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The Comprehensive Evaluation for the Social Benefits of the Natural Gas CCHP Project

Huiru Zhao, Zhao Ma, Nana Li

School of Economics and Management, North China Electric Power University, 102206, China

Abstract. In order to promote the development of natural gas Combined Cooling Heating and Power (CCHP) project in China, it is critical for us to evaluate the social benefits comprehensively. This paper establishes a comprehensive evaluation index system which contains the natural environmental benefit, the social environmental benefits, and the social economy benefits. Moreover, a comprehensive evaluation model based on AHP and GCDM is proposed to evaluate the social benefits of the natural gas CCHP project. At last, an empirical analysis of a project in city Z is presented, which show that the social benefits of this project is "very good", and the feasibility of this model is proved.

Keywords: Combined Cooling Heating and Power, social benefits, AHP, GCDM, comprehensive evaluation

1 Introduction

On the basis of energy cascade utilization, the natural gas CCHP project can integrate the process of cooling, heating and power generation. Facing the serious situation of energy supply, the natural gas CCHP project can improve the utility efficiency of primary energy and cut down the emission of greenhouse gas. However, at present, the use of CCHP project has not been widespread in China, due to the insufficient investment. On one hand, the policies and regulations on energy and environment are still deficient in China, as well as the encourage policies on environmental protection. On the other hand, the feed-in tariff of the CHPC plants has no advantage comparing with the regular energy. What's more, the price of natural gas fluctuates severely. Above all, it is indispensable to evaluate and analyze the social benefits from a comprehensive perspective, so as to improve the development of the natural gas CCHP project in China.

Currently, the research about the natural gas CCHP project mainly focus on the optimizations of system and economic operation. The study on the system optimization includes: the optimization of the principal devices in the CCHP system [1], the optimal running states of the CCHP system under various external conditions[3,4], the optimal allocation of the CCHP system [2], the optimization of running mode for the CCHP system [3], and so on. For the aspect of economic operation, the research mainly focuses on the optimization of economical efficiency.

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Literature [4] established an objective function for minimizing the annual costs, and proposed a best operation strategy.

However, it is still scarce that study on the evaluation of social benefits for the natural gas CCHP project. Moreover, the short of research on the evaluation standard and indicators of the social benefits hinders the application and popularization of the project. Therefore, in order to promote the application and fully exerts the comprehensive benefits of the natural gas CCHP projects, it is vital to build scientifically the evaluation index system and an evaluation model for the comprehensive benefits of the project .This paper establishes a comprehensive evaluation index system which contains three aspects, which contains of the natural environmental benefits, social environmental benefits and society economic benefits. Meanwhile, an comprehensive model is established based on AHP and GCDM model to evaluate the social benefits of the CCHP project.

2 The evaluation index system of the natural gas CCHP project social benefits

The social benefits of natural gas CCHP project are mainly manifested in three aspects: the natural environmental benefits, the economic benefits, and the social environmental benefits. Therefore, the evaluation index system for evaluating the social benefits of CCHP project is established in this part. The specific indicators are shown as follows:

(1) The natural environmental benefits

The environmental benefits evaluation of gas CCHP project mainly covers the energy saving and the emission reduction.

1) The benefits of the fossil energy saving

2) The benefits of the pollutant emissions reduction

3) The benefits of the exhaust gas recycling

(2)The benefits of the social economy

The benefits of the social economy are the economic impact driven by the natural gas CCHP project from a macroeconomic perspective.

1) The benefits of driving related industries

2) The benefits of power grid operation

3) The benefits of land value-added

(3)The social environmental benefits

The social environmental benefits mainly feature in technique progress, sustainable development of industry and the improvement of employment increased by project and other macro indicators.

1) The benefits of the improvement of employment

2) The comprehensive benefits for the electricity industry

3 Case study

3.1 Primary Data

A natural gas CCHP project has been built in city Z, ant the comprehensive evaluation of the social benefits for this project will be presented in this section. The primary data of the evaluation indicators are quantified by experts scoring through releasing the questionnaire. The higher the score is, the better the benefit is. The specific primary data is shown as below:

Table.1 The primary data for the social benefits evaluation

Indicators	Primary data
The benefits of the fossil energy saving	78
The benefits of the pollutant emissions reduction	83
The benefits of the exhaust gas recycling	68
The benefits of the improvement of employment	56
The comprehensive benefits for the electricity industry	71
The benefits of driving related industries	88
The benefits of power grid operation	76
The benefits of land value-added	27

3.2 The evaluation of the social benefits for the project in city Z

(1)Determining the gray classes of evaluation

In order to evaluate the social benefits reasonably, five classes are divided to represents the “very poor”, “poor”, “moderate”, “good”, and “very good”, respectively. Moreover, the ranges of all glasses are [10,20),[20,40),[40,60),[60,80),[80,90].

(2) Determine the weights of indicators

1) Establish the hierarchy model of indicators

It is a primary work to establish the hierarchy model of indicators when using the AHP method. The index system for the social benefit of natural gas CCHP project is divided into three levels, which is shown in Table 3.

