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A hybrid optimization model to assess the investment benefits of biomass power generation enterprises based on AHP-FCE algorithm

The biomass resources represented by crop straw is abundant in China, the biomass power generation has characteristics of good quality of power generated, high reliability and mature technology. It plays significant aspects in maintaining the safety of energy, optimizing energy structure, alleviating environmental pollution and promoting the economic development in the rural areas. Currently, the unit investment cost of biomass power generation is relatively high, which is equivalent to about twice of the same scale of traditional coal-fired power generation, and its economic benefit is poor. This article constructed the investment benefits evaluation model of biomass power generation enterprises based on analytic hierarchy process (AHP) and fuzzy comprehensive evaluation (FCE) from the three angles of economic benefits, environmental benefits and social benefits. The hybrid method can take full advantage of the characteristics of concise and practical, less quantitative data information needed and strong systemic, clear results. Combining of the two methods to evaluate the single evaluation object is one of the most appropriate strategies. The evaluation results showed that the membership degree of comprehensive investment benefits to more strong is 0.4861, the comprehensive benefits of biomass power generation enterprises in China are higher, and which has good development prospects.

Keywords: *Hybrid optimization model, biomass power generation enterprises, investment benefits, AHP-FCE algorithm*

1. Introduction

Nowadays, energy and environmental problems have become the focal point of common attention in the world. Also, they are crucial problems in the process of China's social and economic development. In 2009, China's total annual energy consumption reached about 30 billion tonnes of standard coal, surpassed the United States to become the world's largest energy consuming country. For a fairly long period of time, with the steady and rapid development of economy, energy consumption of China will maintain a rapid growth rate, whilst because the imbalance between supply and demand of energy exist for a long time, the energy shortages will also become increasingly prominent (Fig.1).

The major power generation method in China is still coal-fired power, which account for more than 70% of the total installed capacity. Expected in a short period of time, the thermal-electricity will be difficult to reverse (Fig.2). The large-scale development of thermal power plants produces a large number emission of SO_2, CO_2, NO_X and other greenhouse gases and particulate matters, which become a serious threat to the eco-environment and economic growth. To ensure energy security, optimize energy structure, reduce environment pollution, it is necessary to develop renewable energy such as biomass energy.

In recent years, domestic and foreign scholars have carried out some relevant research on biomass power generation from the aspects of raw material supply mode and economic cost and obtained some research results. Kumar et al. estimated the resource reserves in Canada with the research object of crops straw and forest residues, and proposed a tight link between the capability of capital costs and the transport costs of fuel [1]. Thorsell et al. utilized the intelligent programming to identify the types of machinery that met the minimization of costs, and then determined the purchasing costs, transport costs and storage costs of crops straw [2]. Caputo et al. proposed that the increase of purchasing cost and transport cost and decrease of vehicle carrying capacity would raise the operating costs and reduce the profits of biomass power plant [3]. Lu et al. and Wu et al. suggested that the compression of agricultural residues could reduce the transport costs and storage costs, thus led to lower operation costs of the biomass generation plant [4, 5]. The research of Delivand et al. and Suramaythangkoor et al. showed that transportation had a great influence on the supply of low density biomass power generation fuel and they made a systematically comparative cost analysis of different packaging in different areas [6, 7].

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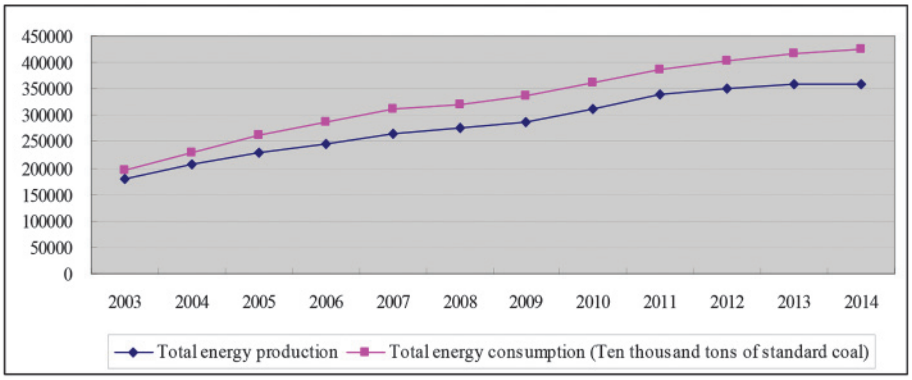

