Energy Internet Policy Evaluation based on Fuzzy Comprehensive Evaluation Method

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Abstract: The Energy Internet policy is crucial driving force for China's Energy Internet (EI) development. Energy Internet Development is a vital issue for the government to consider in the 14th Five Year Plan period. On basis of sorting out Energy Internet policies, this paper analyzes the common ground and shortcomings of domestic Energy Internet policies; establishes the evaluation index system of Energy Internet policies; selects the data of Yangtze River Delta and Beijing Tianjin Hebei region; calculates the results by using fuzzy comprehensive evaluation method; uses the quartile graph model to diagnose and analyze the Energy Internet policies, and making provides guidance for Energy Internet development.

Keywords: Energy Internet, policy evaluation, technological innovation, industrial development

1. Introduction

Energy Internet is a new form of energy industry, which is deeply integrated with energy production, transmission, storage, consumption and energy market. There are main characteristics of intelligent equipment, multi energy coordination, information symmetry, decentralized supply and demand, flat system and open trading [1]. In 2016, the Chinese government promulgated the "guiding opinions on promoting the development of "Internet+" smart energy, Energy Internet was officially published in policy documents, and China have constructed 55 demonstration projects nationwide. From the perspective of distribution, Beijing Tianjin Hebei region, Yangtze River Delta and Pearl River Delta occupy high proportion, and it is gratifying that the development of the western region is active. The Energy Internet demonstration projects in Beijing Tianjin Hebei region, Yangtze River Delta and Pearl River Delta are progressing smoothly. In our analysis, the important reason is that local government has a clear understanding of Energy Internet, and government's ability to promote and coordinate is very strong. In addition, the enthusiasm of local enterprises and the support of Think-tank is important impetus. Therefore, the evaluation of Energy Internet policy at this period can identify the deficiencies in development process Energy Internet, and can draw the differences between regional developments of Energy Internet, so as to further promote development of Energy Internet in policy perspective.

At present, the research on Energy Internet focuses on following aspects. According to the business of Energy Internet enterprises, some scholars set up enterprise evaluation index system to guide the standardized operation of enterprises [2-4]; CS WANG [5], X LI [6], L JIANG [7] evaluated the Energy Internet from the perspective of distribution network and smart grid innovation demonstration area to guide the planning and construction of Energy Internet; SF TIAN [8] applies Energy Internet to urban planning and construction, and analyzes the economic and social benefits of Energy Internet access to urban planning through regional load calculation; Some researchers draw lessons from the energy technology specifications and evaluation standards, and construct index system from the perspective of energy structure, economic benefits, social benefits and business models, and make qualitative analysis on development level of energy Internet [9-12]. The research of business model has gradually become the spot of Energy Internet [13-17], the successful of the Energy Internet demonstration project provides feasible experience for the government, enterprises and customers, which is conducive to the healthy development of the Energy Internet. Consulting domestic and foreign literature, there is very little research on the evaluation of Energy Internet policy. On the one hand, this paper defines the implementation effect of Energy Internet policy, and makes a comparative analysis of Beijing Tianjin Hebei region and Yangtze River Delta region, and analyzes the effect of policy in different regions; on the other hand, it enriches the current research on energy policy, and puts forward suggestions for future development of Energy Internet.

2. Analysis of Energy Internet Policy

2.1. Review of Energy Internet Policy

Energy Internet is in initial stage of development. The current policy aims to guide the future development direction and positively encourage the development of Energy Internet. It can be divided into four policy sets: electricity market policy, clean energy consumption policy, social energy efficiency policy and new energy format policy.

2.1.1. Electricity market policy

In the new round of power system reform launched in 2015, the construction of electric power market is

expected, and the role of electricity spot market will be more prominent. The main policies and contents of national level power market construction since 2017 are shown in APPENDIX A.

2.1.2. Clean energy policy

In order to effectively solve the problem of clean energy consumption, China has successively issued the "notice on the management of fully guaranteed acquisition of wind power and photovoltaic power generation", "implementation plan for solving the problem of abandoned water and wind power", and the notice on establishing and improving the renewable energy electricity consumption guarantee mechanism. Through the establishment of renewable energy target guidance system and the trial implementation of renewable energy power certificate Book (green certificate) trading and "clean energy consumption action plan (2018-2020)" and measures to increase the consumption of clean energy. In 2019, Photovoltaic power generation have entered the era of affordable access to power grid. The National Energy Administration issued the notice on actively promoting the work of wind power and photovoltaic power generation without subsidy and the notice on issues related to the construction of wind power and photovoltaic power generation projects in 2019, giving priority to the construction of low-cost grid projects, fully implementing the conditions of power transmission and consumption, guarantee preferential power generation and full guaranteed acquisition, encouraging the fair price and low-cost projects access to obtain reasonable income compensation through green certificate transaction, strictly regulate the competitive allocation of subsidy projects, takes the on grid electricity price as an important competitive condition, and giving priority to the construction of projects with low subsidy intensity and large recession. In order to promote fair competition in the wind power and photovoltaic power, the National Development and Reform Commission issued the notice on issues related to improving the on grid price mechanism of photovoltaic power generation and the notice on improving the policy of wind power on grid price, which changed the benchmark on grid price of centralized photovoltaic power station, onshore and offshore wind power benchmark on grid price to guide price, and in principle through market competition The new standards for new distributed photovoltaic generation and wind power subsidies are determined and formulated. In November 2019, the National Development and Reform Commission issued the Guiding Catalogue of industrial restructuring (2019 Edition), in which biomass power generation and bio natural gas have been emphasized many times in the new energy category. In April 2020, the Energy Law of the People's Republic of China (Draft for comments) formally wrote the policy of renewable energy consumption security system into the national law, which is also the highest legal effect document to ensure the consumption of renewable energy in the form of legislation.

