Development direction and focus of new energy industry in Jilin Province

Chunyan Qu¹, Jie Guan¹ and Tao Wang¹*

¹ Economic Management Department, Changchun University of Technology, Changchun, Jilin, 130000, China

*Corresponding author’s e-mail: wangtao@ccut.edu.cn

*Corresponding author’s ORCID: https://orcid.org/0000-0002-6101-9018

Abstract. The choice of new energy industry is the key content of the development decision-making of urban new energy industry. Currently, the important problem to be solved in the field of industrial development in China is to adopt scientific methods to select new energy industry conforming to the national industrial adjustment and the characteristics of new energy industry, based on the analysis of the current situation of new energy development in Jilin Province with a reference to the development rule and trend of new energy industry in developed areas in China and abroad. With the basic principle and method of group decision and fuzzy preference relationship, this paper introduces the consistency into the new energy industry selection, constructs the model of new energy industry selection, and proposes the new method of new energy industry selection. With the above methods, evaluation indexes including the industrial scale economy effect and the resources concentration degree, ability to absorb scientific and technological achievements and technological innovation, the industrial correlation effect, the social benefit, the sustainability were adopted, and the emphases and directions of new energy industry development in Jilin Province were selected.

1. Introduction
Energy is the foundation of national economy and social development. It is an important material guarantee for the survival and development of human society. Jilin Province is an important base of energy and heavy chemical industry in China. Under the new development situation, it is necessary to develop new energy industry to adjust the industrial structure, optimize the energy structure, strengthen energy saving and emission reduction, and develop low-carbon economy. According to the direction of industrial adjustment and the characteristics of new energy industry, it is an important problem to be solved for Jilin Province to select new energy industry by scientific and effective methods. The research results of the industrial choice method are relatively few, and they are basically qualitative and based on subjective judgment. There is no effective solution to improve the scientific and objective. In this paper, the basic principles and methods of group decision-making and fuzzy preference relations are used to introduce the uniform weighted average operator into selecting a new energy industry. The new energy industry choice model is constructed and the new method of new energy industry selection is put forward to improve the scientificticity and objectivity of industry selection.
2. Selection principle of the new energy industry

Group decision making is an important branch of modern decision science. It has been widely used in economic analysis and urban or regional planning. The current group decision making has two kinds: homogeneous decision making and heterogeneous decision making. There are two types of preference relation, one is multiplicative preference relation and the other is fuzzy preference relation. At present, the fuzzy preference relation has developed rapidly, and many scholars in China and abroad have carried out a large amount of research on it for continuous development and improvement with a wide application in practice. Aggregation of information is the core step of group decision making. Recently, OWA aggregation operators have been widely used in the aggregation process of group decision making. Index screening and index weight determination are the two common problems in evaluation research, and group decision making method is often used to solve these two problems. Group decision method generally includes three stages: obtaining individual preference, assembling individual preference to form group preference, and selecting the optimal scheme based on the group preference. In order to improve the efficiency and rationality of index selection and index weight determination, an improved fuzzy group decision making method for index selection and index weight determination is proposed by introducing fuzzy preference relation matrix and IOWA operator.

2.1. Basis of fuzzy preference relation matrix construction

In the process of choosing the new energy industry, especially in the process of establishing the fuzzy preference matrix, the new energy industry must be fully compared and analyzed from the economic sustainability, industrial concentration and other industrial selection criteria[1].

2.1.1. Effect of scale economy and degree of resource concentration in the industry. Market demand and development prospect underpin the enterprises’ determination of the production scale. With a large market demand and promising market development prospect, enterprises can expand the production scale to benefit from the large-scale production and the realization of resource concentration. Market demand is closely related to the level of the national income, and a high level of national income is conducive to stimulating domestic demand; The level of the industrial innovation and the quality of the scale effect are related to the level of the national income. In view of this, the more obvious the corresponding industrial scale, the higher the degree of resource concentration, the higher the industrial level will be promoted, and the market demand will be expanded and the income level will be increased.

