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Research on Energy Saving and Environmental Protection Management Evaluation of Listed Companies in Energy Industry Based on Portfolio Weight Cloud Model

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Abstract: Under the background of the "carbon peaking and carbon neutrality" strategy, energy saving and environmental protection (ESEP) management has become one of the most important projects of enterprises. In order to evaluate the ESEP management level of listed companies in the energy industry comprehensively, this study puts forward the evaluation framework of "governance framework-implementation process-governance effectiveness" for ESEP management level. Based on the comprehensive collection and collating of related information reports (e.g., sustainable development reports) of listed energy companies from 2009 to 2018, the ESEP information was extracted, and the portfolio weight cloud model was used to evaluate the ESEP management status of listed energy companies in China. It is of great theoretical innovation and practical significance to promote the evolution of the economy from "green development" to "dark green development". The results show that: (1) the number of SHEE information released by listed companies in the energy industry shows a steady increasing trend, but the release rate is low, and there are differentiation characteristics in different industries. (2) The ESEP management level of most listed companies in the energy industry is still at the low level, and only 17.19% (S = 65) of the sample companies are at the level of "IV level-acceptable" and "V level-claimable". (3) In terms of governance framework-implementation process-governance effectiveness, B1-governance framework (E_x = 3.4451) and B2-implementation process (E_x = 2.9480) are relatively high, but B3-governance effectiveness (E_x = 2.0852) and B4-public welfare (E_x = 2.0556) are relatively low. The expectation of most ESEP evaluation indexes fluctuates between "III level-transition level" and "II Level-improvement level". Finally, some suggestions are put forward to improve ESEP management levels.

Keywords: listed companies in the energy industry; ESEP management evaluation; analytic hierarchy process; entropy weight; cloud model

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1. Introduction

Resources, environment and population are the three major problems that human society is facing, especially the environmental problem, which is posing a serious threat to human survival and development [1–3]. Since economic reform and opening up, China has made historic achievements in development, but also accumulated a large number of ecological and environmental problems; environmental pollution is on the rise, and the discharge of major pollutants is still serious, which has become a weakness in all-round well-off society [4]. In the new historical situation and background, the Chinese government is also positively changing its style of ruling, practicing green concept and actively carrying out the practice of building energy conservation and emissions reduction.

The Chinese government has introduced the "12th five-year plan for energy conservation and emissions reduction ", "13th Five-Year plan for energy conservation and emission reduction comprehensive work plan" and "the evaluation index system of ecological civilization construction" among other laws and regulations and clearly points to "vigorously developing the circulation economy", "the implementation of energy conservation and emissions reduction project", "strengthen the main pollutant emission reduction", etc., and putting forward "strive to achieve carbon dioxide emissions peak before 2030, per unit of GDP carbon dioxide emissions lower than in 2005 by more than 65%, strive to become carbon neutral before 2060" and other "carbon peaking and carbon neutrality" targets and specific indicators. In the face of energy conservation and environmental protection related indicators and enterprise sustainable development strategy demand, many enterprises, especially the energy industry (the main waste water, waste gas, solid waste emissions units) have implemented a series of energy conservation and emissions reduction environmental protection measures (hereinafter referred to as energy saving and environmental protection, ESEP) management measures [5,6]. However, developing these projects has became the burden of the enterprise to a certain extent, which leads to less attention being paid, limited implementation, limited investment and other phenomena. In this context, it has become an important topic to fully understand the implementation of ESEP management in energy industry enterprises, to mobilize enterprises to carry out ESEP management actively, and improve the weak links of enterprises' ESEP management.

Some institutions, organizations and scholars have actively explored the issues of energy saving and environmental protection from different perspectives. Current research mainly focuses on the influencing factors on energy saving and emission reduction [7,8], policies [9,10], efficiency [11,12], and environmental performance evaluation [13,14]. In terms of energy saving and emission reduction efficiency evaluation and environmental performance evaluation, scholars have mainly constructed an evaluation index system from the perspective of product life cycle, sustainable development, input-output and pressure-response framework. For example, Wu and Chen (2014), on the basis of analyzing the content of the whole-process environmental management, established an index system for the performance evaluation of the whole-process of the environmental management of the enterprise, which involves various activities and links between the whole process of the enterprise, including green procurement, ecological design, cleaner production, green transportation, green sales, green use and the construction of green corporate culture [15]. Xue et al. (2022) established a comprehensive evaluation framework based on life cycle assessment and the protection supply curve to evaluate the benefits of energy saving and emission reduction [16]. Wei et al. (2018) constructed an urban environmental performance evaluation indicator system from the four aspects of environmental health, ecological protection, environmental governance and sustainable utilization of resources and energy based on the "driving-pressure-state-impact-response (DPSIR)" model [17]. Li et al. (2019) focus on green behaviors of enterprises and constructed an evaluation index system of green governance from four aspects: green governance framework, green governance mechanism, green governance efficiency and green governance responsibility [18]. The strategies of energy enterprises are very important to their existence and development [19]. Although these studies have carried out a comprehensive evaluation on all aspects of ESEP, they focus more on evaluation research from the perspective of performance, and the measurement of management performance related to ESEP still heavily relies on lagging indicators such as energy consumption, pollutant emission and resource recycling. There is still a lack of systematic and comprehensive evaluation of the ESEP management status of energy industry enterprises from the perspective of management.

In terms of the measurement and evaluation methods of regional energy conservation and environmental protection, most studies adopt qualitative or semi-qualitative methods such as the expert scoring method, questionnaire survey method, analytic hierarchy process and life cycle assessment, etc. [19,20]. The Cloud model is a new evaluation method especially studying compound uncertainty proposed by Li et al. [21]. Compared with traditional assessment methods, cloud model evaluation methods can better describe the randomness and fuzziness of evaluation objects or variables (e.g., judge whether a variable is closer to 2 or to 3 when its primary experimental value is 2.5), and realize the mapping and conversion between qualitative and quantitative uncertainty, which has been widely applied to sustainability assessment, risk assessment and many other fields [22,23]. Based on this, this study constructs the integration of an assessment framework including "governance framework, implementation process, governance effectiveness", and uses the combination weighting method of the cloud model to evaluate the ESEP management ability of listed companies in the energy industry, in order to clarify the present situation of ESEP disclosure, the ESEP management situation and ESEP weak links, investigating ESEP benchmark enterprises and key indicators in various industries, and then putting forward countermeasures and suggestions for improving and strengthening ESEP relevant work.

