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Fuzzy comprehensive evaluation of large and medium biogas project basing on AHP and entropy weight

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ABSTRACT

Due to all indicators of large and medium biogas project comprehensive evaluation have fuzziness and uncertainty,so it brings some difficulties to biogas project comprehensive evaluation, in order to perfect evaluation method of biogas project, utilize the method of combining AHP with entropy weight to calculate comprehensive weight, build a comprehensive evaluation index system, including four aspects altogether twenty-one evaluation indicators of economy, society, environment and technology, and build a large and medium biogas project fuzzy comprehensive evaluation model basing on AHP and entropy weight. Thus it realizes evaluation indicator and evaluation method' scientificity and also achieve convenient and practical purpose. Finally, take some large and medium biogas projects as examples and carry on comprehensive evaluation's empirical research, the evaluation result is objective and realistic.

KEYWORDS

Large and medium biogas project; AHP; Entropy weight; Index system; Fuzzy comprehensive evaluation.

INTRODUCTION

With a large number of construction of large and medium biogas projects, the comprehensive evaluation on them show especial importance. However, the evaluation on biogas project at home and abroad mostly focus on a single aspect, such as economy, finance, its environmental impact evaluation is mostly qualitative analysis and be short of a comprehensive evaluation of large and medium biogas project[1-6]. Due to the large and medium biogas project comprehensive evaluation index selection and index weight have fuzziness and uncertainty, thus it is a difficult point of the weight uncertainty on the evaluation[7-9]. This paper will apply AHP and the entropy value theory in information theory to the comprehensive evaluation of large and medium biogas project, using AHP to determine the subjective weight evaluation index, using entropy to calculate the objective weight, using the combination of subjective and objective weights method to determine the comprehensive weight to make the evaluation results more reasonable and credible.

LARGE AND MEDIUM BIOGAS PROJECT COMPREHENSIVE EVALUATION INDEX SYSTEM

This research takes the fermentation of poultry and animal feces as its main raw material. The produced biogas is mainly used for cooking, biogas slurry and residue mainly used for planting. Through looking up a lot of references and some comprehensive expert advice and refer to the evaluation index which predecessors have put forward, we have selected four aspects ranging from the economic, social, environmental and technical for a total of 21 indicators[10-18], please refer to the TABLE 1.

TABLE 1 : Large and medium biogas project comprehensive evaluation index system

Destination layer	Criterion layer	Index layer		
		Symbol	Index	Unit
Large and medium biogas project comprehensive evaluation (A)	Economy (B1)	C1	Increase revenue and reduce expenditure rate	%
		C2	Pay back period of investment	a
		C3	Biogas income	ten thousand yuan
		C4	Biogas slurry and residue income	ten thousand yuan
		C5	Biogas project cost	ten thousand yuan
		C6	State investment	ten thousand yuan
	Social (B2)	C7	Increase farmers' incomes	yuan/family
		C8	Clear energy supply rate	%
		C9	Fuel saving	t /a
		C10	Pesticides and fertilizers saving	t /a
	Environment (B3)	C11	Dust and emissions reduction	Kg
		C12	CO2 emission reduction	t
		C13	SO2 emission reduction	kg
		C14	Sewage discharge reduction	%
		C15	NOX emission reduction	Kg
		C16	Increase soil organic matter	t / ha
		C17	Protect forest resources	ha/a
	Technology (B4)	C18	Gas generation rate	%
		C19	Waste disposal rate	%
		C20	Escherichia coli removal rate	%
		C21	Parasite ova deposition rate	%

TO DETERMINE THE INDEX WEIGHTS

To determine the subjective weight by AHP

Hierarchical structure construction

Hierarchical structure generally formed by the target layer, criterion layer (index layer), project layer (solution layer).