2) Establish the judgment matrix

Construct the relative importance matrix for the indicators in the principle layer based on the experts scoring, which is show as follows:

Table 2. Matrix of the principle layer

U	U_1	U_2	U_3
U_1	1	2	4

U_2	1/2	1	3
U_3	1/4	1/3	1

Because of CR=CI/RI=0.0147<0.1, the consistency test is approved.

Therefore, w1=0.4433, w2=0.3875 ,w3=0.1692.

(3) Calculating the weight of each indicator

Table 3. The weight of each indicator in the scheme layer

Objective layer	Principle layer		Scheme layer	
The comprehensive social benefits for the natural gas CCHP project	The natural environmental benefits U_1	0.4433	The benefits of the fossil energy saving U_{11}	0.2771
			The benefits of the pollutant emissions	0.1057
			The benefits of the exhaust gas recycling U_{13}	0.0605
	The benefits of the social economy U_2	0.3875	The benefits of driving related industries	0.1291
			The benefits of power grid operation U_{22}	0.2207
			The benefits of land value-added U_{23}	0.0377
	The social environmental benefits U_3	0.1692	The benefits of the improvement of	0.1269
			The benefits of the improvement of	0.0423

(3) Construct triangular white functions

Enlarging the range of the x, it is feasible to stretch the border of range to the left or right at 5 and 95, namely, a0=5；a1=10；a2=20；a3=40；a4=60；a5=80；a6=90；a7=95, so

λ1=15; λ2=30; λ3=50; λ4=70; λ5=85，the triangular white function of each gray class are as follows[5]:

$$f_j^1(x)=\begin{cases}0 & x\notin[5,40]\\ \dfrac{x-5}{10} & x\in[5,15]\\ \dfrac{40-x}{25} & x\in[15,40]\end{cases} \quad (5)$$

$$f_j^2(x)=\begin{cases}0 & x\notin[10,60]\\ \dfrac{x-10}{20} & x\in[10,30]\\ \dfrac{60-x}{30} & x\in[30,60]\end{cases} \quad (6)$$

$$f_j^3(x)=\begin{cases}0 & x\notin[20,80]\\ \dfrac{x-20}{30} & x\in[20,50]\\ \dfrac{80-x}{30} & x\in[50,80]\end{cases} \quad (7)$$

$$f_j^4(x)=\begin{cases}0 & x\notin[40,90]\\ \dfrac{x-40}{30} & x\in[40,70]\\ \dfrac{90-x}{20} & x\in[70,90]\end{cases} \quad (8)$$

$$f_j^5(x)=\begin{cases}0 & x\notin[60,95]\\ \dfrac{x-60}{15} & x\in[60,85]\\ \dfrac{95-x}{10} & x\in[85,95]\end{cases} \quad (9)$$

(5) Calculate the comprehensive clustering coefficient

Take the actual value of each indicator into the triangular white functions, and calculate the clustering coefficient of each gray class for each indicator.

Table 4. The clustering coefficient

Indic	Actual	f_i^1(x	f_i^2(x	f_i^3(x	f_i^4(x	f_i^5(x
U_{11}	78	0	0	0.067	0.9	1.2
U_{12}	83	0	0	0	0.35	1.533
U_{13}	68	0	0	0.4	0.933	0.533
U_{21}	88	0	0	0	0.1	0.7
U_{22}	76	0	0	0.133	0.7	1.067
U_{23}	27	0.52	0.35	0.233	0	0
U_{31}	71	0	0	0.3	0.95	0.733
U_{32}	56	0	0.13	0.8	0.533	0

According to the formula of the comprehensive clustering coefficient, the comprehensive clustering coefficient related to each gray class can be calculated, which is shown as follows:

$$\sigma_j^{\,1} = \sum_{j=1}^{8} \boldsymbol{f_j}^{1}(\boldsymbol{x_{ij}}) \times \omega_j = \ 0.0196$$

$$\sigma_j^{\,2} = \sum_{j=1}^{8} \boldsymbol{f_j}^{2}(\boldsymbol{x_{ij}}) \times \omega_j = \ 0.0187$$

$$\sigma_j^{\,3} = \sum_{j=1}^{8} \boldsymbol{f_j}^{3}(\boldsymbol{x_{ij}}) \times \omega_j = 0.1528 \qquad (10)$$

$$\sigma_j^{\,4} = \sum_{j=1}^{8} \boldsymbol{f_j}^{4}(\boldsymbol{x_{ij}}) \times \omega_j = 0.6533$$

$$\sigma_j^{\,5} = \sum_{j=1}^{8} \boldsymbol{f_j}^{5}(\boldsymbol{x_{ij}}) \times \omega_j = 0.9457$$

(6) Determine the evaluation glass

According to $\max_{1 \le k \le q} = \{\sigma_j^{\,k}\} = \sigma_j^{\,k^*}$, the evaluation level of the social benefit for this project belongs to “very good”[6].

4 Conclusions

In this paper, a comprehensive evaluation framework is proposed. The established index system reflects the social benefit from the natural environment, social environment, and social economy. Moreover, the comprehensive evaluation model is established based on AHP and GCDM model. At last, an empirical analysis of a project in city Z is presented, which show that the social benefits of this project is “very good”, in which the feasibility of this model is proved.

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