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Economic Development of Biomass Energy Industry in Heilongjiang Province Based on Analytic Hierarchy Process

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ABSTRACT

In order to study the comprehensive evaluation index system of biomass energy industry economy in Heilongjiang Province, a hierarchical analysis is made from four aspects: society and technology, energy supply and demand, economy and environment. By analytic hierarchy process (AHP) and expert scoring method, various comprehensive evaluation values affecting the economy of biomass energy industry are calculated. The results show that in the economic development of biomass energy industry in Heilongjiang Province, biomass biogas industry > biomass power generation industry > biomass briquette fuel industry > biomass gasification industry > biomass liquid fuel industry. Finally, in view of the actual situation of Heilongjiang Province, relevant suggestions are proposed for the economic development of biomass energy industry.

INTRODUCTION

The construction of ecological civilization at the 18th National Congress, the blue sky in Beijing during APEC meeting in 2014, the tax levied by Germany on disposable beverage bottles in order to improve the reuse rate of beverage bottles, the "junk bank" in Bangkok, chewing gum for special days in Singapore, and the Brazilian Institute of Environmental Arbitration, almost all over the world, are calling for the protection of natural resources and the sustainable development (Nakomcicsmaragdakis et al. 2016, Edgar et al. 2018, Mohammed 2018). Everyone thinks of biomass energy as an alternative to traditional energy.

Biomass energy is the most widely used renewable energy at present. Its total consumption is second only to coal, oil and natural gas, and it plays an important role in the future sustainable energy system. Biomass energy refers to the energy stored in biomass, which directly or indirectly transforms solar energy into chemical energy through photosynthesis of green plants, and then fixes and stores it in organisms. In addition to direct combustion to release energy for human use, it can also be converted into conventional solid, liquid and gaseous fuels under certain technical conditions. At present, the development and utilization of biomass energy mainly includes five schemes: biomass power generation, biomass solidified briquette fuel, biomass biogas, biomass gasification, and biomass liquid fuel (Zheng et al. 2016, Salem et al. 2017, Abdul Rahman et al. 2018, Md Reaz 2019).

As a new energy source, biomass has attracted intense attention from governments and experts and scholars all over the world for a long time. Many countries have issued a large number of laws and regulations, and formulated medium-term and long-term development plans, and China has been committed to the relevant research of biomass energy. It is expected that if this energy is used in the future, at least 200 million tons of liquid fuel can be supplied, and it can effectively alleviate the energy pressure caused by the rapid economic development (Nishiguchi et al. 2016, Khan 2018, Muhammad et al. 2018, Rohana et al. 2018, Rodeano et al. 2018). Taking the main cities of Heilongjiang Province as the research scope, the reserves of biomass energy in Heilongjiang Province are estimated, and the energy gap of economic development is predicted to find the direction of energy development in Heilongjiang Province. The problems existing in the development of biomass energy are discussed, and finally corresponding countermeasures and suggestions are provided for the development of biomass energy industry in Heilongjiang Province.

EARLIER STUDIES

Jerson pointed out in his article entitled Feasibility of Biomass Energy Promotion in Costa Rica that sustained financial support would bring a lot of attention to biomass energy in the short term. Taking Srikata, a small district minister in southern Italy, as the research object, it is feasible to consider biomass energy as the energy supply of Srikata, and the feasibility plan of promoting biomass energy to the global scope is discussed (Motghare et al. 2016, Ghanshyam et al. 2019, Yanan et al. 2018). The world is facing serious energy crisis

and environmental problems. Under the urgent situation, people turn their attention to biomass energy, a recognized renewable energy (Mekonnen et al. 2017, Sajid et al. 2018, Nurul Syahidah et al. 2018). The advantages and disadvantages of biomass energy, as well as the challenges faced by biomass gasification utilization, were also comprehensively analysed, and the technical difficulties of biomass energy experimental research were explored.