Fig.1 Production and consumption of energy in China from 2003 to 2014
Data sources: China statistical yearbook (2015)

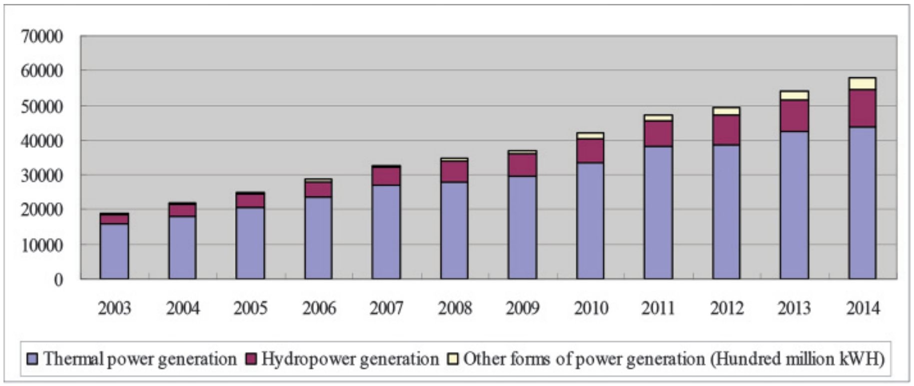

Fig.2 Total power generation and its composition in China from 2003 to 2014
Note: The other forms of power generation include the nuclear power, wind power, solar power and biomass power.
Data sources: China statistical yearbook (2015).

Wang et al. proposed a systematic analysis of gasification power generation, direct-fired power generation and co-combustion power generation and other biomass power generation, and established the biomass fuel consumption model and the fuel cost calculation model. Based on the same power generation capacity, the annual fuel consumption, fuel purchase costs and transport costs of these different power generation methods were calculated [8]. Liu et al. calculated the cost of biomass fuel collection, transportation and storage separately, and proposed 5 models of biomass fuel supply, furthermore, their costs were accounted [9]. Qi et al. analyzed the cost of biomass direct combustion power generation in different provinces of China with the method of optimizing generation cost. The results showed that the cost of direct-fired power generation in Northeast China and the central and eastern parts of China was moderate, and the potential for scaled and industrialized development was vast; at the same time, the maturity of the direct combustion power generation technology and the implementation of the carbon emission pricing policy could significantly improve the economy of biomass direct fired power generation [10]. From the perspectives of expenses origin, expenses payment and quota transactions, Yan et al. carried out a comprehensive comparison of the six biomass power generation subsidy programmes that had been implemented since 2006, and pointed out that the existing cost-sharing mechanism was not suitable for the development of biomass power generation industry [11]. Tan et al. analyzed the composition of straw collection cost with the cost model of straw fuel collection based on infinitesimal calculus method and the results showed that transportation cost was a key component of the cost of straw collection and a reasonable number of brokers were helpful to reduce the collection cost [12]. Zhao et al. calculated the maximum and minimum values of the power generation costs for different straw prices with the biomass power generation system as the research object and carried out a sensitivity analysis of power generation cost. The results showed that fluctuation in fuel costs had the greatest impact on the cost of biomass power generation, followed by depreciation and utility electricity [13].

Biomass power generation has the advantages of high reliability, good power quality and mature technology. Lots of researches have been done on the efficiency of the direct combustion power generation project in recent years. Using Monte Carlo simulation technology, Cai et al. analyzed the dynamic effects of government subsidies and straw costs on the economic benefits of biomass power generation projects, and this could provide guidance for the government to formulate relevant policies in the future [14-17]. Additionally, a principal component analysis was used in SPSS to eliminate the correlation between indicators, Li et al. constructed the index system of economic benefit evaluation of biomass power generation project, which could provide powerful data support for the benefit evaluation of biomass power generation projects [18].

In summary, the current domestic and foreign related research focused on the cost of biomass power generation benefits, comprehensive evaluation of biomass power generation, comprehensive investment benefit on the evaluation index system and evaluation methods are not depth enough. Based on this, this paper will construct an improved AHP-FCE model to evaluate the comprehensive investment benefits of biomass power generation enterprises from three aspects: economic, environmental and social benefits.