2.1.2. Absorbing scientific and technological achievements and technological innovation capabilities. The more the industry absorbs scientific and technological achievements, the stronger the level of technological innovation, the higher the efficiency of the industrial production, the greater the added value of the product, the more obvious the price advantage, the more obvious the market competitive advantage, and the higher the market share of the product will be.

2.1.3. Industrial correlation effect. Industrial correlation effect is the key factor of industrial selection. A stronger industrial correlation effect is more conducive to the realization of industrial agglomeration and the multiplier effect, so as to better promote the integrated development and coordinated development of regional industries and realize the rapid development of regional economy.

2.1.4. Social benefits. Social benefits mainly refer to the employment situation. It uses the number of employees to indicate the employment level of enterprises. Under the current severe global employment situation, the more the number of employees, the more obvious the industrial social benefits will be.

2.1.5. Sustainability. Resource consumption and environmental pollution are two important indicators for the assessment of the level of sustainable development. The lower the resource consumption, the
higher the resource utilization level, the smaller the environmental pollution, and the stronger the sustainable development ability[2]. These two assessment indexes can be measured by the level of economic benefits of the industry. Material consumption and energy consumption are the important contents of economic benefits. On the other hand, the cost of environmental governance can measure the degree of environmental pollution.

2.2. IOWA operator

The IOWA operator is proposed by Yager and is defined as follows[3]:

Definition 1: IOWA is the derived ordered weighted average (IOWA) operator, if

\[
IOWA(\langle u_1, a_1 \rangle, \langle u_2, a_2 \rangle, \ldots, \langle u_n, a_n \rangle) = \sum_{j=1}^{n} \omega_j b_j,
\]

where, \(w = (\omega_1, \omega_2, \ldots, \omega_3)^T\) is a weighted vector associated with the IOWA, and the \(\langle u_i, a_i \rangle\) is the i two-dimensional array in the OWA pair. \(b_j\) is the second component in the OWA pair corresponding to the \(j\) largest element in \(u_i(i = 1, 2, \cdots, n)\), and calls the first component \(u_i\) in \(\langle u_i, a_i \rangle\) the induced component, and \(a_i\) the numerical component.

As with the various classes of operators in the OWA family, how to determine the weighted vectors of IOWA operators is a critical problem in practical applications. The weighted vectors of IOWA operators can be determined by the following formula by fuzzy semantic methods proposed by Yager, using fuzzy semantic quantification:

\[
\omega_j = Q\left(\frac{j}{n}\right) - Q\left(\frac{j-1}{n}\right), j \in N
\]

The fuzzy semantic quantization operator \(Q\) is calculated by the following formula:

\[
Q(r) = \begin{cases} 
0 & r < a \\
\frac{r - a}{b - a} & a \leq r \leq b \\
1 & r > b
\end{cases}
\]

Corresponding to the fuzzy semantic quantization criterion "most", "at least half of ", " as many " operators, parameter pairs in Q are \((a, b) = (0.3, 0.8), (a, b) = (0.05), (a, b) = (0.5, 1)\).

3. Specific steps and application examples of new energy industry selection method

3.1. Specific steps

The following steps are the fuzzy group decision method for index screening and index weight determination using the fuzzy preference relation matrix and IOWA operator:

Step 1: Obscure language scaling using Table 1 to obtain expert personal preferences.

| Scale value | Langage meaning                  | Chinese semantics |
|-------------|----------------------------------|-------------------|
| 0.1         | \(a_i\) vs. \(a_j\), \(a_i\) is extremely important | Divide it 1/9     |
| 0.2         | \(a_i\) vs. \(a_j\), \(a_i\) strongly matters       | Divide it 2/8     |
| 0.3         | \(a_i\) vs. \(a_j\), \(a_i\) is significantly important | Divide it 3/7     |
| 0.4         | \(a_i\) vs. \(a_j\), \(a_i\) is slightly important   | Divide it 4/6     |
| 0.5         | \(a_i\) vs. \(a_j\), with the same importance        | Divide it 5/5     |
| 0.6         | \(a_i\) vs. \(a_j\), \(a_i\) is slightly important   | Divide it 6/4     |
| 0.7         | \(a_i\) vs. \(a_j\), \(a_i\) is significantly important | Divide it 7/3     |
| 0.8         | \(a_i\) vs. \(a_j\), \(a_i\) strongly matters       | Divide it 8/2     |
0.9 a<sub>i</sub> vs. a<sub>j</sub>, a<sub>i</sub> is extremely important  Divide it 9/1