The innovations of this study are as follows: (1) Focusing on listed companies in the energy industry, the ESEP management evaluation system based on the evaluation framework of "governance framework, implementation process, governance effectiveness" is constructed, which enriches the research on ESEP management evaluation; (2) Combine with the information disclosure measurement method, establish the qualitative index rating basis, and collect the evaluation index data information based on the ESEP information disclosed by listed companies, further enriching the relevant research on ESEP management evaluation; (3) The cloud model theory is applied to ESEP management evaluation, and a management evaluation model based on combination weight-cloud evaluation is constructed, which can provide guidance for ESEP management evaluation research.

2. Methods

2.1. Construction of Evaluation Index System

Although some studies have carried out a comprehensive evaluation of enterprise's ESEP management, these studies focus more on evaluation research from the perspective of performance, and the measurement of management performance related to ESEP still heavily relies on lagging indicators such as energy consumption, pollutant emission and resource recycling. There is still a lack of systematic and comprehensive evaluation of ESEP management status of energy industry enterprises from the perspective of management. By reading a large number of relevant laws and regulations and relevant literature, combined with the actual situation of the energy industry and following the principles of scientific, systematic, comparable and operable index design, this study constructs an ESEP management evaluation index system for listed companies in the energy industry. The system is divided into three layers: (1) The target layer is ESEP comprehensive evaluation of listed companies in the energy industry; (2) The criterion layer is divided into four categories: governance framework, implementation process, governance effectiveness, and others; (3) The index layer is composed of 20 first-level indicators reflecting "governance framework, implementation process, governance effectiveness, public welfare, etc.", and calculation and evaluation instructions are provided under each indicator (see Table 1). These indicators can reflect the performance of enterprises in energy saving and environmental management in a comprehensive and systematic way, and the indicators are described below.

Table 1. Energy saving and environmental protection (ESEP) management evaluation index system of listed companies in the energy industry.

Target Layer	Criterion Layer B	Index Layer C	Index Introduction
Comprehensive evaluation on energy saving and environmental protection	B1-governance framework	C1~ESEP institutional system	Degree of completeness of relevant management system, department and committee (1–5)
		C2~ESEP management system	Degree of completeness and systematicness of relevant management system certification and implementation (1–5)
		C3~ESEP management culture	Degree of emphasis on ESEP and richness of education activities
		C4~ESEP clauses and policies	Degree of completeness of environmental provisions for customers or suppliers (1–5)
	B2-implementation process	C5~clean production management	Degree of completeness of green raw material procurement and cleaner production audit (1–5)
		C6~pollution reduction management	Diversity of management measures for emission reduction of three wastes and perfection of implementation (1–5)
		C7~recycling management	Diversity and perfection of resource recycling management measures (1–5)
		C8~energy efficiency improvement management	Diversity and implementation of energy efficiency management measures (1–5)
		C9~tackling climate change management	Diversity and implementation of GHG emission management measures (1–5)
		C10~environmental protection management	Diversity and perfection of environmental protection management measures (1–5)
		C11~green office management	Diversity and perfection of green office management measures (1–5)
	B3-governance effectiveness	C12~environmental pollution events	The number of pollution incidents
		C13~discharge of three wastes	Discharge of COD, SO2, NOX and solid waste per ten thousand yuan of output value
		C14~energy consumption situation,	Comprehensive energy consumption per ten thousand yuan of output value (ton of standard coal/Ten thousand yuan)
		C15~resource recycling	Water resource/ waste resource recycling utilization rate
		C16~other greenhouse emissions	CO2, CH4, N2O and other greenhouse gas emissions per ten thousand yuan output value
		C17~ecological environment construction	Added green area or animal and plant protection per ten thousand yuan of output value
		C18~ESEP influence	Relevant awards/honors/patents/paper grades (1–5)
		C19~ESEP special investment index.	Energy saving per ten thousand yuan output value/environmental protection special fund input
	B4-public welfare and others	C20~ESEP public welfare activities	Degree of participation in environmental public welfare activities (1–5)

(1) Governance framework: A reasonable governance framework can determine the vision, culture, strategy and system of a company's ESEP from the top design level, which is the basis and key to improving a company's ESEP level and sustainable development. Tian et al. (2015) believe that forward-looking environmental strategy can effectively promote enterprise green innovation, enhance enterprise green image and improve enterprise environmental performance [24]. Liao et al. (2015) propose that establishing a social responsibility committee, an environmental protection committee and other organizations to coordinate stakeholder relations can improve corporate social responsibility performance [25]. Baboukardos (2018) emphasizes the importance of environmental clauses and points out that companies with recognized environmental clauses would help investors clarify the future economic benefits and costs related to the company's environmental performance by sending signals of strong future financial performance or improving the reliability of environmental performance information [26]. Therefore, this study believes that the ESEP management system should cover the dimension of governance framework, and sets up indicators such as C1-SEP institutional system, C2-ESEP management system, C3-ESEP management culture, and C4-ESEP clauses and policies to evaluate the governance framework.

(2) Implementation process: Greening production and operation activities of enterprises is an important link to improving ESEP management level and sustainable development ability. For example, Wu and Chen (2014) believe that effective prevention and control measures should be adopted to carry out environmental management across the whole process of procurement, design, production, transportation, sales and use [15]. Du (2013) believes that source management (clean production) and process control (improving resource efficiency) are the key points in the construction of a "environment-friendly and resource-conserving society" [27]. Therefore, this study suggests this dimension of the ESEP management system should cover the implementation process, and has set up C5-clean production management, C6-pollution reduction management, C7-recycling management, C8-energy efficiency improvement management, C9-tackling climate change management, C10-environmental protection management, C11-green office management and other indicators to evaluate the implementation situation.