Judgment matrix construction

As for the same level index, regard the higher level index as a criterion for comparing, thus to make a pairwise comparison to construct a pairwise comparative judgment matrix.

$$A = (a_{ij})_{n\times n} \quad (i, j = 1, 2, \cdots, n)$$

In this formula, a_{ij} represents the ratio of a relative importance on the higher evaluation target between index x_i and index x_j. $a_{ii} = 1$, $a_{ij} = 1/a_{ji}$, the value standard generally adopts one to nine and their reciprocal scaling [19].

Hierarchical single sorting and consistency check

Look for the largest eigenvalue $\lambda_{\max}$ of judgment matrix A and its corresponding and normalized feature vector W, that is each factor weight in this level. Here we use MATLAB software to look for the largest eigenvalue $\lambda_{\max}$ of judgment matrix A and its corresponding and normalized feature vector W, $W = (\omega_1, \omega_2, \cdots \omega_n)^T$.

Introduce the index CI that measure the deviation degree of consistency of judgement matrix,

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (n > 1)$$

When $CI = 0$, A is completely consistent matrix. The smaller the CI value is, the higher the degree of consistency of A will be ; The bigger the CI value is, the lower the degree of consistency of A will be. Saaty introduced average random consistency index RI as **TABLE 2** shows:

TABLE 2 : Average random consistency indicator RI

order	2	3	4	5	6	7	8	9
value	0.00	0.52	0.89	1.12	1.26	1.36	1.41	1.46

When the order is less than two, it naturally has consistency ; When the order is greater than two, we judge consistency by random consistency rate, which say it CR here.

$$CR = \frac{CI}{RI}$$

When $CR < 0.1$, we consider that the consistency of judgment matrix is satisfied, whereas we consider it didn't through and we need to adjust the judgment matrix until consistency check through.

Hierarchy total sorts and consistency check

We suppose that we have looked for the synthetic weight vector of n_{k-1} element in $k-1$ layer to the total target layer is $W^{(k-1)} = (\omega_1^{(k-1)}, \omega_2^{(k-1)}, \cdots \omega_{n_{k-1}}^{(k-1)})^T$.

The vector ordered in single level under the criterion of the n_k element in k layer to the j element in $k-1$ layer is $Y_j^{(k)} = (Y_{1j}^{(k)}, Y_{2j}^{(k)}, \cdots Y_{n_k j}^{(k)})^T$.

In the formula, take zero as the uncontrolled element weight by element j as follow:

$$Y^{(k)} = (Y_1^{(k)}, Y_2^{(k)}, \cdots Y_{n_{k-1}}^{(k)})^T$$

Therefore $Y^{(k)}$ is the $n_k \times n_{k-1}$ order matrix, it represents the synthetic order of the n_k element in k layer to each element in $k-1$ layer, thus the total order of elements to the goal in k layer, that is the weight coefficient in this layer

$$W^{(k)} = (W_1^{(k)}, W_2^{(k)}, \cdots W_{n_{k-1}}^{(k)})^T = Y^{(k)} W^{(k-1)},$$

That is $$\omega_i^{(k)} = \sum_{j=1}^{n_{k-1}} y_{ij}^{(k)} \omega_j^{(k-1)}, \ (i = 1, 2, \cdots, n_k).$$

Take another step and so on: $W^{(k)} = Y^{(k)} W^{(k-1)} = \cdots = Y^{(k)} Y^{(k-1)} \cdots Y^{(3)} W^{(2)}$.

if the consistency index ordered in single level is CI, the corresponding average random consistency index is RI, thus the hierarchy total sorts random consistency rate is $CR = \dfrac{\sum_{j=1}^{n} \omega_j cI_j}{\sum_{j=1}^{n} \omega_j RI_j}$.

When $CR < 0.1$, we consider that the consistency of hierarchy total sorts is satisfied, whereas we consider it didn't through and we need to adjust the judgment matrix value until consistency check through.