2.1.3. Social energy efficiency policy

Since the "Eleventh Five Year Plan" period, China first determined the energy-saving binding objectives in the form of legal, and the energy-saving policies for high-energy consuming enterprises came into being and are gradually improving. During the 11th Five Year Plan period, China implemented the energy conservation action of 1000 enterprises, requiring 9 key energy consuming industries including steel, nonferrous metals, coal, electric power, petroleum and petrochemical, chemical industry, building materials, textile and papermaking. In 2004, 1008 independent accounting enterprises with a comprehensive energy consumption of more than 180000 tons of standard coal signed energy conservation agreements with the government, promising to greatly improve energy utilization efficiency and save 100 million tons of standard coal during the Eleventh Five Year Plan period. Since the eleventh five year plan, Chinese government has realized the important role of establishing the exit mechanism of backward production capacity of small and medium-sized enterprises and speeding up the energy-saving technological transformation of small and medium-sized enterprises for economic restructuring and sustainable development. The notice of the State Council on Further Strengthening the elimination of backward production capacity clearly requires that the power industry eliminate more than 50 million kilowatts of small thermal power units by the end of 2010. During the 12th Five Year Plan period, China has expanded the scope of supervision over high energy consumption enterprises and implemented the energy conservation and low carbon action of 10000 enterprises, requiring energy consuming units with energy consumption of more than 10000 tons of standard coal in 2010 and the annual comprehensive energy consumption of more than 5000 tons of standard coal designated by relevant departments to improve their energy-saving management level and form a long-term energy-saving mechanism, greatly improving energy utilization efficiency and saving 250 million tons of standard coal. The 13th five year comprehensive work plan for energy conservation and emission reduction further strengthened energy conservation management of key energy consuming enterprise, carried out the " One hundred, thousand, ten thousand " action of key energy using enterprise, and evaluated the target responsibility of "100", "1000" and "10000" key energy using enterprise at the national, provincial and municipal levels.

2.1.4. New energy format policy

In July 2015, the National Energy Administration issued the guidance on promoting the construction of new energy micro grid demonstration projects. In February 2016, the National Development and Reform Commission, the National Energy Administration and the Ministry of industry and information technology jointly issued the "guidance on promoting the development of"

Internet + "smart energy. In July 2016, the National Development and Reform Commission and the National Energy Administration jointly issued the" In November 2016, the National Development and Reform Commission issued the notice on standardizing the pilot reform of incremental distribution business; in July 2017, the National Development and Reform Commission and the National Energy Administration jointly issued the Trial Measures for promoting the construction of grid connected micro grid; in 2017, the National Development and Reform Commission and the National Energy Administration jointly issued the Trial Measures for promoting the construction of grid connected micro grid. The five ministries issued the guiding opinions on promoting the development of energy storage technology and industry. State Grid Corporation of China (SGCC) entered the field of integrated energy services in 2017 and established 26 provincial-level integrated energy service companies. At the beginning of 2019, the SGCC issued the action plan for promoting the development of integrated energy services business in 2019-2020, and China Southern Power Grid also issued the notice on clarifying matters related to the development of integrated energy services in early 2019. At the beginning of 2019, the two power grid companies have issued guidelines to promote the development of electrochemical energy storage. China Southern Power Grid Corporation took the lead in issuing the draft of guidance on promoting the development of electrochemical energy storage, followed by the general office of State Grid Corporation of China printing and distributing the guiding opinions of State Grid Corporation of China on promoting the healthy development of electrochemical energy storage (Trial).

2.2. Analysis of Energy Internet Policy

By summarizing and sorting out domestic Energy Internet development policies and comparing with foreign Energy Internet policies, it is found that Energy Internet development policies focus on the following four aspects:

2.2.1. Priority should be given to the acceptance of renewable energy

With the gradual depletion of fossil energy, all countries pay attention to the consumption of renewable energy in the process of energy transformation. Especially after the Fukushima nuclear power plant accident in Japan, renewable energy has become the primary consideration of many countries. For example, the European SET-Plan set up to 55% of the investment in renewable energy. The Energy Internet provides a more effective way to absorb renewable energy, especially for distributed energy. At the present period of rapid development of wind power in China, some contradictions and problems are exposed in the process of wind power grid connection and coordinated operation. The newly revised renewable energy law strengthens the guiding role of regulation, highlights the guaranteed full purchase of renewable energy, and through the establishment of Renewable energy development fund solves the grid connection costs and related costs incurred by power grid enterprises to absorb renewable energy. As shown in TABLE I, these new policies more truly reflect the current reality of wind power integration into the power system, so the policy formulation can ensure the orderly generation, scientific development and reasonable integration and consumption of renewable energy.