(3) Governance efficiency: the ESEP governance efficiency index mainly reflects the situation of enterprises in energy conservation, "three wastes" emission reduction, resource recycling and waste reuse, which can intuitively measure the performance of enterprises from environmental aspects. Some scholars also introduced these indicators in their studies to measure the environmental performance of enterprises. For example, Qin et al. (2004) synthesize the emission indexes of important pollution factors such as SO2, NOX and COD into a comprehensive index to express the environmental performance of enterprises [28]. Hao et al. (2014) use CO2 emissions as a proxy variable to study the environmental impact of industrial enterprises [29]. Wang et al. (2018) select R&D investment per unit energy consumption to measure the level of green innovation of enterprises [30]. Therefore, this study believes that it is necessary to incorporate the dimension of governance effectiveness into the ESEP evaluation system. Specifically, it includes C12-environmental pollution events, C13-discharge of three wastes, C14-energy consumption situation, C15-resource recycling, C16-other greenhouse emissions, C17-ecological environment construction, C18-ESEP influence, and C19-ESEP special investment index.

(4) Others: The setting of other dimensions is mainly to measure the participation of enterprises in environmental public welfare activities. Wang et al. (2015) point out that enterprises' active participation in environmental protection and public welfare can convey signals of enterprises' green governance status to investors on the one hand, and objectively reflect the implementation status of enterprises' environmental management on the other hand. Therefore, in this study, some factors of ESG related evaluation are used for reference, and ESEP public welfare and other dimensions are incorporated into the ESEP evaluation system, so as to comprehensively measure the performance of enterprises in external environmental public welfare and other aspects.

2.2. Combination Weight-Cloud Evaluation Comprehensive Evaluation Model

2.2.1. Combination Weight Model

The analytic hierarchy process (AHP) is a method of subjective empowerment, and its basic idea is to use the systematic idea of decomposition followed by synthesis to organize and synthesize people's subjective judgments, realize the organic combination of qualitative and quantitative analysis, and complete quantitative decision-making [31,32]. The general steps of the research using this method are: (1) establishing the hierarchical structure model; (2) constructing the judgment matrix; (3) calculating the index weights; (4) testing the consistency of the judgment matrix. In the specific operation, due to the problems of large calculation workload and tedious testing process, this study uses Yahhp software for subjective weight measurement. The entropy weight (EW) method is a method of objective assignment of weights, the core of which is to use the amount of data information of each indicator to determine the weight; when the evaluation data value of an evaluation indicator differs greatly, its entropy value is smaller, indicating that the evaluator has a greater difference in the sensitivity degree of the indicator, that is, the indicator can provide more reference information for the evaluation of the merits, and has greater significance within the evaluation system [33,34]. The general steps when using this method for research are: (1) standardization of data; (2) calculation of the entropy value of each indicator; (3) calculation of the weight vector of each indicator. This study used AHP-EW for combined weighting to obtain more accurate and objective weights. The specific formula can be found in the related literature [35].

2.2.2. Cloud Evaluation Model

The cloud model is a kind of evaluation method based on probability statistics and fuzzy set theory, and its evaluation results can be expressed by cloud digital features (E_x, E_n, H_e), which is schematically shown in Figure 1. When cloud model evaluation method is used, it can be realized by the cloud generator (CG), and four types of each cloud generator algorithm are shown in Figure 2. Specific algorithms can be found in the related literature.

2.2.3. Comprehensive Evaluation Model

This study uses a combination of combined weights and cloud model to evaluate the energy saving and environmental protection management status of the company, and the specific steps are as follows. When using this method for evaluation, the general steps are: (1) establish the weight factor set $W = \{\omega_1, \omega_2, \ldots, \omega_n\}$ of indicators; (2) determine the indicator set and the evaluation language domain $V = \{V_1, V_2, \ldots, V_m\}$, in this study, the evaluation language is divided into five levels: vigilance-level, improvement-level, transition-level, acceptable-level, and declarable-level; (3) determine the cloud parameter matrix (E_x, E_n, H_e) for each level of each indicator; (4) calculate the affiliation degree of each sample and each indicator; and (5) determine the evaluation level. The specific formula for each step is referred to in the related literature [36].

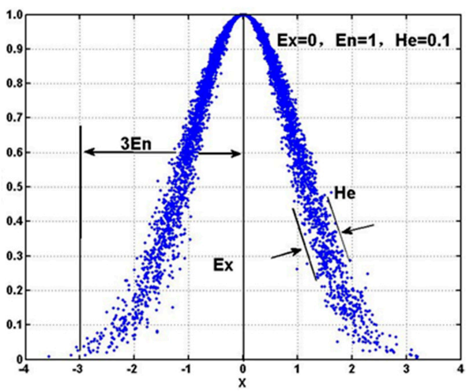

Figure 1. Normal cloud and digital features $(E_x = 0,\ E_n = 1,\ H_e = 0.1)$.

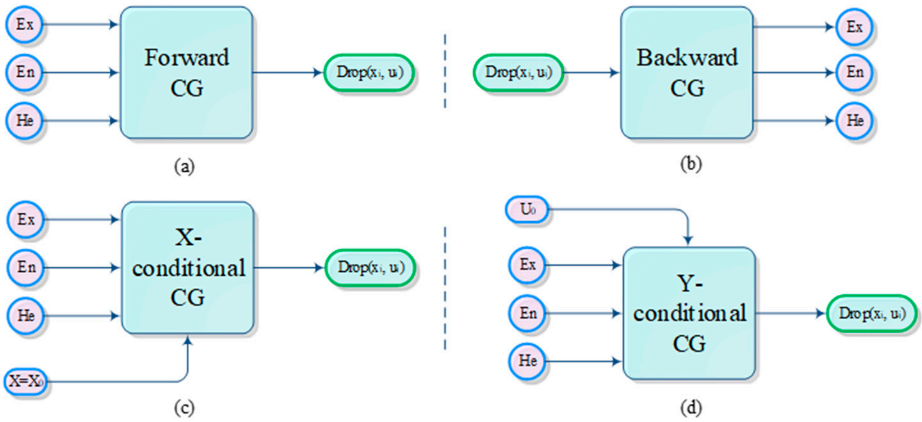

Figure 2. Schematic diagram of cloud generator. (**a**) Forward CG. (**b**) Backward CG. (**c**) X-conditional CG. (**d**) Y-conditional CG.