After analysing the current situation of international biomass energy development, the targets of biomass power generation, biomass briquette fuel and biogas in China from 2015 to 2020, the difficulties of raw material transportation and low energy density need to be overcome in developing biomass energy. Starting from four kinds of biomass: herbaceous biomass, woody biomass, microalgae and lipids, various methods of liquid fuel synthesis and discussed in detail the influence of parameters in various research methods (Tziolas et al. 2016, Zaleha et al. 2018, Nwankwo et al. 2018, Xiao et al. 2018). It was concluded that most of the liquid fuel preparation technologies were still in the stage of research and development, and only the oil-vinegar exchange and fermentation alcohols had reached the stage of commercialization and large-scale development and biomass forming machine can be vigorously promoted and developed. The HPB-resistance hydraulic drive two-way extrusion dry Xuan forming machine developed by Henan Agricultural University had been put into the market very well. There is still a long way to go to be in line with the international standards.

MATERIALS AND METHODS

Comprehensive evaluation index system for economic development of biomass energy industry: According to the actual development of Heilongjiang Province, the comprehensive evaluation index system is put forward from the aspects of technology maturity, social acceptance, energy demand, supply stability, economic feasibility and environment. Table 1 is the comprehensive evaluation index system of biomass energy development plan in Heilongjiang Province. The system is mainly divided into four aspects: technology, energy supply and demand, social economy and environment.

Basic process of analytic hierarchy process (AHP): AHP was founded in 1970s by American operations researcher and Professor Sadie of the University of Pittsburgh. It decomposes the complex problem into each component factor, and then divides these factors into hierarchical structures according to the dominant relationship and determines the relative importance of each factor in the hierarchy by comparing them in two ways. It also synthesizes the decision maker's judgment, determines the total ranking of the relative importance of the decision-making scheme, and finally obtains the optimal sequence of each factor relative to the decision-making goal. It is a combination of qualitative and quantitative method to express and deal with human subjective judgment in quantitative form, which greatly improves the effectiveness, reliability and feasibility of decision-making.

Construction and selection of index system: The development of biomass energy in Heilongjiang Province is mainly considered from three aspects: feasibility, macro environment and benefit. Among them, the feasibility factors include four sub-factors, i.e. resource inspection, social demand, technological level and management. The macro-environmental

Table 1: Evaluation index system for economic development of biomass energy industry.

Criterion level	Index level
Technology B_1	Maturity of technology C_1
	Integration of technology with local society C_2
	Acceptance of local residents C_3
Energy supply and consumption B_2	Abundance of local resources C_4
	Stability of resource supply C_5
	Demand for energy generation C_6
	Generating stability in energy supply C_7
	Convenience of production energy use C_8
Economy B_3	Unit cost of energy supply C_9
	Acceptability of total investment C_{10}
Environment B_4	Carbon dioxide emission reduction rate C_{11}
	Degree of impact on water resources C_{12}
	Influence on cultivated land C_{13}

factors include three sub-factors: supporting service system, financial and taxation support, laws and policies support. The benefit factors are composed of three sub-factors: economic benefit, social benefit, and ecological benefit. These ten factors ultimately reflect the goal of biomass energy development project in Heilongjiang Province. Four projects of rural biogas, biodiesel, fuel ethanol and straw solidified gasification power generation are mainly selected for analysis. The main reason for choosing these four items as the main analysis objects is that the utilization of biomass energy in China is mainly concentrated in biogas utilization, biomass fuel utilization, straw utilization, biomass gasification, biomass power generation, biomass solidification and shaping. The indicator system is shown in Fig. 1.

Construct two-to-two comparison judgment matrix: Each element establishes the same level between any two elements for a certain element at the upper level and compares two factors among all factors. According to the importance of the factors, experts in the field of biomass energy development are invited to construct the judgment matrix according to the scale meaning in Table 2 by using the expert consultation method. The judgment values of the judgment matrices of the biomass energy development schemes are shown in Tables 3 to 7.

