_4, E_6 and E_9 have the same evaluation degree of the effect of energy-saving and emission reduction. But from J^* value we could know rankings that is $E_9>E_6>E_4$ about three TPEs. Energy efficiency evaluation grade of thermal power enterprise is E_2 "bad". Building a unified evaluation system of energy-saving and emission reduction. Method of entropy-weighted matter-element model was employed to evaluate the effect of energy-saving and emission reduction.. There is a certain comparability among TPEs about the effect of energy-saving and emission reduction. It could evaluate good and bad efficiently about energy-saving and emission reduction of each TPEs. Reference is provided to assessment word of energy-saving and emission reduction and improve energy conservation.

Table 3: Sectional field and classical field of each index

	Gradee				
Index	Rp	R01 (bad)	R02 (mod-)	R03 (good)	R04 (well)
C_1	(0, 1)	(0, 0.25)	(0.25, 0.5)	(0.50, 0.75)	(0.75, 1)
C_2	(0, 1)	(0, 0.25)	(0.25, 0.5)	(0.50, 0.75)	(0.75, 1)
C_3	(0, 1)	(0, 0.25)	(0.25, 0.5)	(0.50, 0.75)	(0.75, 1)
C_4	(0, 1)	(0, 0.25)	(0.25, 0.5)	(0.50, 0.75)	(0.75, 1)
C_5	(0, 1)	(0, 0.25)	(0.25, 0.5)	(0.50, 0.75)	(0.75, 1)
C_6	(0, 1)	(0, 0.25)	(0.25, 0.5)	(0.50, 0.75)	(0.75, 1)
C_7	(0, 1)	(0, 0.25)	(0.25, 0.5)	(0.50, 0.75)	(0.75, 1)
C_8	(0, 1)	(0, 0.25)	(0.25, 0.5)	(0.50, 0.75)	(0.75, 1)
C_9	(0, 1)	(0, 0.25)	(0.25, 0.5)	(0.50, 0.75)	(0.75, 1)
C_{10}	(0, 1)	(0, 0.25)	(0.25, 0.5)	(0.50, 0.75)	(0.75, 1)
C_{11}	(0, 1)	(0, 0.25)	(0.25, 0.5)	(0.50, 0.75)	(0.75, 1)

Table 4: TPEs E1-E10 energy saving targets and four levels of correlation value and the evaluation results

	Region								
Enterprise	R_{01}	R_{02}	R_{03}	R_{04}	R_{max}	j	J^*	Grade	Rank
E_1	-0.698	-0.528	-0.214	-0.010	-0.010	4	3.388	well	3
E_2	-0.107	-0.281	-0.493	-0.540	-0.110	1	1.471	bad	10
E_3	-0.756	-0.635	-0.281	0.078	-0.760	4	3.498	well	1
E_4	-0.381	-0.299	-0.449	-0.340	-0.380	2	2.451	mod-	9
E_5	-0.664	-0.470	-0.162	0.042	0.021	4	3.365	well	4
E_6	-0.386	-0.221	-0.222	-0.310	-0.160	2	2.770	mod-	8
E_7	-0.453	-0.504	-0.435	-0.190	-0.200	4	3.490	well	2
E_8	-0.672	-0.498	-0.215	-0.060	-0.670	4	3.349	well	5
E_9	-0.383	-0.281	-0.361	-0.300	-0.280	2	2.935	mod-	7
E_{10}	-0.442	-0.311	-0.388	-0.260	-0.280	4	3.130	well	6

CONCLUSION

- This study establishes effect evaluation system of energy-saving and emission reduction about TPEs. It reflects the effect of energy-saving and emission reduction comprehensively and truly. It could get reality effect of energy-saving and emission reduction of TPEs and guide the word of energy-saving and emission reduction better

- The evaluation system and entropy-weighted extentic matter-element model are proved to be reasonable and feasible by evaluation results. Evaluation system could improve the efficiency of work of energy-saving and emission reduction. The poor effect of TPEs is guided better in energy-saving and emission reduction
- The evaluation results are reasonable and feasible based on information entropy theory. The effect of energy-saving and emission reduction is reflected objectively and clearly. This method can also be applied to select the comparison of multiple programs and Sort multi-project progress

ACKNOWLEDGMENT

Supported by "the Social Science Fund of Hebei Province (HB11YJ011)" and "the Fundamental Research Funds for the Central Universities".

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