2.3. Data Collection and Samples

According to the Guidelines on Industry Classification of Listed Companies issued by CSRC, listed companies in the energy industry from 2006–2017 were selected for this study (industry codes 06, 07, 25, 44, 45, 46). The sample was also carefully screened (e.g., shaving off ST and *ST companies; shaving off companies listed after 2006, etc.), and after sample screening, 59 companies with 378 sample observations finally remained. It is worth noting that there are still 78 companies that did not release any ESEP-related reports during 2006–2018 and did not participate in this evaluation study.

The original data of this study can be divided into quantitative index data and qualitative index data. Quantitative indicators such as COD per ten thousand yuan output value, SO2, NOX, solid waste emissions, comprehensive energy consumption of ten thousand yuan output value (ton of standard coal/ten thousand yuan), etc. can be obtained or calculated through the social responsibility report, CSMAR database, enterprise official website and other channels. Quantitative indicators are difficult to be quantified by themselves, and they need to be quantified in combination with expert scoring and information disclosure measurement methods. Referring to relevant literature [37,38], this study uses 1–5 score points for quantification (see quantification standard of indicators in Table 2).

Table 2. Institutional indicators—Quantitative scoring standard.

Score	Specific Standard
5	The relevant institutions of ESEP are well established, such as systematic ESEP management system, specialized ESEP management department, ESEP management committee, and detailed text charts, data and information explanation
4	The relevant institutions of ESEP are relatively complete, such as ESEP management system, ESEP management department and ESEP management Committee.
3	The relevant institutions of ESEP are generally complete, with ESEP management system and departments, but no management committee.
2	The relevant institutions system of ESEP are not perfect, with only ESEP management system, no management department and management committee.
1	The relevant institutions system of ESEP is extremely imperfect, and there is no explanation on the construction of the institutional system of ESEP.

3. Results and Discussion

3.1. Analysis of Current Situation of Energy Saving and Environmental Protection Information

3.1.1. Quantitative Distribution of ESEP Information

Sorting out the quantity, quality and content of ESEP information released by listed companies in the energy industry is helpful for us to grasp its development status and trends as a whole. In order to investigate the quantity of ESEP information release, this study provides statistics on the ESEP information release of sample companies from 2006 to 2017, and the year-by-year change trend is shown in Figure 3.

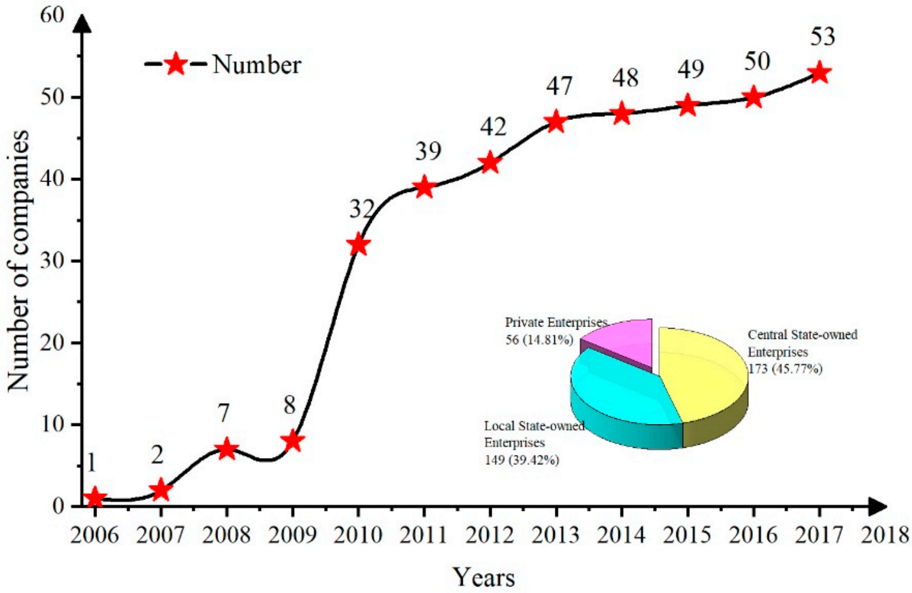

Figure 3. Quantity distribution of energy saving and environmental protection information disclosure.

As can be seen from Figure 4, the amount of ESEP information released in the energy industry showed a steady increasing trend during 2006–2017, but the release rate was still low. From 2006 to 2017, only 42.44% (N = 59) of enterprises in the energy industry released ESEP-related information reports (378 social responsibility reports/sustainability reports/employee responsibility reports), and 56.12% (N = 78) of enterprises did not release any ESEP-related information reports during this period. This shows that regular release of ESEP information has gradually become the consensus of listed companies in the energy industry, but there is still a big gap between the development of the national strategy of “beautiful China” and “healthy China”. After further concluding ESEP related information of the company, it can be found that the central state-owned enterprises ESEP information release quantity (45.41%) was significantly better than that of local state-owned enterprises and private enterprises, reflecting that the central state-owned enterprise society responsibility consciousness is stronger and ESEP management level is higher, but the local state-owned enterprises and private enterprises release quantity remains to be further improved.

3.1.2. Industry Distribution of ESEP Information

This study further provides statistics on the industry of the company releasing ESEP information. It can be seen from Table 3 that different industrys’ nature leads to great difference in the release rate of ESEP information. The oil and gas extraction industry has the highest release rate (80.00% in the last three years), while the gas production and supply industry has the lowest release rate (25.57%).