Calculate the weight vector and eigenvalue: For a given judgment matrix, determine the weight vector $w = (w_1, w_2, \cdots, w_n)^T$ and the maximum eigenvalue λ_{max}

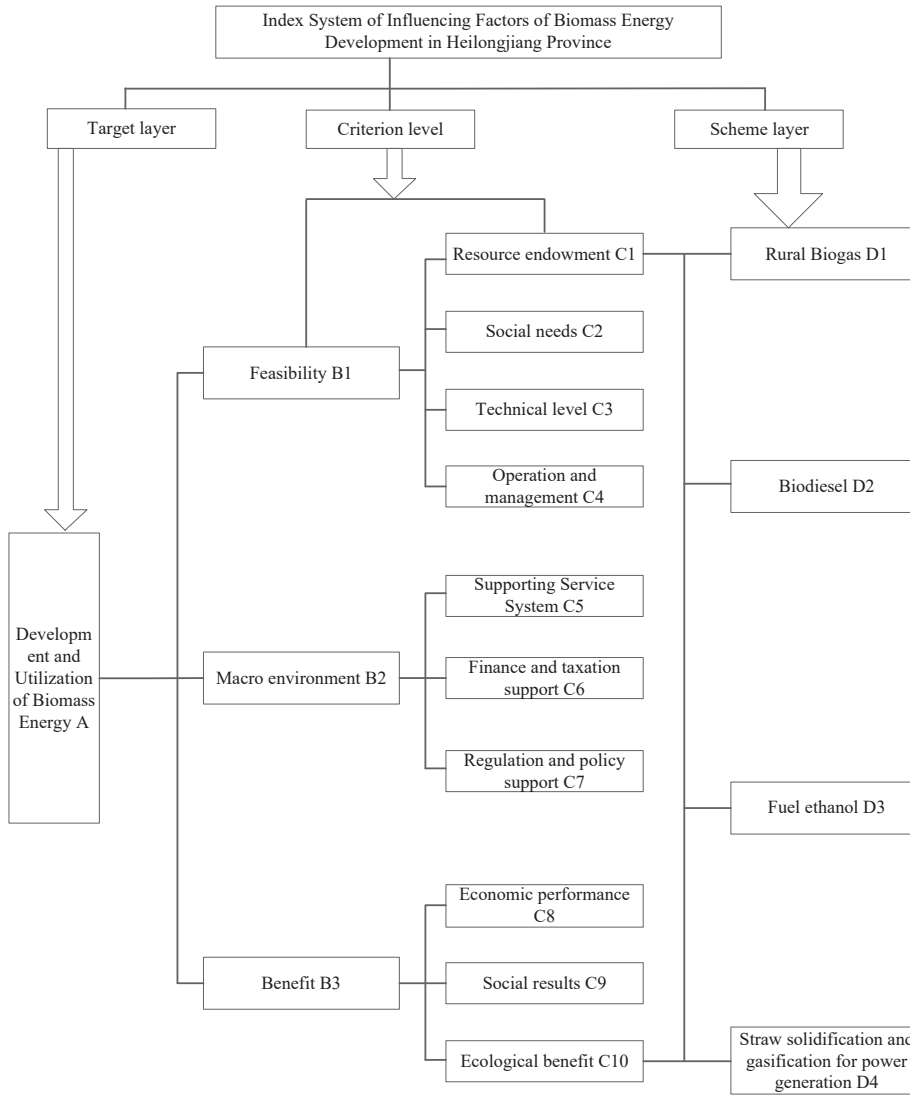

Fig. 1: Framework of biomass energy development and utilization index system.

The calculation formulas are as follows:

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

$$\lambda_{\max} = \frac{1}{n}\sum_{j=1}^{n}\frac{\sum_{j=1}^{n}a_{ij}w_j}{w_i} \quad \ldots(2)$$

Consistency test: The consistency index of judgment matrix is CI, the random consistency index is RI (the value of RI is shown in Table 8), and the consistency ratio is CR.

$$CI = \frac{\lambda_{\max} - m}{n-1}(n>1) \quad \ldots(3)$$

$$CR = \frac{CI}{RI} \quad \ldots(4)$$

When CR＜0.1, it is considered that the consistency requirement is satisfied. The weight vectors and consistency ratios of each judgment matrix are shown in Table 9.

RESULTS AND DISCUSSION

Through the analysis of the above steps, the weight results of the lower layer relative to the upper layer are calculated, and the comprehensive weights of the index layer relative to the target layer (C layer versus A layer) are obtained. The weights of each layer and comprehensive weights are shown in Table 10.