2.2.2. Encouraging the development of electric vehicles

Many countries attach importance to the role of electric vehicles in improving energy efficiency, energy conservation and emission reduction, and give preferential measures from the aspects of management mode, production qualification and technology, as shown in TABLE II. In addition, China employs relevant experts to form a new energy vehicle expert committee, which is responsible for determining and adjusting the technical development stage of new energy vehicle product categories, proposing special technical conditions and inspection specifications suitable for new energy vehicles, so as to promote the technical progress and encourage enterprises to research, develop and produce new energy vehicles.

TABLE 1. Policy documents and measures of renewable energy consumption in various countries

Nation	Stage Goal	Financial Incentives
US	20% of power generation in 2020	$23 billion in support of renewable energy technologies
EU	More than 30% of electricity generation in 2020	EUR 25 billion (direct subsidy in 2016)
JPN	22% renewable energy in 2030	115.3 billion yen for renewable energy
CN	27% of power generation in 2020	$126.6 billion in renewable energy (2018)
nation	stage goal	financial incentives

TABLE 2. Development measures of electric vehicles in CN, US, JPN and GER

Nation	Types of measures				
	R & D	Purchase	Use	Infrastructure	Industrial support
CN	3	11	12	5	1
US	1	6	12	3	2
JPN	1	6	4	2	3
GER	1	6	4	1	1

2.2.3. One common feature is that developing Energy Internet according to resource endowment and technological advantages

Different countries adopt different technical routes to realize Energy Internet. The United States, as the first country to develop smart grid. Through smart grid, various micro energy grids are interconnected to form Energy Internet. Therefore, the Energy Internet policy of

the United States takes smart grid as the core. Renewable energy accounts for a high proportion of energy consumption in Germany. According to actual situation, it adopts the integration of information network and power grid, so as to transform the unified power supply of power plants into the power supply mode dominated by distributed generation. Therefore, Germany builds the German energy legal framework with the renewable energy law as the core to promote the development of Energy Internet, and pays more attention to the development of Energy Internet in Germany Information and communication technology. China has a vast territory with uneven distribution of resources from east to west. In order to fully and rationally utilize resources, the long distance transmission technology has been developed. In addition it is expected that the "One Belt and One Road" strategy achieve adequate energy supply. China's Energy Internet policy is similar to United States. The smart grid is the core of the Energy Internet, and it concerns the problem of multifunction and renewable energy consumption.

2.2.4. It is a significant feature of the development of Energy Internet in various countries: Phased promotion and pilot first. Both the United States and Europe have earlier practiced Energy Internet

China and other developing countries, take demonstration projects as the guide, actively introduce policies to promote the construction of demonstration projects, give full play to the driving role of demonstration projects, and carry out subsequent promotion and application. Taking the United States as an example, in the early stage of research, the policies issued by the United States are mainly planning policies, which clarify the goals and tasks of building the Energy Internet in the United States, and plan the technical route to realize the energy Internet, and stipulate the organizational leadership to lay the foundation for the further development of energy interconnection; in the second stage, two federal laws were promulgated; and in the third stage, the United States issued A large number of policies and regulations include financial support, R & D investment and promoting the construction of FREEDM project. In the process of practicing the Energy Internet, Germany first implemented the E-Energy project in stages. After gaining some experience, it promoted and implemented the C-sells project, and gradually revised the main energy law of Germany—Renewable Energy Law.

Through comparison, we can find that there are deficiencies in the policy level of China's development of Energy Internet. First of all, the overall planning is relatively lacking. The Energy Internet involves the close cooperation in the fields of energy industry, electrical appliance industry and information industry. However, China's Energy Internet planning lacks a comprehensive and systematic positioning and perfect standard system. Secondly, the system operation and auxiliary service policies need to be improved. Wind power, photovoltaic and other intermittent energy generation are connected to the power grid, which brings a series of prominent problems such as peak load regulation and frequency regulation for the stable operation of the power system. How to improve the auxiliary service market is the focus of policy formulation in the next step. Finally, the construction of power market should be further accelerated, especially in the receiving end power grid connected by multi infeed DC system in the East, the areas with large peak valley difference, high proportion of external power and high proportion of air conditioning load, should explore the demand response mechanism suitable for the transition period.

3. Model of Energy Internet Policy

3.1. Energy Internet Policy Evaluation Process

The evaluation process of Energy Internet policy is shown in Figure 1.