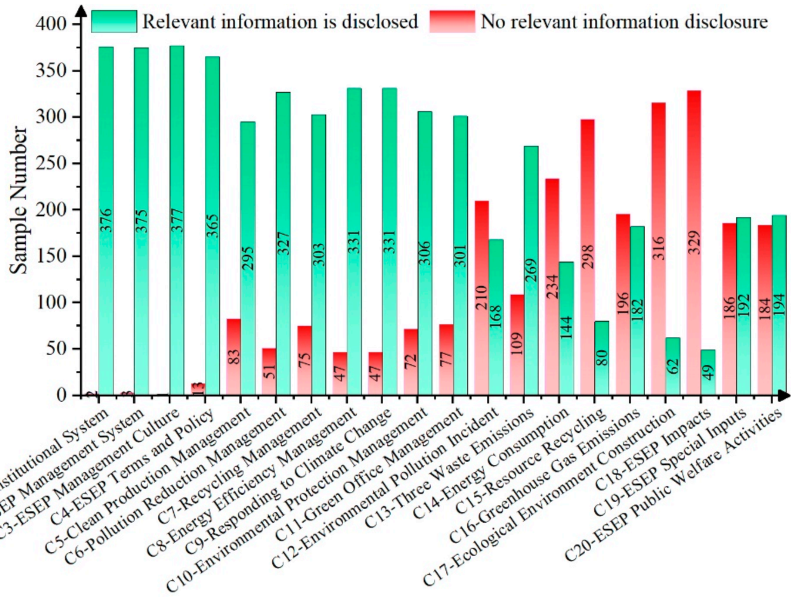

Figure 4. Distribution of energy saving and environmental protection information disclosure.

Table 3. Occupational safety and health related information industry distribution (in last three years).

The Name of the Industry	Release Quantity			Release Proportion		
	2015	2016	2017	2015	2016	2017
Coal mining and washing industry	13	14	13	48.15%	51.85%	48.15%
Oil and gas extraction	4	4	4	80.00%	80.00%	80.00%
Power and heat production and supply	23	22	23	32.86%	32.86%	32.86%
Gas production and supply	4	5	7	16.67%	20.83%	39.17%
Water production and supply industries	5	5	6	33.33%	33.33%	40.00%

3.1.3. Content Distribution of ESEP Information

In order to investigate the distribution of ESEP information content of sample companies, this study sorts out the distribution of ESEP information content based on the ESEP management evaluation system designed above (see Figure 4). As can be seen from Figure 3, on the whole, ESEP information content in the energy industry is relatively comprehensive, and the disclosure level of indicators that are represented by C1-management system, C2-management culture, C3-management system, and C4-clauses and policies reaches more than 90%. However, from the perspective of the disclosure quantity of each index, there are still problems such as the lack of standardization, systematization and comparability of ESEP information content. For example, the disclosure level of quantitative information of C18-ESEP influence, C17-ecological environment construction, C15-resource recycling and other indicators is low, and the disclosure is not scientific enough.

3.2. Evaluation Analysis of Cloud Model of Each Company

According to the ESEP evaluation framework constructed above, this study adopts the comprehensive evaluation cloud model to conduct equivalent evaluation of each sample company. The brief evaluation steps are as follows:

(1) AHP-EW method is selected to determine the factor subset of each index weight. (1) Firstly, on the basis of fully combing and referring to the ideas and methods of AHP, the subjective weight is obtained according to the operation steps of AHP; (2) Secondly, on the basis of obtaining relevant index data, the objective weight is obtained according to the operation steps of the entropy weight method (Formulas (1)–(4)). After getting the

subjective weight by AHP and the objective weight by entropy weight method, calculating according to Formula (5), the comprehensive weight of SHEE management evaluation of mineral resource-based listed companies can be obtained.

(2) According to the data value range of each index, determine the evaluation grade theory domain. By referring to relevant literature, this paper divides each indicator into five grades, which are used to evaluate the level of a company in a certain index: I-alert level, II-improvement level, III-transition level, IV-acceptable level, V-claimable level. Specific index levels are divided as follows: Taking index X1 (degree of perfection of mechanism system) as an example, the level I interval is [1, 1.5], the level II interval is [1.5, 2.5], the level III interval is [2.5, 3.5], the level IV interval is [3.5, 4.5], and the level V interval is [4.5, 5]. In the same way, all index grades can be obtained according to the Formula (10).

(3) According to Formula (6), the evaluation level corresponding to each indicator is represented by the corresponding cloud parameters $(E_x,\ E_n,\ H_e)$. Taking indicator X1 (degree of perfection of mechanism system) as an example, the parameters of level I interval cloud model are $(E_x,\ E_n,\ H_e) = (1,\ 0.17,\ 0.05)$. The parameters of the II level interval cloud model are $(E_x,\ E_n,\ H_e) = (2,\ 0.17,\ 0.05)$. The parameters of level III interval cloud model are $(E_x,\ E_n,\ H_e) = (3,\ 0.17,\ 0.05)$. The parameters of IV level interval cloud model were $(E_x,\ E_n,\ H_e) = (4,\ 0.17,\ 0.05)$. The parameters of the V level interval cloud model were $(E_x,\ E_n,\ H_e) = (5,\ 0.17,\ 0.05)$; Similarly, according to Formula (10), cloud parameter matrices of all indicators at all levels can be obtained.

(4) Taking the screened indicator data and acquired cloud digital characteristic values as parameters, and the X-conditional cloud generator in the model is used to input the algorithm program into Matlab2014 software for calculation, so as to obtain the membership degree of an experiment. In order to improve the accuracy and credibility of the data, the number of experiments was set as K = 2000, and the final membership degree could be obtained according to Formula (7). Due to space limitations, the membership calculation results of SINOPEC in 2017 are taken as an example (see Table 4).

Table 4. Membership degree of each index of SINOPEC ESEP management in 2017.