2. The investment benefits evaluation model based on AHP-FCE algorithm

Analytic hierarchy process (AHP) is a hierarchical weighted decision analysis method which breaks down the elements related to decision-making into objectives, principles, scheme, and then make the qualitative and quantitative analysis. Fuzzy comprehensive evaluation method is a kind of comprehensive evaluation based on the membership degree theory of fuzzy mathematics to translate qualitative evaluation into quantitative evaluation and evaluate the objects influenced by many overall factors. It is one of the most suitable strategies to combine the two methods to make a comprehensive evaluation for a single evaluation object. In this way, the two methods make full use of the characteristics, namely, concise, practical, systemic, clear and less quantitative data information needed.

2.1 Determination of index weight based on analytic hierarchy process

(1) Determine the overall objectives of the evaluation and establish a multi-level hierarchical model

On the basis of comprehensive analysis of the evaluation objects, we decomposed the factors that always affect the evaluation object and then established a hierarchical structure model of the system. The model generally includes the: target layer, criterion layer and programme layer, which is shown in Fig.3.

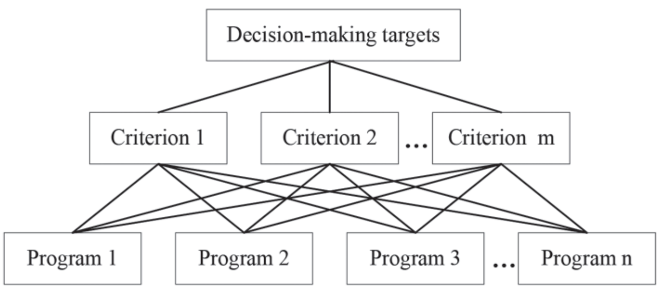

Fig.3 AHP hierarchical model

(2) Construction of the weight judgment matrix

According to the specific situation and evaluation experts' own experience, we make pairwise comparison between elements which affect the target layer and rule layer. Meanwhile, we use to 1-9 scaling methods to quantify the preliminary evaluation results (Table 1) and then establish the weight judgment matrix $A = (a_{ij})_{n\times n}$.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{21} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad ...(1)$$

(3) Calculate the corresponding weight of each index

Using the characteristic root method to calculate the corresponding weight of each index, and the concrete steps are as follows:

Table 1: Method of 1-9 scaling

Scale	Definitions
1	Two factors of the same importance
3	Experience to determine the former factor is slightly more important than the latter factor
5	Experience to determine the former factor is more important than the latter factor
7	Practice has proved that the former factor is more important than the latter factor
9	The former factor is much more important than the latter
2, 4, 6, 8	Adjacent two factors' importance compromise

First, normalize the matrix A:

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}, (i, j = 1,2,\cdots,n) \quad ...(2)$$

Secondly, add the normalized processing matrix by rows:

$$W_i = \sum_{j=1}^{i} b_{ij} \quad ...(3)$$

Again, normalize the sum vector to obtain the corresponding weight vector:

$$\overline{W_i} = \frac{W_i}{\sum_{i=1}^{n} W_i}, (i = 1,2,\cdots,n) \quad ...(4)$$

Finally, calculate the largest eigenvalue of the matrix:

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{\lfloor A\overline{W_i} \rfloor}{n(\overline{W_i})_i} \quad ...(5)$$

(4) The consistency of judgment matrix

Factitious factors in the process of index weight determination can lead to the inconsistency in the logical judgment, and the weight results need to carry on the consistency test.

The consistency ratio (*C.R.*) calculation formula is:

$$C.R. = \frac{C.I.}{R.I.} \quad ...(6)$$

In formula 6, *C.I.* is the consistency index, and *R.I.* is the average random consistency index (the specific values are shown in Table 2). The consistency indicator is calculated as:

$$C.I. = \frac{\lambda_{\max} - n}{n-1} \quad ...(7)$$

When C.R.<0.1, the judgment matrix passed the consistency test; when C.R.e > 0.1, the judgment matrix cannot pass the consistency test, and the judgment matrix needs to be modified or reconstructed.

(5) To calculate each elements' synthetic weight of the decision-making target, and make the final sequences

When the relative importance degree of all the elements in the same level to the decision-making target is determined, we carry on the sorting, calculate corresponding weights of the single factor, and then calculate the index weight from top to bottom in turn.