Step 2: Use the principle of consistency deviation to calculate the objective weight reflected by the expert's bias information, modify the subjective weight of the expert, and get the revised expert weight. First, the subjective weight $s_k$ of the expert is given and use equation (4)

$$||A - B|| = \sum_{i}^{n} \sum_{j=1}^{n} |a_{ij} - b_{ij}| , \forall i, j \in I$$

(4)

to calculate the degree of deviation between the fuzzy preference relationship matrix $A_k$ given by the experts and the adjusted consistency matrix $B_k$. Let $d^{(k)} = d(A_k, B_k), k \in m$. According to the nature of $A_k$, the objective weight $v_k$ obtained by experts from the consistency bias is calculated in the following three cases:

1. If $A_k$ is a fuzzy consistent matrix, $d^{(k)} = 0$ or $d^{(k)} = 0$ then:

$$v_k = \frac{1}{m}$$

(5)

2. If $A_k$ are fuzzy non-consistent matrix, $d^{(k)} \neq 0$ then:

$$v_k = (d^{(k)})^{-\alpha} \left[ \sum_{k=1}^{m} (d^{(k)})^{-\alpha} \right]^{-1}$$

(6)

where $\alpha \geq 1$, generally takes $\alpha = 1$.

3. If $s(1 \leq s \leq m)$ of the m fuzzy judgment matrices are fuzzy consistent judgment moment matrices and $m - s$ are fuzzy non-consistent judgment matrices, then:

$$v_k = \begin{cases} 
\frac{1}{l} \left[ 1 + \sum_{k=l+1}^{m} (d^{(k)})^{-\alpha} \right]^{-1}, & 1 \leq k \leq l \\
(d^{(k)})^{-\alpha} \left[ 1 + \sum_{k=l+1}^{m} (d^{(k)})^{-\alpha} \right]^{-1}, & l + 1 \leq k \leq m 
\end{cases}$$

(7)

Finally, use the following formula to assemble the subjective and objective weights of the experts for the revised expert weights $w_k$:

$$w_k = \beta s_k + (1 - \beta)v_k, 0 \leq \beta \leq 1$$

(8)

where $\beta$ is the preference coefficient, which reflects the decision maker's preference for the subjective and objective weight.

Step 3: Use the IOWA operator to select the corresponding fuzzy semantic quantification criteria, such as "most", and gather the expert personal preference as the group preference.

The modified weight $w_k$ of each expert is used as the OWA pair $u_i$ in the OWA operator and the inductive component $(u_i, a_i)$. The "majority" criterion of fuzzy semantic quantification is selected, and the consistency matrix corresponding to the fuzzy preference relation matrix provided by all experts is used to assemble the fuzzy preference homogeneity matrix $\bar{A} = (\bar{a}_{ij})_{nxn}$ of the expert group.

Step 4: According to the fuzzy preference consistency matrix of the group, the fuzzy complementary consistency matrix sorting method was used to calculate the weight of each index.

There are three main methods for the ordering of fuzzy complementary consistent matrix, namely, square root method, line and normalization method, and sorting method given by element and weight relation of fuzzy complementary consistent matrix. The practice has proved that the third method has the highest resolution, a reliable theoretical foundation, and is more scientific and feasible[4]. Therefore, the third method is used to sort the fuzzy complementary consistent matrix so as to improve the scientific nature of decision-making.