According to the comprehensive weight values of the indicators obtained by AHP in Table 10 and the scoring results of expert schemes, the comprehensive evaluation values of biomass energy for economic development from various aspects are obtained by weighted summation method.

For a specific project, the form of consultation sheet is used, and the five-point system is used to evaluate the factors. Consultants are mainly experts in the field of biomass energy research. A total of 15 consultation tables are issued and 15 are recovered. The results of statistical scoring for each scheme are shown in Table 11.

From the comprehensive evaluation value in Table 11, it can be concluded that biomass biogas industry > biomass power generation industry > biomass briquette fuel industry > biomass gasification industry > biomass liquid fuel industry.

According to the above multi-level index construction, judgment and weight analysis, the time series of biomass energy development in Heilongjiang Province is rural biogas,

Table 2: The meaning of number (1-9) scale.

Importance scale	Meaning
1	Two elements are equivalently important.
3	The former is slightly more important than the latter.
5	The former is obviously more important than the latter.
7	The former is strongly more important than the latter.
9	The former is extremely more important than the latter.
2,4,6,8	The median value of the above judgment.
Reciprocal	If the importance ratio of element i to element j is a_{ij}, then the importance ratio of element j to element i is $a_{ji} = 1 / a_{ij}$.

Table 3: Binary judgment A.

A	B_1	B_2	B_3	B_4
B_1	1	4	3	4
B_2	1/4	1	4	2
B_3	1/3	¼	1	1
B_4	1/4	½	1	1

Table 4: Binary judgment B_1.

B_1	C_1	C_2	C_3
C_1	1	1/2	1/4
C_2	2	1	1/3
C_3	4	3	1

Table 5: Binary judgment B_2.

B_2	C_4	C_5	C_6	C_7	C_8
C_4	1	3	2	3	3
C_5	1/3	1	2	1	2
C_6	1/2	1/2	1	1/2	1/3
C_7	1/3	1	2	1	1
C_8	1/3	1/2	3	1	1

Table 6: Binary judgment B_3.

B_3	C_9	C_1
C_9	1	4
C_{10}	¼	1

Table 7: Binary judgment B_4.

B_4	C_{11}	C_{12}	C_{13}
C_{11}	1	5	4
C_{12}	1/5	1	1/2
C_{13}	1/4	2	1

straw solidified gasification power generation, biodiesel, and fuel ethanol. That is to say, according to the scores of many experts, a time sequence of the development of biomass energy in Heilongjiang Province, or a priority development plan can be obtained. Relatively speaking, rural biogas is the most important and should be given priority to development. At present, the development and utilization of biogas biomass energy in rural areas in Heilongjiang Province is much larger than that of other types of biomass energy. From the reality of biomass energy development in Heilongjiang Province, biogas has the longest history in Heilongjiang Province, technology has matured, and management, capital, policy and other supporting measures are more systematic. At present, China is actively building a new socialist countryside. As an important rural energy, biogas has solved most of the rural energy demand, and its environment-friendly characteristics also make the countryside look greatly changed. Biogas is the urgent need for rural development in Heilongjiang Province. Therefore, from the analysis results, the development and utilization of biogas projects ranked first in line with the actual development needs.

The development of fuel ethanol in Heilongjiang Province is relatively slow. The main reason is the shortage of raw materials. In order to ensure national food security, the development of fuel ethanol can only consider non-food crops as raw materials. At present, corn, sorghum, wheat

Table 8: Value table of RI.

n	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.52	0.89	1.12	1.26	1.36	1.41	1.46

Table 9: Weight vectors and consistency ratio values of judgment matrix.

Judgement matrix	Weight vector W	Consistency ratio
A	$[0.5134, 0.2401, 0.1085, 0.1200]^T$	0.0924
B_1	$[0.1365, 0.2385, 0.6250]^T$	0.0176
B_2	$[0.3964, 0.1891, 0.0945, 0.1646, 0.1554]^T$	0.0758
B_3	$[0.8000, 0.2000]^T$	0.000
B_4	$[0.6833, 0.1168, 0.1998]^T$	0.0236

Table 10: Comprehensive weight value of indicators.

