

Evaluation of Energy-Saving & Emission Reduction Performance of Chinese Electric Power Industry

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Keywords: electric power industry; energy-saving & emission reduction; performance evaluation; combination model

Abstract. Scientific performance evaluation is an important basis for government decision. This paper established the performance evaluation index system of electric power industry based on environmental technology, and then, SE-DEA model, entropy weight TOPSIS model and factor analysis model are used to calculate the scores and rankings respectively by means of the sectional data of Chinese regions in 2013. Then, Kendall-W correlation is used to verify the coherence of different evaluation results. Finally, fussy Borda model is applied to combine the independent evaluation results so that the combined evaluation result can be achieved.

Introduction

As a pillar industry of the national economy, the electric power industry consumes a large amount of energy and causes serious environmental pollution while promoting economic development and meeting the demand of electric power. In recent years, though the Chinese government has taken relevant measures, the policies of energy-saving & emission reduction have not played a positive role in some regions. Thus, to improve the performance of energy saving & emission reduction has become a common problem. The key to this problem is a reasonable performance evaluation which helps to provide theoretical basis for scientific and effective decision-making.

At present, the evaluation methods of environmental performance mainly include DEA [1], improved DEA [2], entropy weight TOPSIS [3], factor analysis [4] and so on. However, in order to evaluate the performance of energy saving & emission reduction in power generation, if only one method is used, it seems one-sided and limited. So based on the single evaluation method, a kind of combination evaluation method is put forward in this paper. Moreover, the performance of energy saving & emission reduction of China's electric power industry is evaluated and analyzed.

Evaluation index system

Less inputs, more outputs and less emissions are the ideal state of industrial production. But in fact, the desirable outputs are always accompanied by all kinds of pollution, called undesirable outputs. Given this background, [5] proposed the theory of *environmental technology*, which describes the relationship between inputs and 2 kinds of outputs.

Based on the environmental technology, the output sets are got, which contain the desirable outputs and the undesirable outputs. Meanwhile, the most important factors which affecting the performance of energy-saving & emission reduction is taken into consideration. As a result, an evaluation index system can be established, shown in Fig. 1.

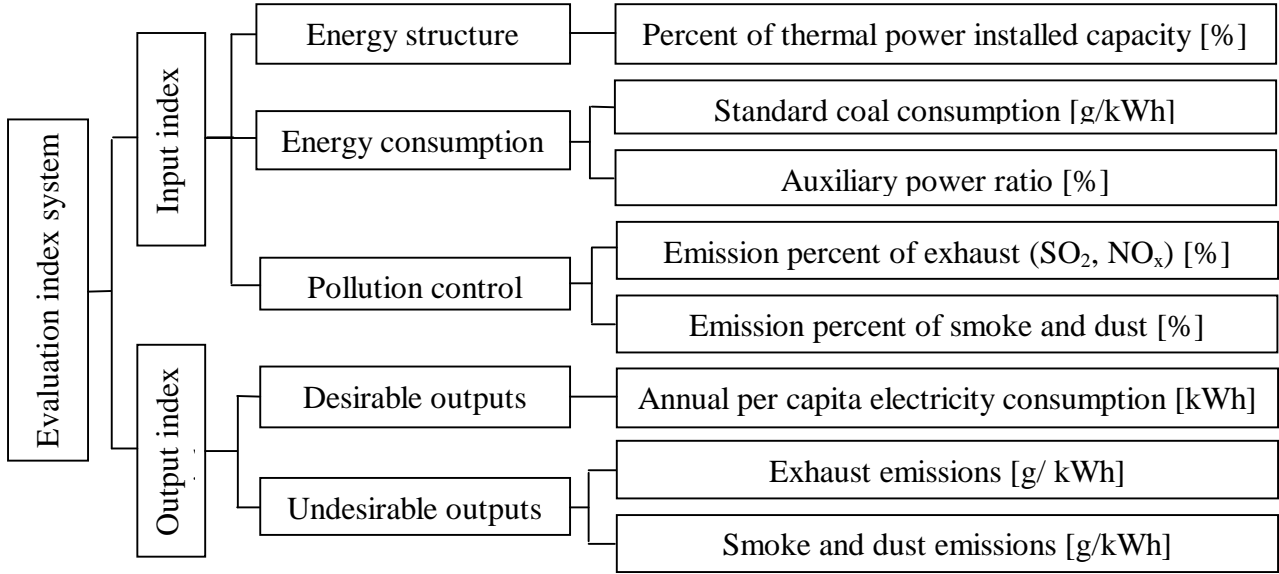


Fig. 1 Evaluation index system of energy-saving & emission reduction performance.

For the goal of energy-saving & emission reduction, on the one hand, energy consumption and pollution emissions should be reduced. On the other hand, the industrial structure should be adjusted so that the clean energy can achieve development. Therefore, energy consumption, pollution control and energy structure respectively corresponds to energy-saving performance, emission reduction performance and clean energy performance.

Combination evaluation method

Steps of combination evaluation

1. SE-DEA model, entropy weight TOPSIS model and factor analysis model are used to calculate the scores and rankings respectively of every region.
2. Kendall-W correlation is used to verify the coherence of different evaluation results (ex ante verification).
3. Fussy Borda model is applied to combine the independent evaluation results, through which the combined evaluation result can be got .
4. Spearman rank correlation is used to verify the coherence between individual evaluation results and combined evaluation result (ex post verification).

Model calculation

The sectional data of 30 regions (except Tibet) in 2013 is selected for calculation . Firstly, the data should be non-dimensionalized as follows.