Entropy weight method to determine the index objective weights

(1) To set up judgment matrix X that has m evaluation indexes, n evaluation objects

$$X = (x_{ij})_{m \times n} \quad (i = 1, 2, \cdots, m; \ j = 1, 2, \cdots, n)$$

(2) To make judgment matrix X normalization processing to get matrix B, as for benefit index, the element B is:

$$b_{ij} = \frac{x_{ij} - \min\limits_{1 \le j \le n} \{x_{ij}\}}{\max\limits_{1 \le j \le n} \{x_{ij}\} - \min\limits_{1 \le j \le n} \{x_{ij}\}}$$

As for cost index, the element B is:

$$b_{ij} = \frac{\max\limits_{1 \le j \le n} \{x_{ij}\} - x_{ij}}{\max\limits_{1 \le j \le n} \{x_{ij}\} - \min\limits_{1 \le j \le n} \{x_{ij}\}}$$

(3) According to the definition of information entropy, the i index entropy is:

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

In this formula, $f_{ij} = (1+b_{ij}) / \sum_{j=1}^{n}(1+b_{ij})$, $k = 1/\ln(n)$.

(4) Utilize entropy to calculate the index entropy weight

$$\omega_i^* = \frac{1 - H_i}{m - \sum_{i=1}^{m} H_i}$$

In this formula, ω_i^* is the objective weight of index m, meet $\sum_{i=1}^{m} \omega_i^* = 1$ condition. Therefore the weight of evaluation indexes of m is $W^* = (\omega_i^*)_{1\times m}$.

Calculate comprehensive weights

Calculate the subjective weight and objective weight as the follow formula to get each index comprehensive weight.

$$\omega_i = \frac{\omega_i^* \omega_i'}{\sum_{i=1}^{m} \omega_i^* \omega_i'}$$

$$W = (\omega_i)_{1\times m}$$

In this formula, ω_i' is the subjective weight of index i, ensured by AHP method; ω_i^* is the objective weight of index i, ensured by entropy weight method.

FUZZY COMPREHENSIVE EVALUATION MODEL

Fuzzy comprehensive evaluation steps

(1) Set up factor aggregation $U = \{u_1, u_2, \cdots, u_n\}$。

(2) Set up evaluation aggregation $V = \{v_1, v_2, \cdots, v_m\}$。

(3) Evaluation of single factor.

$$\underset{\sim}{f}: U \to J(V)$$

$$u_i \to \underset{\sim}{f}(u_i) = (r_{i1}, r_{i2}, \cdots, r_{im}) \in J(V)$$

Fuzzy relation $\underset{\sim}{R}_f \in J(U \times V)$, that is

$$\underset{\sim}{R}_f(u_i)(v_j) = \underset{\sim}{f}(u_i)(v_j) = r_{ij}$$

$$R=\begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{pmatrix}$$

In the formula, r_{ij} represents the relative membership degree of the i element u_i in the factor aggregation U corresponding to the j element in the v_j layer.

(4) Fuzzy comprehensive evaluation

According to the weight $W=(\omega_1,\omega_2,\cdots,\omega_n)$, we can get the comprehensive evaluation: $B=W*R$ In the formula, comprehensive weight $W=(\omega_1,\omega_2,\cdots,\omega_n)$, meet $\sum_{i=1}^{n}\omega_i=1$ condition, ensured by AHP and entropy weight methods; "$*$"is the weighted average fuzzy arithmetic operator, that is $M(\bullet,+)$ operator; $B=(b_1,b_2,\cdots,b_n)$ is comprehensive evaluation result, b_j, $j=1,2,\cdots,n$ is the degree of membership of j judgment. According to the maximum membership principle, choose $\max_{1\le j\le n}\{b_j\}$ corresponding judgment as the final evaluation decision result [20].

To ensure the relative membership degree

The standard values of corresponding indicators of evaluation aggregation $V=\{v_1,v_2,\cdots,v_m\}$ are $(a_1,a_2,\cdots,a_m)$.