2.2 Construction of hierarchical fuzzy comprehensive evaluation model

Based on the analytic hierarchy process (AHP), we obtained the weights of each index in the evaluation index system, and then carried out hierarchical fuzzy comprehensive evaluation on the evaluation objects. Hierarchical fuzzy comprehensive evaluation includes six basic elements: factor set, comment set, relation matrix, factor weight vector, fuzzy operator and evaluation vector. The evaluation process needs to use the fuzzy mathematics method to determine the membership degree of each evaluation index to "good" or "bad", such as "excellent", "good", "medium", "may", "poor" and so on. Specific evaluation procedure is as follows:

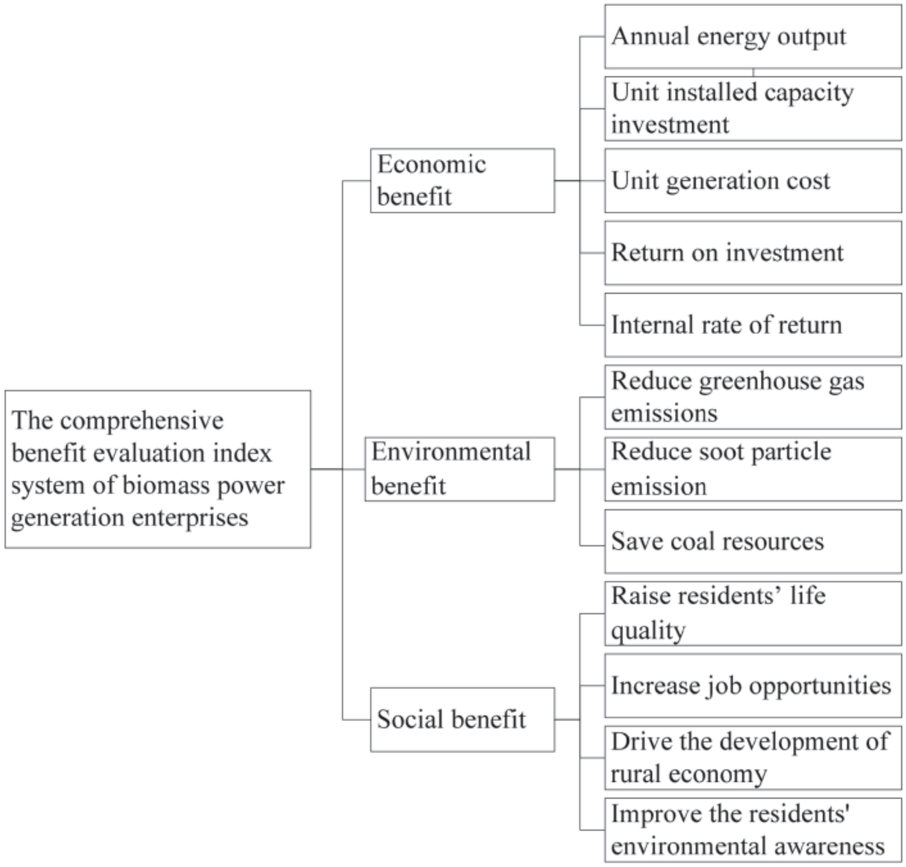

Fig.4 Comprehensive benefit evaluation index system of biomass power generation enterprises

(1) Determine the evaluation of the object sets of factors and reviews

Factor set: $X = \{x_1,...,xm\}$

Comment set $Y = \{y_1, y_2,...,yn\}$

The above-mentioned factor set X indicates that the evaluation object has m evaluation indexes, and the comment set Y has n comment levels, wherein $4<n<9$。

(2) Establish the factor weight vector W consisted of m evaluation factors

In order to reflect the importance of the factors on the decision-making target, the research assign a corresponding weights w_i ($i = 1, 2,...,m$) to each factor x. The weight set is the various weight of fuzzy set, namely, the weight vector W. Among them: $0<w_i<1$.