Theorem 1: Let $A = (a_{ij})_{nxn}$ be a fuzzy complementary consistent judgment matrix, then its weight vector $\omega = (\omega_1, \omega_2, \cdots, \omega_n)^T$ can be calculated by the following formula:

$$\omega_i = \frac{1}{n} - \frac{1}{2\alpha} + \frac{1}{na} \sum_{j=1}^{n} a_{ij}, i \in I$$

(9)
where \( a \geq \frac{n-1}{2} \), and the smaller the parameters a, the more the decision-makers pay attention to the difference in importance degree between schemes; the larger a is, the less the decision-makers pay attention to the difference in importance degree between schemes. In practical application, we choose \( a \geq \frac{n-1}{2} \), that is, the method that pays the most attention to the difference in importance degree between schemes.

3.2. Application Example

The screening and weight determination of the evaluation indicators for the industrial correlation effect in wind energy, solar energy, biomass energy and nuclear energy are taken as example, and the specific steps for the application of the above methods are elaborated in detail.

Three experts participate in index selection and weight determination, then expert set: \( E = \{e_1, e_2, e_3, e_4\} \), index set: \( CR = \{CR_1, CR_2, CR_3, CR_4\} \).

Step 1: Get expert personal preferences using a fuzzy language scale. Organize three experts to use the fuzzy language scale given in Table 1.

For \( CR = \{CR_1, CR_2, CR_3, CR_4\} \), establish the following fuzzy preference relation matrix \( A_k = (a_{ij}^{(k)}) \) \( (k = 1,2,3) \) by pairwise comparison:

\[
A_{E1} = \begin{pmatrix}
0.5 & 0.8 & 0.8 & 0.7 \\
0.2 & 0.5 & 0.6 & 0.4 \\
0.2 & 0.4 & 0.5 & 0.3 \\
0.6 & 0.2 & 0.8 & 0.5
\end{pmatrix},
A_{E2} = \begin{pmatrix}
0.5 & 0.7 & 0.9 & 0.5 \\
0.3 & 0.5 & 0.5 & 0.2 \\
0.1 & 0.5 & 0.5 & 0.1 \\
0.5 & 0.5 & 0.5 & 0.5
\end{pmatrix},
A_{E3} = \begin{pmatrix}
0.5 & 0.9 & 0.9 & 0.6 \\
0.1 & 0.5 & 0.3 & 0.2 \\
0.1 & 0.7 & 0.5 & 0.4 \\
0.4 & 0.6 & 0.6 & 0.5
\end{pmatrix}.
\]

Step 2: Modify the weight of each expert by using the subjective and objective integration method.

According to the judgment, the judgment matrices given by the above three experts are all fuzzy non-consistency matrix. Use the formula for the consistency adjustment, and their corresponding consistency matrix can be obtained as follows:

\[
B_{E1} = \begin{pmatrix}
0.50 & 0.78 & 0.85 & 0.68 \\
0.22 & 0.50 & 0.58 & 0.40 \\
0.15 & 0.42 & 0.50 & 0.32 \\
0.32 & 0.50 & 0.68 & 0.50
\end{pmatrix},
B_{E2} = \begin{pmatrix}
0.50 & 0.78 & 0.85 & 0.47 \\
0.22 & 0.50 & 0.57 & 0.20 \\
0.15 & 0.43 & 0.50 & 0.12 \\
0.53 & 0.80 & 0.88 & 0.50
\end{pmatrix},\]

\[
B_{E3} = \begin{pmatrix}
0.50 & 0.95 & 0.80 & 0.70 \\
0.05 & 0.50 & 0.35 & 0.25 \\
0.20 & 0.65 & 0.50 & 0.40 \\
0.30 & 0.75 & 0.60 & 0.50
\end{pmatrix}.
\]

Compute the distance between \( A_{EK} \) and \( B_{EK} \) according to formula (4), \( d^{(EK)} \) is obtained as:

\[ d^{(E1)} = 0.325, d^{(E2)} = 0.51, d^{(E3)} = 0.80 \]

The objective weight of the experts according to the consistency deviation calculated from formula 6 is:

\[ V_{E1} = 0.489, V_{E2} = 0.312, V_{E3} = 0.199 \]