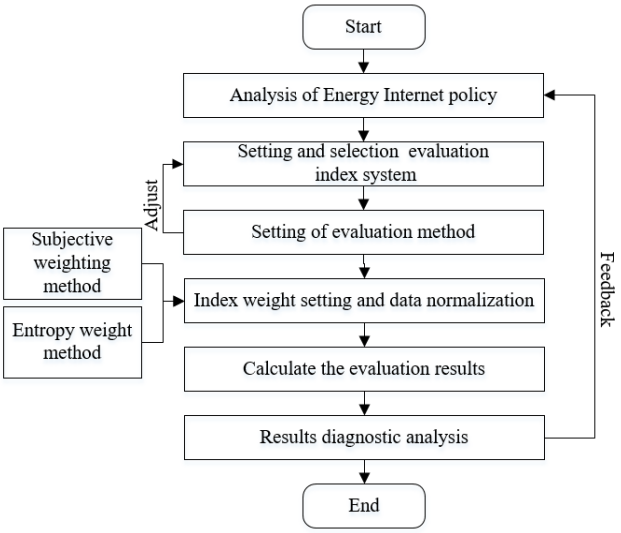

Figure 1. Evaluation process of Energy Internet policy.

(1) The construction of Energy Internet policy evaluation index system: For qualitative indicators, specific description features should be given; for quantitative indicators, quantitative calculation methods should be clear.

(2) Selection of comprehensive evaluation method: Based on the selection method, the evaluation indicators are further optimized and adjusted. In this paper, AHP is selected, which need to be set as target level, criterion level and indicator level according to the framework of AHP.

(3) Normalization processing and giving index weight: According to the evaluation requirements, the indicators are collected and normalized. In this paper, the combination weighting method is used to get the index weight. Firstly, we set the subjective weight by referring to the existing literature, calculates and corrects the results of subjective weight by anonymous scoring and expressing opinions, and finally takes the mean value of various opinions as the subjective weight. Secondly, the entropy weight method is used to determine the objective weight, that is to get the entropy value and weight of each evaluation index based on the original data.

(4) Calculation of evaluation results: This paper selects the data of Energy Internet policy in Beijing Tianjin Hebei region and Yangtze River Delta.

(5) Results analysis: Feedback the results with the current development status, combined with the policy analysis results, put forward relevant suggestions on the development of Energy Internet from the perspective of policy.

3.2. Evaluation Index System of Energy Internet Policy

In this paper, the indicators are set from two aspects: the policy effect index and the policy efficiency index of the Energy Internet. When the above two kinds of indicators are set as the secondary indicators of the target layer, seven indicators are set, including industrial development, technological innovation, fairness, economic input efficiency, administrative efficiency, environmental effect and synergistic effect. 20 scheme level (third level) indicators are set considering various factors such as energy, economy and environment.

The index system includes qualitative analysis index and quantitative analysis index. Qualitative indicators or quantitative analysis indicators are positive values (the higher the score and the greater the value, the better the effect of policy). The index system is shown in TABLE 3.

TABLE 3. Index system of Energy Internet policy

Object	Primary indicators	Weight	Secondary Indicators	Weight
Energy Internet policy Evaluation	Industrial Development	0.339	Industry standards and entry barriers	0.172
			Application of development mode	0.090
			Industrial Development Roadmap	0.048
			Policy subsidy	0.029
	Technological innovation	0.139	Degree of technical demand	0.051
			Number of new EI enterprises	0.017
			Number of new patents	0.016
			Application of achievements	0.055
	Fairness	0.087	Fairness of policy in resource allocation	0.047
			The fairness of policies among regions	0.020
			The fairness of policy among market subjects	0.020
	Economic input efficiency	0.087	Growth rate of capital in the field of Energy Internet	0.058
			Growth rate of investment in Energy Internet	0.029
	Administrative efficiency	0.054	Implementation of Energy Internet policy	0.008
			Acceptance of Energy Internet policy	0.023
			Coordination between Energy Internet policy and other policies	0.023
	environmental effect	0.263	Effect of Energy Internet policy on CO_2 emission reduction	0.081
			Energy Internet policy improves energy consumption structure	0.182
	synergistic effect	0.031	The impact of Energy Internet policy on Sustainable Development	0.020
			Promotion of Energy Internet policy to other industries	0.011

3.3. Energy Internet Policy Evaluation Model

Fuzzy comprehensive evaluation method is widely used in policy evaluation. For example, HJ HUANG [18] thinks that the evaluation of public policy is the combination of value judgment and fact judgment. The evaluation object is systematic and fuzzy, and it is difficult to quantify the policy effect. The application of fuzzy comprehensive evaluation method can avoid the fuzziness of the evaluation system and obtain the evaluation results under limited conditions. The fuzzy comprehensive evaluation method is mainly applied to energy conservation and emission reduction policy analysis [19], sports industry policy analysis [20], population and fertility policy analysis [21] and environmental policy analysis [22]. In this paper, this method is used to evaluate the Energy Internet policy.