(3) Determine the membership degree of various factors, and establish the fuzzy relationship matrix

We can determine the membership degree of x_i to the comment set Y through fuzzy evaluation of a certain factor x_i in the factor set X and then get a comment set of x_i:

$$\gamma_i = (\gamma_{i1}, \gamma_{i2}, \cdots, \gamma_{im}) \quad \text{... (8)}$$

And then obtain the fuzzy relation matrix R:

$$R = \begin{bmatrix} \gamma_{11} & \gamma_{12} & \cdots & \gamma_{1n} \\ \gamma_{21} & \gamma_{21} & \cdots & \gamma_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \gamma_{m1} & \gamma_{m2} & \cdots & \gamma_{mn} \end{bmatrix} \quad \text{... (9)}$$

(4) Determine the final evaluation vector B

The weight vector W and the fuzzy relation matrix R are integrated to obtain the final evaluation vector:

$$B = W \cdot R = (w_1, w_{2,} \cdots, w_m) \cdot \begin{bmatrix} \gamma_{11} & \gamma_{12} & \cdots & \gamma_{1n} \\ \gamma_{21} & \gamma_{21} & \cdots & \gamma_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \gamma_{m1} & \gamma_{m2} & \cdots & \gamma_{mn} \end{bmatrix} = b_1, b_2,...,b_n \quad \text{... (10)}$$

3. The index system construction of investment benefits evaluation

In this paper, the comprehensive evaluation index system of biomass power generation enterprises based on fuzzy comprehensive evaluation is constructed according to the economic, environmental and social impacts of biomass power generation, as shown in Fig.4.

The comprehensive evaluation index system of biomass power generation enterprises includes three primary indicators and 12 secondary indicators. The specific

Table 2: Average random consistency index values

Judgment matrix dimension	1	2	3	4	5	6	7	8	9	10
Index values	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

description and explanation of the evaluation indicators are as follows:

(1) Economic benefit evaluation index

In theory, biomass power generation has good economic benefits. Taking 1×30 MW biomass direct-fired power generation project invested and constructed by Henan as an example, the total investment is 251.44 million Yuan and the annual generating capacity is 2.1×10^8 kWh with a tax-inclusive price 0.75 Yuan/kWh and excluding tariff electricity price 0.641 Yuan/kWh. The normal operating income excluding tax of the biomass power generation is 119.13 million Yuan, if the CDM income is not considered. The biomass power generation project can achieve a net profit of 410 million Yuan, if the project calculation period is 21 years (including the project construction period of 1 year). However, often faced with insufficient supply of fuel, low prices etc, the biomass power generation profit is meager or even makes loss. Specifically, it can be measured by five secondary indicators, namely, annual power generation capacity, unit installed capacity investment, unit power generation cost, investment yield rate and internal rate of return.

(2) Environmental benefit evaluation index

Compared to traditional fossil fuels such as coal, the sulfur content of biomass resources is very low, the average sulfur content of crops straw is only 0.38%, much lower than the average sulfur content of coal-fired power plants at 1% level. Thus, developing biomass power generation vigorously has significant environmental benefits, not only can effectively alleviate the crops straw burning caused by greenhouse gas and dust particles emissions, but also saves a lot of coal resources. Specifically, it can be measured by three secondary indicators, namely, reduce greenhouse gas emissions, reduce dust particles and save coal resources.

(3) Social benefit evaluation index

Most of the biomass power generations can achieve central heating, which is a cogeneration project. Taking 1×30 MW biomass direct fired power plant as an example, the annual power generation is about 160 million kWh and the annual heat supply is about 750,000 gigawatts. It can replace the small boilers with high energy consumption and serious pollution, meet the heating demand of 1 million square meters of local residents, and alleviate China's current energy shortage to a certain extent. In addition, one 1×30 MW biomass direct fired power plant, which annual crops straw consumption is about 250,000 tonnes, can bring direct income of 50 million Yuan for the local farmers, if the purchase price of crops straw is 200 Yuan/tonne. Also, for the local and surrounding counties of rural labour force, the acquisition, transportation and other sectors of crops straw can provide about 1000 employment positions. Specifically, it can be measured by four secondary indicators, namely, improve the life quality of residents, increase employment opportunities, promote rural economic development and improve the environmental awareness of residents.

Table 3: First index weight of comprehensive benefit evaluation of biomass power generation enterprises

Comprehensive benefit evaluation of biomass power generation	Economic benefit	Environmental benefit	Social benefit	Weight
Economic benefit	1	1/2	2	0.28
Environmental benefit	2	1	3	0.55
Social benefit	1/2	1/3	1	0.17

4. Evaluation results and analysis

4.1 Determine the index weights

According to 1-9 scaling method, we consulted about 20 professionals of biomass power generation enterprise operation, management and research, and determined the primary indicators' and secondary indicators' influence degree of the comprehensive benefits to the biomass power generation company respectively, namely, the index weight. And then we checked out the consistency of judgment matrix. The specific weight of the calculation results are showen in Tables 3 to 6.