Comments	I Level	II Level	III Level	IV Level	V Level	Conclusion
C1~ESEP institutional system	0.0000	0.0001	0.2984	0.3233	0.3781	III level
C2~ESEP management system	0.0000	0.0000	0.0021	0.0012	0.9967	V level
C3~ESEP management culture	0.0000	0.0000	0.0002	0.0002	0.9997	V level
C4~ESEP clauses and policies	0.0000	0.0000	0.0501	0.0373	0.9126	V level
C5~clean production management	0.0000	0.0011	0.5001	0.4988	0.0000	III level
C6~pollution reduction management	0.0000	0.0003	0.2686	0.3138	0.4173	V level
C7~recycling management	0.0000	0.0011	0.4983	0.5006	0.0000	IV level
C8~energy efficiency improvement management	0.0000	0.0001	0.3175	0.3439	0.3384	III level
C9~tackling climate change management	0.0000	0.0000	0.2646	0.2760	0.4594	V level
C10~environmental protection management	0.0000	0.0002	0.2770	0.2875	0.4353	V level
C11~green office management	0.0000	0.0002	0.3903	0.2849	0.3247	V level
C12~environmental pollution events	0.0000	0.0000	0.0000	0.0000	1.0000	V level
C13~discharge of three wastes	0.0000	0.0011	0.4991	0.4998	0.0000	IV level
C14~energy consumption situation,	0.0000	0.0000	0.0409	0.0371	0.9219	V level
C15~resource recycling	0.0025	0.9940	0.0015	0.0020	0.0000	V level
C16~other greenhouse emissions	0.0000	0.0000	0.0000	0.0000	1.0000	V level
C17~ecological environment construction	0.9977	0.0023	0.0000	0.0000	0.0000	I level
C18~ESEP influence	0.1714	0.8268	0.0008	0.0010	0.0000	II level
C19~ESEP special investment index.	0.0000	0.0000	0.0000	0.0000	1.0000	V level
C20~ESEP public welfare activities	0.0000	0.0000	0.0000	0.0000	1.0000	V level

Comprehensive evaluation results vector are obtained by computing Formula (8): {0.0000, 0.0000, 0.4582, 0.4657, 0.0761}, based on the principles of maximum membership degree, corresponding to the maximum membership degree of evaluation grade as a result of comprehensive evaluation, that is, the comprehensive evaluation results for IV SINOPEC in 2017 indicate that its ESEP management level is at an acceptable level.

Similarly, the evaluation cloud level of all sample companies can be obtained, and the company level can be visualized after quantitative processing, as shown in Figure 5.

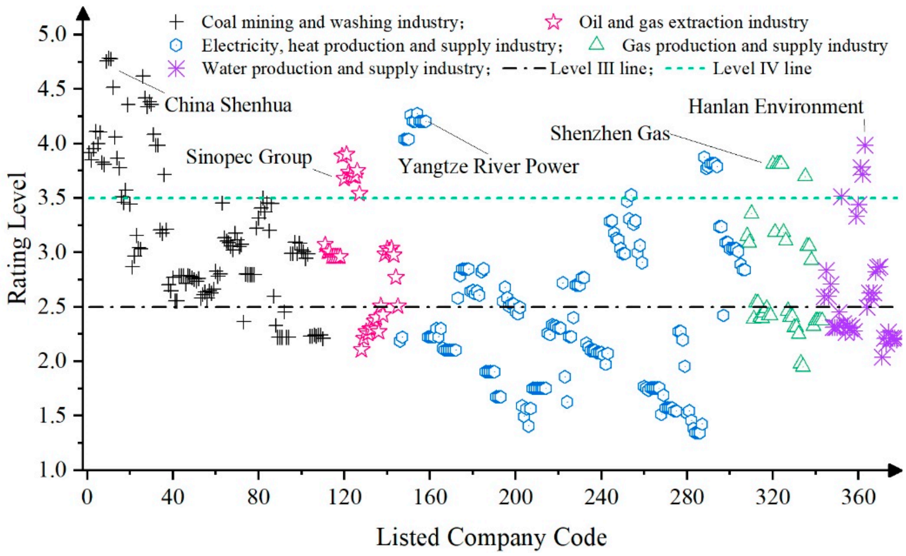

Figure 5. Comprehensive membership evaluation results of each company.

Figure 6 shows that the ESEP management level of most listed companies in the energy industry is between level II and III, indicating that the ESEP management level of most companies is between "transition level" and "improvement level". Further statistics on the number of samples at all levels showed that 1.32% (S = 5) of the samples belonged to class V, indicating that their ESEP management level reached the "claimable level"; 15.87% (S = 60) of the samples belonged to level IV, indicating that the ESEP management level reached the "acceptable level"; 56.611% (S = 214) of the samples belonged to level III, indicating that their ESEP management level reached the "transition level" level; 24.07% (S = 91) of the samples belonged to level II, indicating that their ESEP management level was at the "improvement level"; 2.11% (S = 8) of the samples belong to level I, indicating that their ESEP management level is at the "alert level". Further research shows that different industries have different ESEP management levels. The ESEP management levels from high to low are the coal mining and washing industry, oil and natural gas extraction industry, gas production and supply industry, water production and supply industry, power and heat production and supply industry. Among them, the coal mining and washing industry, oil and gas industry, electricity, heat production and supply industry, gas production and supply industry, water production and supply industry of 2018 ESEP management benchmarking enterprise respectively for China Shenhua (V), SINOPEC (IV), China Yangtze Power (IV), Shenzhen Gas (IV), Grandblue Environment (IV), etc. Some studies have found that the internationalization of the board of directors would enhance the tendency of listed companies' green business behavior [39], and the incentives of championships would also have a positive impact on the CEOs of listed companies to take environmental responsibility [40]. In the future, it can try to improve the level of energy saving and environmental protection practices of listed companies by guiding the internationalization of their boards of directors and actively carrying out ESEP activities in bidding competitions.