As for input and desirable output index, let

$$y_{ik} = 0.1 + 0.9 \times \frac{x_{ik} - x_{\min(k)}}{x_{\max(k)} - x_{\min(k)}} \quad (1)$$

as for undesirable output index, let

$$y_{ik} = 0.1 + 0.9 \times \frac{x_{\max(k)} - x_{ik}}{x_{\max(k)} - x_{\min(k)}} \quad (2)$$

where x_{ik} is the value of the i th region among the k th index , $x_{\max(k)}$ is the maximum value among the k th index while $x_{\min(k)}$ is the minimum.

Then scores and rankings of the performances can be calculated by 3 models, shown in Table 1.

Table. 1 Scores and rankings of the performances calculated by single model

Region	Model	SE-DEA		Entropy weight TOPSIS		Factor analysis	
		Score	Ranking	Score	Ranking	Score	Ranking
Beijing		6.016	2	0.707	7	0.572	6
Tianjin		1.787	5	0.692	13	0.467	18
Hebei		0.704	21	0.661	18	0.458	19
Shanxi		0.629	23	0.566	26	0.380	26
Inner Mongolia		0.749	19	0.616	22	0.435	21
Liaoning		0.549	27	0.568	25	0.388	25
Jilin		0.535	28	0.492	28	0.343	29
Heilongjiang		0.122	30	0.059	30	0.156	30
Shanghai		0.869	15	0.689	14	0.511	14
Jiangsu		0.934	11	0.705	8	0.532	11
Zhejiang		0.920	12	0.726	4	0.550	8
Anhui		0.914	13	0.672	17	0.497	15
Fujian		1.155	8	0.726	3	0.576	5
Jiangxi		0.736	20	0.647	20	0.470	17
Shandong		0.750	18	0.658	19	0.446	20
Henan		0.584	25	0.612	23	0.425	22
Hubei		0.969	10	0.702	10	0.591	4
Hunan		0.848	16	0.676	15	0.512	13
Guangdong		0.892	14	0.715	5	0.536	10
Guangxi		1.400	7	0.705	9	0.567	7
Hainan		1.045	9	0.676	16	0.480	16
Chongqing		0.485	29	0.485	29	0.352	28
Sichuan		1.649	6	0.700	11	0.608	3
Guizhou		0.621	24	0.549	27	0.391	24
Yunnan		1.905	4	0.739	1	0.635	2
Shaanxi		0.553	26	0.580	24	0.369	27
Gansu		0.768	17	0.696	12	0.528	12
Qinghai		7.653	1	0.713	6	0.644	1
Ningxia		3.763	3	0.729	2	0.541	9
Xinjiang		0.654	22	0.642	21	0.407	23

Kendall-W correlation: $X^2 = 81.74 > X_{0.025}^2(29)$. Verification passed.

Fuzzy Borda model strikes a balance between the scores and rankings, which makes it an advantage over other similar models in optimization [6]. By applying fuzzy Borda model to combine the independent evaluation results, the combined evaluation result can be got, shown in Table. 2.

Spearman rank correlation: $t = 18.132 > t_{0.025}(28)$. Verification passed.

With a standard of the scores, the 30 regions can be clustered into 4 types as follows.

Type A: Yunnan, Qinghai, Fujian, Ningxia, Beijing.

Type B: Zhejiang, Sichuan, Hubei, Guangdong, Guangxi, Jiangsu.

Type C: Gansu, Tianjin, Shanghai, Hunan, Hainan, Anhui.

Type D: Hebei, Jiangxi, Shandong, Inner Mongolia, Xinjiang, Henan, Shaanxi, Liaoning, Guizhou, Shanxi, Jilin, Chongqing, Heilongjiang.

Table. 2 Combined evaluation result

Region	Score	Ranking	Region	Score	Ranking
Beijing	323.68	5	Henan	29.74	23
Tianjin	153.51	13	Hubei	271.90	8
Hebei	70.18	18	Hunan	131.91	15
Shanxi	12.00	27	Guangdong	259.53	9
Inner Mongolia	42.62	21	Guangxi	255.19	10
Liaoning	14.06	25	Hainan	119.53	16
Jilin	2.30	28	Chongqing	1.73	29
Heilongjiang	0.00	30	Sichuan	285.44	7
Shanghai	134.39	14	Guizhou	13.21	26
Jiangsu	220.94	11	Yunnan	411.13	1
Zhejiang	293.05	6	Shaanxi	14.68	24
Anhui	109.09	17	Gansu	163.56	12
Fujian	342.32	3	Qinghai	391.04	2
Jiangxi	69.12	19	Ningxia	338.79	4
Shandong	63.13	20	Xinjiang	38.09	22

Conclusions

In this paper, SE-DEA model, entropy weight TOPSIS model and factor analysis model are respectively used to evaluate of China's regional energy-saving & emission reduction performance of electric power industry. Moreover, fussy Borda model is applied to combine the independent evaluation results which can lead to the combined evaluation result.

According to the research result, the performances of different regions still have a big diversity and imbalance. Type A should process steadily on the basis of the current advantages, and provide a good demonstration effect for the others. Because of the similar development model, Type B can learn from the successful experience of Type A. Among Type C and D, the regions where the environment is suitable for the development of new energy, should take great pains to make full use of the regional advantages, while the small and medium-sized thermal power plants should be shut down. The regions where the development of new energy is limited, should take some policies of constructing major projects and suppressing small projects to fulfill the goal of structure reduction, and improve flue gas desulfurization to fulfill the goal of project reduction while exploring the way to the development of new energy.

Acknowledgements

This work was financially supported by the Shanghai Philosophy and Social Sciences Fund.

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