(1) The primary index weight of the biomass power generation enterprise level of comprehensive benefit evaluation

By the calculation, the maximum characteristic root of the matrix is 3.0092, the consistency ratio is 0.0079 (<0.1), so the matrix goes through the consistency check.

(2) The secondary index weight of economic effect evaluation of the biomass power generation

By the calculation, the maximum characteristic root of the matrix is 5.0133, the consistency ratio is 0.0030 (<0.1), so the matrix goes through the consistency check.

(3) The secondary index weight of environmental benefit evaluation of the biomass power generation

The maximum characteristic root of the matrix is 3, and the consistency ratio is 0 (<0.1), so the matrix goes through the consistency check.

(4) The second index weight of social benefit evaluation of biomass power generation

The maximum characteristic root of the matrix is 4.0813, the consistency ratio is 0.0301 (<0.1), so the matrix goes through the consistency check.

Table 4: Second index weight of economic benefit evaluation of biomass power generation enterprises

Economic benefit evaluation	Annual energy output	Unit installed capacity investment	Unit generation cost	Return on investment	Internal rate of return	Weight
Annual energy output	1	2	2	3	3	0.36
Unit installed capacity investment	1/2	1	1	2	2	0.20
Unit generation cost	1/2	1	1	2	2	0.20
Economic benefit evaluation	1/3	1/2	1/2	1	1	0.12
Annual energy output	1/3	1/2	1/2	1	1	0.12

Table 5: Second index weight of environmental benefit evaluation of biomass power generation enterprises

Environmental benefit evaluation	Reduce greenhouse gas emissions	Reduce soot particle emissions	Save coal resources	Weight
Reduce greenhouse gas emissions	1	1	1/2	0.25
Reduce soot particle emiss	1	1	1/2	0.25
Save coal resources	2	2	1	0.50

Table 6: Second index weight of social benefit evaluation of biomass power generation enterprises

Social benefit evaluation	Raise residents' life quality	Increase job opportunities	Drive the development of rural economy	Improve the residents' environmental awareness	Weight
Raise residents' life quality	1	2	3	1	0.37
Increase job opportunities	1/2	1	1	1	0.20
Drive the development of rural economy	1/3	1	1	1/2	0.15
Improve the residents' environmental awareness	1	1	2	1	0.28

(5) The final weight of distribution

We can get the final weight of the second index when the weight of primary index (w_m) multiplied by the weight of the secondary index (w_{mn}). The final weight distribution is shown in Table 7.

4.2 The single factor fuzzy comprehensive evaluation

In order to evaluate the economic benefit, environmental benefit and social benefit of biomass power generation, we constructed the single factor fuzzy evaluation model of the secondary indexes based on the biomass power generation comprehensive benefit evaluation index system. In this paper, we determined the evaluation object set {excellent, good, medium, may, poor}, and invited 20 professionals who were versed in biomass power generations' operation, management and research to judge the subordination degree of the secondary indexes.

Table 7: Final weight of the second index

The primary indexes	The secondary indexes	The final weight
Economic benefit(0.28)	Annual energy output	0.1008
	Unit installed capacity investment	0.0560
	Unit generation cost	0.0560
	Return on investment	0.0336
	Internal rate of return	0.0336
Environmental benefit(0.55)	Reduce greenhouse gas emissions	0.1375
	Reduce soot particle emissions	0.1375
	Save coal resources	0.2750
Social benefit (0.17)	Raise residents' life quality	0.0629
	Increase job opportunities	0.0340
	Drive the development of rural economy	0.0255
	Improve the residents' environmental awareness	0.0476

TABLE 8: EXPERT VOTE RESULTS OF ECONOMIC BENEFIT EVALUATION OF BIOMASS POWER GENERATION ENTERPRISES

Economic benefit	Excellent	Good	Medium	May	Poor
Annual energy output	2	10	5	2	1
Unit installed capacity investment	5	10	4	1	0
Unit generation cost	3	8	5	2	2
Return on investment	6	8	4	2	0
Internal rate of return	5	8	6	1	0