Assuming that the above three expert subjective determined weight vectors are \( s_{ek} = (0.40,0.25,0.35)^T \), using the master and objective weight integration formula:

\[ \omega_k = \beta s_k + (1 - \beta) v_k, 0 \leq \beta \leq 1 \]

In this paper, \( \beta = 0.4 \), that is, a little attention is paid to the objective weight, and the revised expert weight vector can be calculated as follows:

\[ \omega_{ek} = (0.453,0.287,0.259)^T \]

Step 3: Use the IOWA operator to assemble the expert personal preference as a group preference based on the revised expert weight.
Due to the influence of various subjective and objective factors, the judgment matrix given by experts is often not the consistency matrix. The aggregation of judgment matrices without consistency may lead to the distortion of judgment information, so the aggregation of fuzzy preference consistency matrix of expert group can be obtained by using the homogeneity matrix obtained after the adjustment of fuzzy judgment matrix is given by each expert.

In the following, the modified weights of each expert are used as the induced component $u_i$ in the OWA pair $\langle u_i, a_i \rangle$ in the IOWA operator, and the uniformity matrix is obtained after the adjustment of the fuzzy judgment matrix given by each expert. The fuzzy preference consistency matrix $\overline{A} = (\overline{a}_{ij})_{n \times n}$ of the group of experts is obtained by aggregation. The weight gravimetric vector of the three specialists applied to the aggregation is $\omega = (0.453, 0.287, 0.259)^T$, and the "majority" criterion of fuzzy semantic quantization is selected, then the parameter pair $(a, b)$ in the fuzzy quantization operator $Q = (0.3, 0.8)$. The weighted vector of OWA operator can be obtained as:

$$
\omega = \left( \frac{1}{15}, \frac{2}{3}, \frac{4}{15} \right)^T
$$

Limited to space, this example takes the assembly process of an element $a_{12}$ in the group judgment matrix as an example to detail the specific calculation process:

1. Order the $a_{ij}^{(k)}$ with the weights of the various experts as the induced component $u_i$, to get the $b_{ij}^{(k)}$, and apparently the $u_1 > u_2 > u_3$, then has the $b_1 = 0.78, b_2 = 0.78, b_3 = 0.95$;

2. Assumed by IOWA operator formula 5:

$$
\overline{a}_{12} = \sum_{j=1}^{n} \omega_i b_j = \frac{1}{15} \bigotimes 0.78 \bigotimes \frac{3}{2} \bigotimes 0.78 \bigotimes \frac{4}{15} \bigotimes 0.95 \approx 0.82
$$

Similarly, the value of the other elements in the $\overline{A} = (\overline{a}_{ij})_{n \times n}$ can be obtained. Finally the fuzzy preference relation consistency matrix $\overline{A} = (\overline{a}_{ij})_{n \times n}$ of the group is obtained as follows:

$$
\overline{A} = \begin{pmatrix}
0.50 & 0.82 & 0.84 & 0.54 \\
0.18 & 0.50 & 0.51 & 0.23 \\
0.16 & 0.49 & 0.50 & 0.21 \\
0.46 & 0.77 & 0.79 & 0.50
\end{pmatrix}
$$

Step 4: According to the fuzzy preference consistency matrix of the group, the index weights are calculated by formula 9.

According to the fuzzy preference relation consistency matrix $\overline{A} = (\overline{a}_{ij})_{n \times n}$ of the group, the weight vectors of each index can be calculated by formula 9 are as follows:

$$
\omega_{CR1} = 0.368, \omega_{CR2} = 0.152, \omega_{CR3} = 0.144, \omega_{CR4} = 0.336
$$

The above calculation process can be completed through Matlab or excel programming. When determining the index weight, we only provide each expert’s corresponding fuzzy preference relationship for each evaluation index.