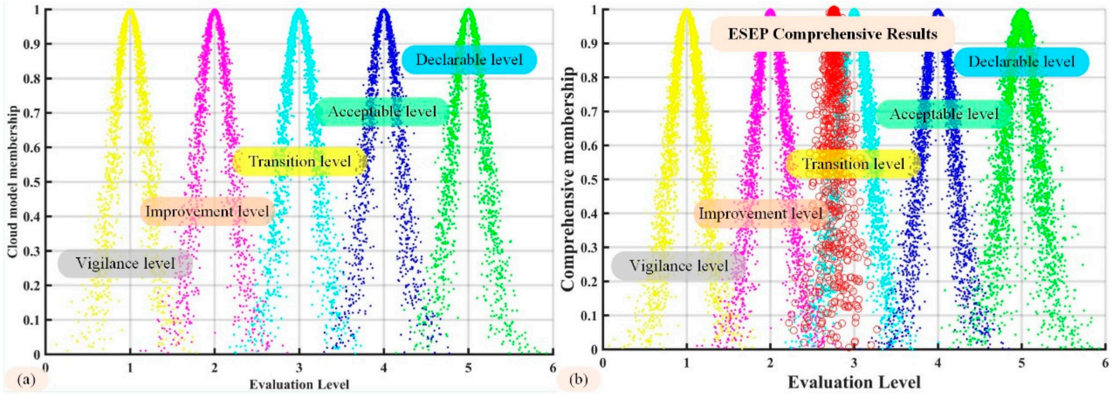

Figure 6. Evaluation cloud map of target layer and criterion layer. (**a**) Evaluation grade cloud scale; (**b**) ESEP comprehensive evaluation cloud chart.

3.3. Evaluation and Analysis of Each Indicator Cloud Model

Based on the screening index data, this study uses cloud generator in the cloud model, inputs the algorithm program operations into Matlab2014 software, sets all samples of each target cloud characteristic parameters (see Table 4), and sets cloud characteristic parameters of the criterion layer and target layer in turn by fuzzy arithmetic according to the Formula (8) (see Table 5).

Table 5. Characteristic values of cloud model.

Criterion Layer B	Index Layer C	Index Layer Cloud Model Parameter			Criterion Layer Cloud Model Parameter
		E_x	E_n	H_e	(E_x,E_n,H_e)
B1-governance framework	C1~ESEP institutional system	3.2078	0.0024	0.1440	3.4451, 0.0018, 0.1543
	C2~ESEP management system	3.6852	0.0009	0.1643	
	C3~ESEP management culture	3.5466	0.0018	0.1594	
	C4~ESEP clauses and policies	3.3735	0.0019	0.1509	
B2-implementation process	C5~clean production management	2.5137	0.0004	0.1022	2.9480, 0.0030, 0.1330
	C6~pollution reduction management	3.0846	0.0069	0.1504	
	C7~recycling management	2.9709	0.0032	0.1346	
	C8~energy efficiency improvement management	3.1635	0.0005	0.1363	
	C9~tackling climate change management	3.1196	0.0017	0.1376	
B3-governance effectiveness	C10~environmental protection management	2.9772	0.0001	0.1247	2.0852, 0.0019, 0.0776
	C11~green office management	2.9815	0.0066	0.1448	
	C12~environmental pollution events	2.5344	0.0082	0.0620	
	C13~discharge of three wastes	2.3127	0.0010	0.0854	
	C14~energy consumption situation,	1.9618	0.0032	0.0870	
	C15~resource recycling	1.6587	0.0022	0.0682	
	C16~other greenhouse emissions	1.9140	0.0030	0.0841	
	C17~ecological environment construction	1.4868	0.0016	0.0567	
	C18~ESEP influence	1.0831	0.0003	0.0214	
	C19~ESEP special investment index.	2.4651	0.0049	0.1161	
B4-others	C20~ESEP public welfare activities	2.0556	0.0035	0.0926	2.0556, 0.0035, 0.0926

After calculating, the cloud characteristic parameters of ESEP management are (2.7598, 0.0019, 0.1199). Based on the cloud characteristic parameters obtained above, combine with the cloud evaluation scale (Formula (6)), and use the forward cloud generator in the model to input the algorithm program into Matlab2014 software for calculation, so as to get the evaluation cloud map of target layer and criterion layer (see Figure 6).

As can be seen from Figure 6, the expected value of the comprehensive cloud of energy saving and environmental protection evaluation of listed companies in the energy industry $E_x = 2.7598$ falls between the "improvement level" and the "transition level", and it is more inclined to the "transition level". It can be seen that the energy conservation and environmental protection management of the energy industry is at the level between the "improvement level" and the "transition level". In addition, the entropy E_n of the evaluation result cloud is much smaller than that of the evaluation cloud, so it can be concluded that the evaluation result has a small range and good stability, reflecting that there is little difference between listed companies in energy conservation and environmental protection management, which may be caused by the fact that most companies are weak in energy conservation and environmental protection management. The result shows that H_e is relatively large, reflecting that cloud thickness is larger than the evaluation cloud, indicating that the energy conservation and environmental protection management of each company needs to be improved.

Similarly, cloud model graphs of B1-ESEP governance framework, B2-ESEP management implementation process, B3-ESEP governance efficiency, B4-ESEP public welfare and other criteria can be obtained, as shown in Figure 7.