As for benefit index, membership function is [21]:

$$\mu_{v_1}(x)=\begin{cases} 1, & x\le a_1 \\ \dfrac{a_2-x}{a_2-a_1}, & x\in[a_1,a_2] \\ 0, & \text{others} \end{cases}$$

$$\mu_{v_i}(x)=\begin{cases} \dfrac{x-a_{i-1}}{a_i-a_{i-1}}, & x\in[a_{i-1},a_i] \\ \dfrac{a_{i+1}-x}{a_{i+1}-a_i}, & x\in[a_i,a_{i+1}] \\ 0, & \text{others} \end{cases} \quad (i=2,\cdots,m-1) \qquad \mu_{v_m}(x)=\begin{cases} 1, & x\ge a_m \\ \dfrac{x-a_m}{a_m-a_{m-1}}, & x\in[a_{m-1},a_m] \\ 0, & \text{others} \end{cases}$$

However as for cost index, membership function is :

$$\mu_{v_1}(x)=\begin{cases} 1, & x\ge a_1 \\ \dfrac{x-a_1}{a_1-a_2}, & x\in[a_2,a_1] \\ 0, & \text{others} \end{cases}$$

$$\mu_{v_i}(x)=\begin{cases} \dfrac{x-a_{i+1}}{a_i-a_{i+1}}, & x\in[a_{i+1},a_i] \\ \dfrac{a_{i-1}-x}{a_{i-1}-a_i}, & x\in[a_i,a_{i-1}] \\ 0, & \text{others} \end{cases} \quad (i=2,\cdots,m-1) \qquad \mu_{v_m}(x)=\begin{cases} 1, & x\le a_m \\ \dfrac{a_{m-1}-x}{a_{m-1}-a_m}, & x\in[a_m,a_{m-1}] \\ 0, & \text{others} \end{cases}$$

FUZZY COMPREHENSIVE EVALUATION OF LARGE AND MEDIUM BIOGAS PROJECT

Now take some large and medium biogas projects as examples and carry on comprehensive evaluation's empirical research basing on AHP and entropy weight.

The subjective weight that AHP determines the evaluation index

TABLE 3 : A-B judgment matrix

A-B	B1	B2	B3	B4	Weight WB
B1	1	1/2	1/3	2	0.1638
B2	2	1	1	3	0.3375
B3	3	1	1	4	0.4013
B4	1/2	1/3	1/4	1	0.0974

CR=0.0116<0.1, meet the consistency condition.

The same procedure may be easily adapted to the index weights of other layers. In the formula B1-C, CR=0.0000<0.1; B2-C, CR=0.0226<0.1, B3-C, CR=0.0066<0.1, B4-C, CR=0.0093<0.1, all of them meet the consistency condition.

TABLE 4 : Total of administrative levels

	B1	B2	B3	B4	Total weight ω_i'
	0.1638	**0.3375**	**0.4013**	**0.0974**	
C1	0.1000				0.0164
C2	0.1000				0.0164
C3	0.3000				0.0491
C4	0.3000				0.0491
C5	0.1000				0.0164
C6	0.1000				0.0164
C7		0.2053			0.1165
C8		0.2441			0.0824
C9		0.3453			0.0693
C10		0.2053			0.0693
C11			0.2275		0.0788
C12			0.2226		0.0913
C13			0.1334		0.0893
C14			0.1964		0.0535
C15			0.1160		0.0465
C16			0.0683		0.0274
C17			0.0357		0.0143
C18				0.0894	0.0477
C19				0.2316	0.0226
C20				0.1891	0.0184
C21				0.1898	0.0087

CR=0.0098<0.1, meet the consistency condition.