a. Establish factor set. U is a collection of factors that evaluate Energy Internet policy, expressed as:

$$U = \{U_1,\ U_2,\cdots,\ U_m\}, \tag{1}$$

$$\bigcup_{i=1}^{m} U_i = U,\ U_i \bigcap U_j = \Phi,\ i \neq j$$

Further, U_i can be divided into sub factor sets

$$U_i = \{U_{i1},\ U_{i2},\cdots,\ U_{ij},\cdots,\ U_{in}\} \tag{2}$$

b. Determine the evaluation set.

$$V = \{V_1,\ V_2,\ V_3,\ V_4,\ V_5\} \tag{3}$$

V_j is the standard of evaluation grade. We establish measurement scale vector (4) for target layer index, the evaluation set of the scheme level (third level) indicators using the same measurement scale vector

$$H = \{5,4,3,2,1\} \tag{4}$$

c. Membership Matrix Construction. After constructing the evaluation factor set, it is necessary to determine the membership degree of the single factor evaluated object to the hierarchical fuzzy subset, and obtain the fuzzy relation matrix:

c_i. For qualitative indicators, according to the statistical results of Delphi method, the statistical table of single factor evaluation results is established. In this paper, the sum product method is used to normalize the evaluation results, and the judgment matrix of each qualitative factor is obtained, and the fuzzy relation matrix is determined by the first level fuzzy synthesis. The specific steps are as follows:

$$R_i = \{r_{i1},\ r_{i2},\cdots,\ r_{in}\} \tag{5}$$

R_i is the *i*-th index in factors, corresponding to the membership degree of each evaluation standard $V_1,\ V_2,\ V_3,\ V_4,\ V_5$ in the evaluation set.

$$r_{ij} = \frac{number\ of\ who\ choose\ V_i}{total\ \ participants}\ (j = 1,2,3,\cdots,\ n) \tag{6}$$

c_{ii}. For quantitative indicators, X_i was normalized to determine the membership degree, and then index value was standardized to [0, 5].

$$Z_i = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}} \times 5 \tag{7}$$

For outlier data, the following methods are used for normalization:

$$Z_i = \begin{cases} 0, & X_i < X^*_{min} \\ \dfrac{X_i - X^*_{min}}{X^*_{max} - X^*_{min}} \times 100, & X^*_{min} \le X_i \le X^*_{max} \\ 100, & X_i > X^*_{max} \end{cases} \tag{8}$$

We can get the fuzzy matrix R :

$$R = \begin{Bmatrix} r_{11} & \cdots & r_{1n} \\ \cdots & \ddots & \cdots \\ r_{n1} & \cdots & r_{nn} \end{Bmatrix} \tag{9}$$

d. Giving index weight. This paper uses combination weighting to give index weight:

$$\omega_i = \frac{\omega_j^* - \omega_j^{**}}{\sum_j^n \omega_j^* \omega_j^{**}},\quad j = 1,2,\cdots,n \tag{10}$$

ω_j^* and ω_j^{**} are subjective weight vector based on expert scoring method and objective weight vector based on entropy weight method. In the subjective evaluation process, 10 experts in field of Energy Internet research are invited to rate index evaluation, including professors and doctor researchers of colleges (4), staff of State Grid Corporation of China (2), and staff of scientific research institutions (4). The weight calculation results are shown in TABLE III.

e. Calculate the evaluation results. Set weight vector to $A_i = \{a_{i1},\ a_{i2},\cdots,\ a_{in}\}$. The fuzzy operator is used to synthesize R_i and weight vector A_i, and the evaluation result B_i of the hierarchical factor set U_i is calculated.

$$B_i = A \circ R = (a_{i1},\ a_{i2},\cdots,\ a_{in}) \circ \begin{bmatrix} r_{11} & \cdots & r_{1n} \\ \cdots & \ddots & \cdots \\ r_{n1} & \cdots & r_{nn} \end{bmatrix} \tag{11}$$

$$= (b_{i1},\ b_{i2},\cdots,\ b_{in})$$

"$\circ$" is fuzzy operator. There are four common types of fuzzy operator relations: single factor determined type, main factor prominent type, weighted average type and main factor determining type. In this paper, the weighted average fuzzy operator is selected because it takes into account the weight of each evaluation index, and can fully reflect the overall characteristics of the Energy Internet policy.