TABLE 9: EXPERT VOTE RESULTS OF ENVIRONMENTAL BENEFIT EVALUATION OF BIOMASS POWER GENERATION ENTERPRISES

Environmental benefit	Excellent	Good	Medium	May	Poor
Reduce greenhouse gas emissions	6	10	3	1	0
Save coal resources	8	10	2	0	0
Reduce soot particle emissions	9	11	0	0	0

TABLE 10: EXPERT VOTE RESULTS OF SOCIAL BENEFIT EVALUATION OF BIOMASS POWER GENERATION ENTERPRISES

Social benefit	Excellent	Good	Medium	May	Poor
Raise residents' life quality	4	8	5	2	1
Increase job opportunities	5	9	4	2	0
Drive the development of rural economy	4	8	4	3	1
Improve the residents' environmental awareness	10	8	2	0	0

(1) The expert vote results of economic benefit evaluation of biomass power generation

We can get the relation matrix of the enterprise economic benefit factors:

The weight vector is: $w_1 = [0.36, 0.2, 0.2, 0.12, 0.12]$

According to the formula $\gamma_i = W_i . R_i$, we can get the subordination degree of economic factors on the evaluation set. From the point of the evaluation results, the enterprise economic benefit factor has the highest membership degree.

$r_1 = w_1 \cdot R_1 = [0.182, 0.456, 0.24, 0.0516, 0.038]$

(2) The experts' vote results of environmental benefit evaluation of biomass power generation

We can get the relation matrix of the enterprise environmental factors:

$$R_2 = \begin{bmatrix} 0.3 & 0.5 & 0.15 & 0.05 & 0 \\ 0.4 & 0.5 & 0.1 & 0 & 0 \\ 0.45 & 0.55 & 0 & 0 & 0 \end{bmatrix}$$

The weight vector is: $w_2 = [0.25, 0.25, 0.5]$

The subordination degree of environmental benefit factors on the evaluation set is:

$r_2 = w_2 \cdot R_2 = [0.4, 0.525, 0.0625, 0.0125, 0]$

(3) The experts' vote results of social benefit evaluation of biomass power generation

We can get the relation matrix of the enterprise social benefit factors:

$$R_3 = \begin{bmatrix} 0.2 & 0.4 & 0.25 & 0.1 & 0.05 \\ 0.25 & 0.45 & 0.2 & 0.1 & 0 \\ 0.2 & 0.4 & 0.2 & 0.15 & 0.01 \\ 0.5 & 0.4 & 0.1 & 0 & 0 \end{bmatrix}$$

The weight vector is: $w_3 = [0.37, 0.2, 0.15, 0.28]$

The subordination degree of social benefit factors on the evaluation set is:

$r_3 = w_3 \cdot R_3 = [0.29, 0.41, 0.19, 0.08, 0.02]$

4.3 THE FUZZY COMPREHENSIVE EVALUATION RESULTS

According to the results of the single factor fuzzy comprehensive evaluation, we get the subordination degree of economic benefit, social benefit and environmental benefit factors on the evaluation set respectively, and then build evaluation matrix of enterprise comprehensive benefit evaluation primary indexes based on three subordination degree.

The weight vector of the primary evaluation index is:

$w = [0.28, 0.55, 0.17]$

According to the formula $B = W \cdot R$, the final result of comprehensive benefit evaluation of biomass power generation is:

$B = w.R = [0.3203, 0.4861, 0.1339, 0.00349, 0.0184]$

From the point of the evaluation results, the comprehensive benefits evaluation of biomass power generation is 0.4861, when the subordination degree is good. It is 0.3203 when the subordination degree is excellent.

According to maximum subordination degree principle, comprehensive benefit evaluation results of biomass power generation enterprises is good.

5. Conclusions

The comprehensive investment benefits evaluation of biomass power generation enterprises is associated with many factors, it needs large numbers of statistical calculation, and the factitious factors can be mixed into easily, which make the competitiveness evaluation work is difficult. Analytic hierarchy process is a hierarchical weight decision analysis method which decomposes decision-related elements into objectives, criteria and schemes, and then analyses them qualitatively and quantitatively. Fuzzy comprehensive evaluation method is a comprehensive evaluation method based on fuzzy mathematics, which is based on membership degree theory of fuzzy mathematics to convert qualitative evaluation into quantitative evaluation, and evaluate the objects influenced by many factors. Based on AHP-FCE hybrid method, the comprehensive benefits of biomass power generation enterprises can be evaluated. And the two methods are simple and practical; the quantitative data information required is less. Therefore, it is the most suitable strategy to evaluate the objects comprehensively. The evaluation results show that the comprehensive benefit evaluation have a strong membership degree, namely 0.4861. There are strong comprehensive benefits and good development prospects of biomass power generation enterprises in China.