The objective weight that entropy-right method determines the evaluation index

Original data matrix as TABLE 5 follows:

TABLE 5 : Data matrix

Index	Data				
C1	4.59	6.87	10.35	35.3	48.56
C2	8	6.8	7.9	16	10.7
C3	14.3	20.65	37.03	24.64	76.8
C4	13.5	19.23	71.25	50.4	83.2
C5	138.01	218	435.26	188.41	1012
C6	67	98	174	95	506
C7	1200	1500	938	1000	1300
C8	32.8	40.1	36.4	38	39.2
C9	205	365	560	360	780
C10	2.44	4.55	11	25.8	45
C11	6.4	7.6	8.1	6.9	10.2
C12	384	214	137.16	267	580
C13	11.01	19.28	23.13	14.83	34.12
C14	47	30	35	40	45
C15	5.88	10.72	15.82	8.93	24.3
C16	5.1	3.9	4.5	4.06	6.02
C17	138.95	147.09	118.86	58.60	106.67
C18	39	41	29	56	71
C19	82	86	78	100	95
C20	98	99	93	100	100
C21	95	98	96	100	99

From the formula calculation, we can get each index entropy H, and further get each index objective weight W^*

$$W^* = (0.0694, 0.0033, 0.0470, 0.0298, 0.0230,$$
$$0.0572, 0.0637, 0.0354, 0.0326, 0.0603, 0.0413,$$
$$0.0739, 0.0371, 0.0499, 0.0370, 0.0537, 0.0100,$$
$$0.0744, 0.0696, 0.0776, 0.0540)$$

Ensure the comprehensive weight according to the formula

$$\omega_i = \frac{\omega_i^* \omega_i'}{\sum_{i=1}^{m} \omega_i^* \omega_i'},$$

We can get each judgment index comprehensive weight W,

$$W = (0.0230, 0.0011, 0.0467, 0.0296, 0.0076,$$
$$0.0190, 0.1502, 0.0590, 0.0458, 0.0846, 0.0658,$$
$$0.1367, 0.0671, 0.0540, 0.0348, 0.0298, 0.0029,$$
$$0.0719, 0.0318, 0.0289, 0.0095)$$

Fuzzy comprehensive evaluation model

factor aggregation $U = \{C_1, C_2, ..., C_{21}\}$, evaluation aggregation $V = \{v_1.v_2, ..., v_5\}$, $v_1, v_2, ..., v_5$ are respectively bad、poor、general、good、excellent five grades.

According to the above formula calculation of each index membership degree, set up single factor fuzzy evaluation matrix R, then on the basis of the formula $B = W * R$, we can get fuzzy comprehensive evaluation decision result as follow:

$$B = W * R = (0.0100, 0.0581, 0.0233, 0.4603, 0.3175)$$

By the principle of maximum membership, the maximum membership degree of"good"is 0.4603, thus this biogas project finally get an evaluation of "good".

CONCLUSION

The establishment contains four aspects and 21 indicators of large and medium biogas project comprehensive evaluation decision index system. The 21 indicators are basically cover all the effective information about comprehensive evaluation for large and medium biogas project, so use higher dimensional array to depict comprehensive evaluation information for large and medium biogas project is feasible. It also provides the empirical basis for the artificial intelligence method in comprehensive evaluation of the large and medium biogas project application.

Having established fuzzy comprehensive evaluation decision model for large and medium biogas project basing on AHP and entropy weight, it enriched and improved the large and medium biogas project comprehensive evaluation method, and the whole process of judging is clear and simple calculation. At the same time, it overcame the defect of using AHP to determine the index weight alone. AHP is based on expert knowledge and experiences and it quantifies the qualitative indexes, but only by expert knowledge and experiences has more subjectivity and not based on the actual data analysis. This can have a direct impact on the facts, the accuracy of the evaluation results and quantitative accuracy. The combination of AHP and entropy in information theory, determine the comprehensive weights and just to make up for the defects. Regard each index as the objective weight making full use of the data information to achieve the good combination of the objectivity of the data information and the subjectivity of expert opinion. Solve the the problems of big subjectivity and the result is not accurate in the comprehensive evaluation, thus make the results be more reasonable and reliable.

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