Weighted average fuzzy operator $M(\cdot,+)$

$$b_j = \sum_{i=1}^{n} a_i \cdot r_{ij},\ (j = 1,2,3,\cdots,\ n) \tag{12}$$

Multi factor evaluation: From single factor evaluation results, evaluation matrix $U = \{U_1,\ U_2,\cdots,\ U_m\}$ can be obtained, expressed as B .

$$B = \begin{bmatrix} B_1 \\ \vdots \\ B_M \end{bmatrix} = \begin{bmatrix} b_{11} & \cdots & b_{1n} \\ \vdots & \ddots & \vdots \\ b_{m1} & \cdots & b_{mn} \end{bmatrix} \tag{13}$$

If the weight vector of $U_i = \{U_1,\ U_2,\cdots,\ U_m\}$ is $A_i = \{A_1,\ A_2,\cdots,\ A_m\}$, the evaluation result of Energy Internet policy are as follows (14).

$$B = A \circ R = (b_1,\ b_2,\cdots,\ b_n) \tag{14}$$

4. Empirical Analysis

4.1. Energy Internet Policy Evaluation Results

The Energy Internet demonstration project is the most intuitive performance of China's Energy Internet policy. China's first batch of 55 Energy Internet demonstration projects are widely concentrated in the Yangtze River Delta and Beijing Tianjin Hebei region, including 16 in the Yangtze River Delta region and 9 in the Beijing Tianjin Hebei region, accounting for half of the first batch of demonstration projects. The pilot application units of Energy Internet include power technology enterprises, power grid enterprises, enterprises in non-electric and non-energy, energy enterprises, government agencies, etc. Demonstration projects involve urban Energy Internet demonstration project, park Energy Internet demonstration project, cross regional multi energy cooperation demonstration project, electric vehicle Energy Internet demonstration project, and green energy flexible trading Energy Internet demonstration project. The Yangtze River Delta region vigorously develops regional Energy Internet through the "wind power generation" in Shanghai, the centralized treatment of high-temperature straw in Zhejiang, and the solar cell base in Jiangsu. "Beijing Tianjin Hebei" takes electric power construction as the center, and gradually develops electric energy substitution, aiming at building an open, diversified, clean, safe and economic energy security system around the capital circle.

This paper selects the data of Yangtze River Delta and Beijing Tianjin Hebei region to evaluate the implementation effect and efficiency of Energy Internet policy, and compares the development differences of Energy Internet between the two regions, which can provide reference for formulating Energy Internet policy. During the evaluation process, the quantitative data from the websites of provincial and municipal statistical bureaus, EPS data platform and the annual development report of China's electric power industry 2019. The qualitative data are from the questionnaire survey of experts. The calculation results are shown in TABLE IV and TABLE 5 and Figure 2.

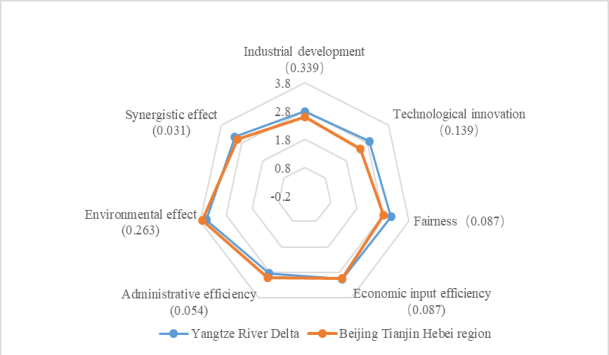

Figure 2. Score of Energy Internet policy in Yangtze River Delta and Beijing Tianjin Hebei region.

TABLE 4. Evaluation results of Energy Internet policy criteria layer in Yangtze River Delta and Beijing Tianjin Hebei region

Criterion layer	Regions	(5)	(4)	(3)	(2)	(1)	Score
Industrial development	Yangtze River Delta	0	0.2359	0.4420	0.1941	0.1280	2.7859
	Beijing Tianjin Hebei region	0	0.1201	0.4101	0.4007	0.0691	2.5831
Technological innovation	Yangtze River Delta	0	0.2248	0.4993	0.2216	0.0553	2.8957
	Beijing Tianjin Hebei region	0	0.1363	0.3579	0.3445	0.1623	2.4703
Fairness	Yangtze River Delta	0.0655	0.2102	0.5045	0.2198	0	3.1214
	Beijing Tianjin Hebei region	0	0.2198	0.43	0.3174	0.0328	2.8368
Economic input efficiency	Yangtze River Delta	0	0.2900	0.4766	0.2334	0	3.0566
	Beijing Tianjin Hebei region	0	0.29	0.43	0.28	0	3.01
Administrative efficiency	Yangtze River Delta	0	0.2263	0.3915	0.3822	0	2.8440
	Beijing Tianjin Hebei region	0.0595	0.2262	0.4343	0.2205	0.0595	3.0058
Environmental effect	Yangtze River Delta	0.1400	0.3867	0.3765	0.0968	0	3.57
	Beijing Tianjin Hebei region	0.14	0.4835	0.3333	0.0432	0	3.7202
Synergistic effect	Yangtze River Delta	0	0.29	0.57	0.14	0	3.15
	Beijing Tianjin Hebei region	0	0.3239	0.3788	0.2973	0	3.0265

TABLE 5. Score of Energy Internet policy in Yangtze River Delta and Beijing Tianjin Hebei region

Index (weight)	U_1 **0.339**	U_2 **0.139**	U_3 **0.087**	U_4 **0.087**	U_5 **0.054**	U_6 **0.263**	U_7 **0.031**	**Score**
Yangtze River Delta	2.7859	2.8957	3.1214	3.0566	2.8440	3.57	3.15	3.0746
Beijing Tianjin Hebei region	2.5831	2.4703	2.8368	3.0233	3.0058	3.7202	3.0265	2.9634

4.2. Diagnosis and analysis of Energy Internet policy

In order to further analyze the improvement direction of Energy Internet policy in Yangtze River Delta and Beijing Tianjin Hebei region, this paper analyzes the implementation effect of Energy Internet policy by using the Quartile graph model.