A	B_1	B_2	B_3	B_4	C
	0.5314	0.2401	0.1085	0.1200	
C_1	0.1365	-	-	-	0.0725
C_2	0.2385	-	-	-	0.1267
C_3	0.6250	-	-	-	0.3321
C_4	-	0.3964	-	-	0.0952
C_5	-	0.1891	-	-	0.0454
C_6	-	0.0945	-	-	0.0227
C_7	-	0.1646	-	-	0.0395
C_8	-	0.1554	-	-	0.0373
C_9	-	-	0.800	-	0.0868
C_{10}	-	-	0.200	-	0.0217
C_{11}	-	-	-	0.6833	0.0820
C_{12}	-	-	-	0.1168	0.0140
C_{13}	-	-	-	0.1998	0.0240

Table 11: Industrial economic evaluation table.

Evaluation content	Electricity generation	Briquette fuel	Methane	Gasification	Biological liquid fuels
Maturity of technology C_1	3	3	4	2	2
Integration of technology with local society C_2	3	3	5	3	2
Acceptance of local residents C_3	3	3	4	3	2
Abundance of local resources C_4	3	4	5	4	3
Stability of resource supply C_5	2	3	4	2	2
Demand for energy generation C_6	3	3	4	2	3
Generating stability in energy supply C_7	4	3	4	2	3
Convenience of energy production C_8	3	2	4	2	4
Unit cost of energy supply C_9	2	2	5	2	3
Acceptability of total investment C_{10}	3	4	5	3	2
Carbon dioxide emission reduction rate C_{11}	5	1	3	3	3
Impact on water resources C_{12}	3	2	1	2	2
Influence on cultivated land C_{13}	3	2	2	3	4
Comprehensive evaluation value	3.07	2.79	4.16	2.78	2.45

and other food crops are the main raw materials for fuel ethanol production abroad, which is unrealistic for the short of land resources for China. Therefore, facing the problems of selecting reasonable raw materials and further improving fuel ethanol technology, it is more reasonable to list fuel ethanol development in the long-term plan of biomass energy development in Heilongjiang Province.

CONCLUSIONS

Firstly, the research background of the subject and the related research results at home and abroad are described, and the basic process of AHP is explained, including the construction and selection of index system, the construction of judgment matrix and expert scoring. The expert's subjective judgment is sorted out and analysed by mathematical method, and the conclusion of judgment is obtained. According to the multi-level index construction, judgment and weight analysis, the conclusion drawn in the economic industry is biomass biogas industry > biomass power generation industry > biomass briquette fuel industry > biomass gasification industry > bio-liquid fuel industry.

Based on the research conclusion, the following suggestions for the economic development of biomass energy industry in Heilongjiang Province are put forward: First, vigorously popularize rural biogas. Heilongjiang Province has a good foundation for rural biogas construction and a high degree of technical maturity. In the future, priority should be given to the development of biomass biogas projects, vigorously building the service network system of rural biogas projects, and forming a "pre-production, mid-production and post-production" integrated service chain. Secondly, biomass power generation should be steadily promoted. In the future, the approved biomass power generation projects under construction in Heilongjiang Province are focused on, suitable sites for new biomass power generation projects in areas with abundant biomass resources and no large-scale utilization projects are selected, and new biomass power generation projects re scientifically planned, so as to steadily promote the development of biomass power generation industry. Then, solid briquette fuels and biomass gasification are actively promoted. According to the development demand of biomass power generation and gasification industries, it is suggested to actively promote the biomass solidified briquette industry. Due to the technical bottleneck and environmental secondary pollution of biomass gasification, it is suggested that biomass gasification should be properly developed. Finally, the bio-liquid fuels are developed, mainly through the use of biomass or cultivation of non-food energy crops, from which biodiesel and fuel ethanol are developed. Heilongjiang Province's biodiesel production capacity and technology research and development are in the leading domestic level, striving to build a biodiesel production base as soon as possible.

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