### 4. Key points and direction of new energy industry development

With the above methods, evaluation indicators including the scale effect and resource concentration of the economy of the industry, absorbing scientific and technological achievements and technological innovation ability, industrial correlation effect, social benefits, sustainable development are adopted to screen the focus and direction of the new energy industry development of Jilin Province are selected as follows:
4.1. The wind power industry makes every effort to develop towards the direction of regional cluster
We will strengthen wind power planning, attract large domestic backbone enterprises to Jilin Province to develop and construct wind farms, expand the installed capacity of wind power in Jilin Province, and promote the large-scale development of wind power[5]. We will make full use of the rich wind resources in the western regions of Jilin Province (Baicheng, Songyuan and Siping areas) and speed up the construction of a wind power base of 10 million kilowatts. For areas with rich wind resources in central China (Changchun, Jilin, Yanbian and other places), the development and construction of wind farms will be started orderly. At the same time, we will introduce wind power equipment projects from a high starting point, optimize industrial structure, improve the manufacturing chain of the wind power equipment, gradually form industrial cluster advantages, and finally create a manufacturing industry base of wind power equipment in China to fulfill the domestic market in wind power equipment. With the improvement of industrial competitiveness, the wind power equipment manufacturing industry can also aim at the international market and take the road of international operation.

4.2. Making full use of solar energy and develop various forms of solar power generation
In remote areas, independent solar power stations and household photovoltaic power supplies will be built; in cities with good economic conditions, grid-connected photovoltaic power supplies will be developed; and in areas with good resource conditions, large solar power stations will be constructed. Different demonstration projects of solar power shall be constructed to achieve technical breakthroughs and gather experience. Investors shall be guided to be proactive in investing the upstream industry of solar power generation in local regions and extending the industrial chain. The solar photovoltaic modules and thin-film solar cells shall be particularly emphasized, the polysilicon production shall be developed properly with strict gatekeeping, and the solar-powered building integration shall be explored for applications.

4.3. Speeding up the development and utilization of biomass energy
Power plants of biomass energy use straw and municipal solid waste as fuel and promote liquid biomass fuel development and utilization. Projects specializing in biological (non-food) ethanol and biobutanol shall be prioritized, and straw gasification and conversion projects as well as biomass solid fuel projects shall be accelerated. Biomass energy should adopt advanced technologies in China and abroad for a more effective development and utilization, and achieve scale expansion as soon as possible. At the same time, the development and industrialization of biomass energy technology should also be sped up.

4.4. Doing a Good Job of Chisong Nuclear Power Project
We will do a good job in the temporary construction of the Chisong Nuclear Power project, and start construction and put it into operation according to the plan[6]. At the same time, we will actively promote the research and development of nuclear power supporting equipment and the construction of production bases.

5. Conclusion
Group decision making is an important branch of modern decision science. It has been widely used in economic analysis, urban or regional planning. In this paper, the equipollent Preference Relation Matrix and IOWA operator are used. Furthermore, an improved group decision-making method is proposed to improve the efficiency and rationality of index screening and index weight determination.

Acknowledgments
Social science project of Jilin Provincial Department of Education, Research on technical route and countermeasures of new energy industry development in Jilin Province under the environment of supply side reform.
References
[1] Qiao M., Li S.L.(2016) Research on the Development Barrier and Countermeasures of the New Energy Industry in China. J. Journal of Changchun University, 26:6-11.
[2] Liu X.F, Zheng Y.D.(2011) On Patent Strategy Construction of New Energy Technology. J. China Science and Technology Forum, 6:23-28.
[3] Liu X.W., Zhang, Y.(2011) A fuzzy group decision making method based on fuzzy preference matrix and IOWA operator. Journal of Hainan Normal University, 24:39-43.
[4] Meng H., Chen, Y.J.(2016) Comprehensive evaluation of new energy industry development capacity based on Analytic Hierarchy Process. J. China Science and Technology Forum, 6:25-28.
[5] Dou Z. J., Li S.L.(2017)Research on the Incentive Control of the Government in the Development Process of the New Energy Industry. J. Modern Business, 12:265-266.
[6] Dou Z.J., Li S.L., Li N.(2016) New Energy Industry Development Countermeasures in Jilin Province. J. Science and Technology Economic Guide, 34:102-103.