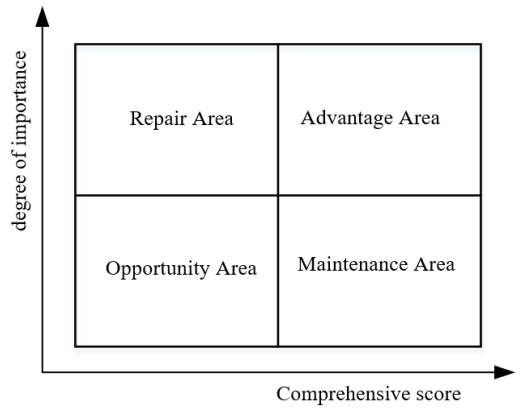

Figure 3. Quartile graph model.

According to the two dimensions of index score and importance, the quad chart is divided into four quadrants: advantage area (importance, high score, continue to maintain), repair area (importance, low score, key improvement), maintenance area (average importance, high score, continue to maintain) and opportunity area (average importance, low score, consider improvement), as shown in Figure 3.

Taking the score results of the Energy Internet policy criterion level index (U_1~U_7) as the X, the degree of importance as the Y, and the average value of each importance degree and the average value of each index score as the coordinate point, the four point graph is drawn.

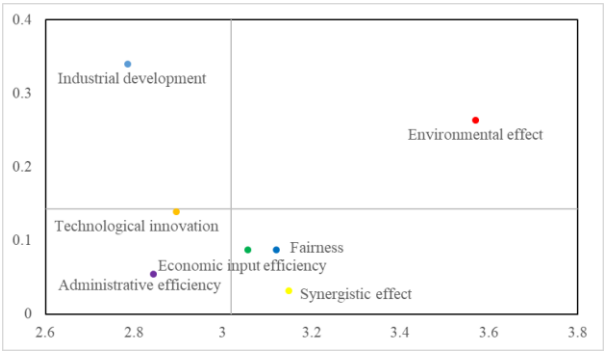

Figure 4. Quartile graph model of policy evaluation indicators in Yangtze River Delta.

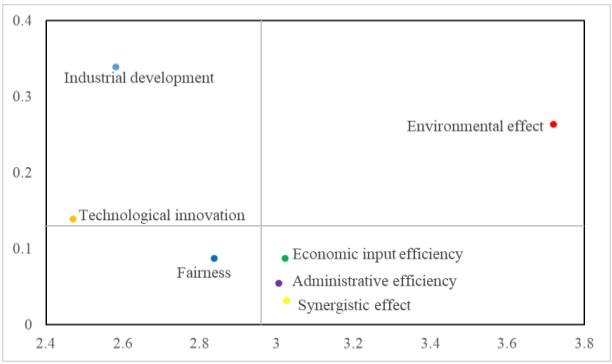

Figure 5. Quartile graph model of policy evaluation indicators in Beijing Tianjin Hebei region.

According to Figure 4. And Figure 5. It can be concluded that:

- Current Energy Internet policies in the Yangtze River Delta and Beijing Tianjin Hebei region have well done in environmental effects, which is the same as the essential appeal of proposing the concept of Energy Internet. The integration of distributed renewable energy generation into the power grid has greatly improved the energy consumption structure, reduced carbon emissions and other environmental pollution, and improved the environmental quality.
- The Yangtze River Delta and Beijing Tianjin Hebei region need to focus on improvement in both industrial development and technological innovation, which indicates that the policy support in industrial development and technological innovation is not enough, and it should be focused on in the development stage of the 14th five year plan. Technology has always been obstacle to the development of Energy Internet. It is undeniable that the first batch of Energy Internet demonstration projects cultivated a number of new forms of Energy Internet, and broke the barriers in governments, application enterprise of demonstration projects, communication operators, energy supply enterprises, energy customers, automobile companies and municipal enterprises, and explored new business models. However, how to realize the "multi network integration"(power grid, communication network, municipal network), the "multi station integration" (substation, energy storage station, data center), the "multi meter integration" (electricity meter, water meter, gas meter in user side, the comprehensive utilization of electric vehicle charging pile and large-scale energy storage should be considered by the government and Energy Internet enterprises.
- These three indicators of fairness, economic input efficiency and synergy effect in the Yangtze River Delta region are in the maintenance area, and the indicators in this region are secondary advantages. In the case of limited resources, it is not necessary to pay attention to these three indicators in the near future. However, if the resources are sufficient, these indicators can be properly paid attention to when formulating policies, which will play a role of icing on the cake. The administrative efficiency, economic input efficiency and synergy effect of Beijing Tianjin Hebei region are in the maintenance area. It should be noted that economic input efficiency and synergy effect both of two regions in maintenance area, which can also reflect that economic input efficiency and synergy effect are the dimensions that Energy Internet policy should show solicitude for a long time. The index of administrative efficiency in the Yangtze River Delta is in the area of opportunity, while that in Beijing Tianjin Hebei region is fairness. It is enough to maintain the status quo in

the case of limited resources, but appropriate improvement can be considered if the resources are sufficient.