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7. References

[1] Kumar A., Cameron J.B. Flynn P.C.(2003): "Biomass Power Cost and Optimum Plant Size in Western Canada", *Biomass and Bioenergy*, (6), p445-464.

[2] Thorsell S., Epplin F.M., Huhnke R.L.(2004): "Economics of a Coordinated Biorefinery Feedstock Harvest System: Lignocellulosic Biomass Harvest Cost", *Biomass and Bioenergy*, (4), p327-337.

[3] Caputo A.C., Palumbo M., Pelagagge P.M., et al.(2005): "Economics of Biomass Energy Utilization in Combustion and Gasification Plants: Effects of Logistic Variables", *Biomass and Bioenergy,* (1), p35-51.

[4] Lu L. X., Zhou Y. H.(2007): "Following Foreign Experience to Impels Chinese Biology Development", *Ecological Economy*, (2), p437-439.

[5] Wu, J. Z., Ma L., Lin W. S.(2012): "Literature Review on Biomass Power Generation Technology and Economic Feasibility", *Forest Engineering*, Vol. 28 (5), p102-106

[6] Delivand, M. K., Barz, M., Gheewala, S. H.(2011): "Logistics Cost Analysis of Rice Straw for Biomass Power Generation in Thailand", *Energy,* (3), p1435-1441.

[7] Suramaythangkoor, T., Gheewala, S.H.(2008): "Potential of Practical Implementation of Rice Straw-Based Power Generation in Thailand", *Energy Policy*, (8), p3193-3197.

[8] Wang A. J., Zhang Y., Zhang X. T.(2011): "Fuel Cost Analysis of Biomass Power Generation", *Transactions of the CSAE*, Vol. 27 (1), p17-20.

[9] Liu H. C., Yin X. L., Wu C. Z (2011): "Cost Analysis of Crop Residue Supplies", *Transactions of the Chinese Society for Agricultural Machinery*, Vol. 42 (1), p106-112.

[10] Qi T. Y., Zhang X. L., Ou X. M.(2011): "The Regional Cost of Biomass Direct Combustion Power Generation in China and Development Potential Analysis", *Renewable Energy*, Vol. 29 (2), p115-118, 124

[11] Yan Q. Y., Li Z (2011): "An Analysis of Biomass Power Generation Cost-sharing Mechanism in China", *Economic Management*, Vol. 33 (2), p1-6.

[12] Tan Q. L., Yang H. P., Zhang X. P., et al.(2014): "Measurement Model and Empirical Analysis of Fuel Collection Cost for Biomass Power Generation", *Forum on Science and Technology in China,* (5), p117-123.

[13] Zhao H. L., Zhang X., Zhai M. L.(2015): "Analysis on Dynamic Cost of Straw Direct Combustion Power Generation", *Journal of Chinese Society of Power Engineering,* Vol. 35 (5), p412-417.

[14] Cai S. W.(2007): "Benefit Evaluation and Countermeasures Research of Biomass Power Generation", *Economic Review*, (1), p23-25.

[15] Liu Z. Q., Sun X. F.(2009): "25MW Biomass Direct Combustion Power Generation Project and Its Benefit Analysis Evaluation", *Applied Energy Technology,* (6), p32-34.

[16] Wei Y. J., Qin D. S., Chang Y. P. (2012): "30 MW Biomass Straight Burning Power Projects and Benefit Analysis Evaluation", *Energy Conservation Technology*, Vol. 30 (3), p278-281.

[17] Zhang S. L., Zheng M. L.(2013): "Economic Benefit Analysis and Policy Choice of Biomass Power Generation Project", *Journal of Hangzhou Dianzi University (Social Sciences),* Vol. 9 (1), p36-41.

[18] Li J. Y., Tian J. L., Zhang C. L.(2012): "Research on the Benefit Evaluation of Biomass Power Generation Projects Based on Principal Component Analysis", *Energy Technology and Economics,* Vol. 24 (2), p33-37.