- Based on the analysis of the evaluation results of Energy Internet policy, it is found that Current energy Internet policy needs to be improved in industrial development and technological innovation. In industrial development, under the strategic background of energy security during the "14th five year plan" period, with public service institutions in the energy sector as the core, a multi-level cooperation mechanism of industry and industry alliance should be forming. A number of leading enterprises with core competitiveness will be cultivated, and Energy Internet will be gradually brought into the market-oriented track, and the policy system of Energy Internet finance, law and taxation will be improved, at the same time, taking the construction of Xiong'an New Area as an opportunity, we will explore new business models of urban Energy Internet. In technological innovation, we should improve construction of Energy Internet technology standard system as soon as possible.

In the long run, the policy focuses on economic input efficiency and synergy effect. The specific performance of the economic input efficiency is establishing the idea of "operating finance", strengthening the concept of performance finance, strengthening the management and process supervision of local financial investment, reasonably defining the scope of government intervention, encouraging diversified business innovation of Energy Internet enterprises, and promote business model innovation. The synergy effect of the policy requires the government to avoid separate planning of electricity, gas, heat, cold, oil and gas, and to explore the implementation path of the energy infrastructure interconnection.

5. Conclusion

Based on the analysis of domestic Energy Internet policies, this paper constructs the evaluation index system of Energy Internet policies, and compares the Energy Internet policies of Yangtze River Delta and Beijing Tianjin Hebei region by using fuzzy comprehensive evaluation method. Based on the evaluation results, the paper puts forward policy suggestions to promote the development of Energy Internet in China. The possible contribution of this paper lies in: firstly, we systematically analyzed the domestic Energy Internet policy, and obtained the common ground of Energy Internet development at home and abroad; secondly, the evaluation index system of Energy Internet policy is constructed, which improves the research on Energy Internet policy evaluation; finally, the evaluation results of Energy Internet policy in the Yangtze River Delta and Beijing Tianjin Hebei region show that what the future policy should be focusing is Energy Internet technology and industrial policy. In June 2019, 55 Energy Internet demonstration projects have been checked and accepted, 37 are facing delay, 4 are cancelled, and only 14 projects have passed the acceptance. The future path of Energy Internet is blocked and difficult. What role of policy in the development of Energy Internet and how technology integration can drive industrial development still deserve attention.

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Appendix A. Power market policy

Publish time	**Policy title**	**Key content**
2017.8	*Notice on carrying out pilot work of spot electricity market construction*	Eight provinces and regions, including southern China, Western Mongolia, Zhejiang, Shanxi, Shandong, Fujian, Sichuan and Gansu, were selected as the first batch of pilot projects for the construction of spot electricity markets.
2018.11	*Notice of the comprehensive Department of the State Energy Administration on improving the pilot working mechanism of power spot market construction*	The first batch of pilot projects will be put into trial operation before the end of June 2019.
2019.1.	*Notice on further recommendation of incremental distribution business reform*	The power sales companies with the operation right of distribution network are encouraged to separate the electricity sales business from the competitive business.
2019.3	*Notice on Soliciting Opinions on further promoting pilot construction of electric power spot market*	Exploring the establishment of a sharing mechanism for power users to bear the cost of ancillary services, and encourage third parties such as energy storage facilities to participate in the auxiliary service market.
2019.5	*Supervision and examination method of transmission and distribution pricing cost*	It is stipulated that the depreciation cost of fixed assets of power transmission and distribution shall not be included in the pricing cost of power transmission and distribution.
2019.7	*Opinions on deepening the pilot work of power spot market construction*	We should further give play to the role of the market in determining prices, establish and improve the spot trading mechanism, guide the production and consumption of electric power with flexible market price signals, accelerate the development and utilization plan of electricity, stimulate the vitality of market entities, and enhance the regulation ability of power system.
2019.9	*Opinions on strengthening the supervision of medium and long term transactions in the store*	We should standardize market trading rules, trading behavior and market intervention behavior, and strengthen the supervision of information disclosure and submission. We should establish a supervision system that combines government supervision with external specialized supervision.
2019.12	*Notice on signing medium and long term power contracts in 2020*	All localities strictly implement the transmission and distribution electricity prices approved by the state. In principle, the electricity energy prices in direct electricity trading are formed in the form of favorable price.