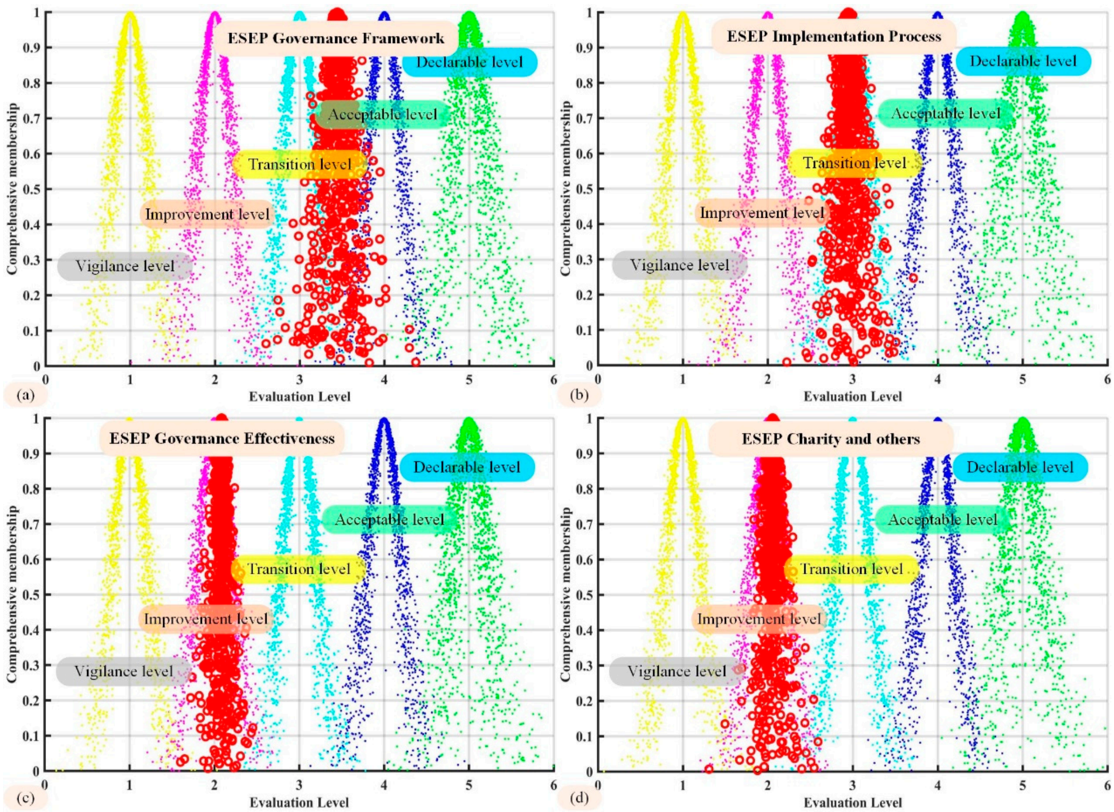

Figure 7. Evaluation cloud chart. (**a**) ESEP governance framework; (**b**) ESEP implementation process; (**c**) ESEP governance effectiveness; (**d**) ESEP charity and others.

This study further visualized E_x and its standard deviation in cloud model parameters for each indicator. It can be seen from Figure 8 that the cloud expectation value of most indicators fluctuated up and down the dividing line of level II~III, among which C2- management culture had the highest expectation value. This is followed by C3-management system, C4-clauses and policies, C1-institutional system, C8-energy efficiency management, and C9-tackling climate change management, indicating that most listed companies perform better in these aspects. It is worth noting that the C18-ESEP influence, C17-ecological environment construction, C16-greenhouse gas emissions, C14-energy consumption, and C13-waste emissions are weak. This indicates that the C18-ESEP influence, C17-ecological environment construction, C16-greenhouse gas emissions, C14-energy consumption, and C13-waste emissions are the key to further improving energy conservation and environmental protection management.

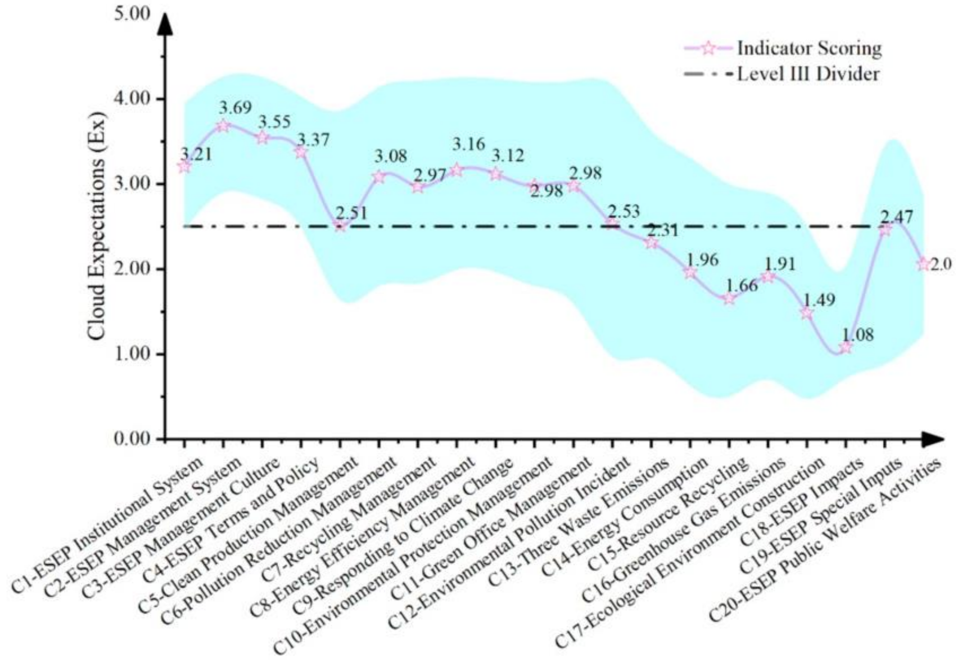

Figure 8. Expected value of each index cloud model.

This study further analyzes the original data of companies of all levels to clarify the focus of improvement of companies at all levels. The specific results are shown in Table 6.

3.4. Limitations

In the construction of the ESEP index system and quantitative research, this study strives to be scientific and rigorous, but there are still some deficiencies due to the limitations of many factors, and the specific limitations are as follows.

(1) The evaluation framework system and its indicators need to be further supplemented and modified. Due to the restriction of data availability, the index system itself cannot fully guarantee that it covers all the evaluation indicators reflecting ESEP management level, especially the evaluation of ESEP management performance. With the deepening of people's understanding of ESEP management, related evaluation indicators would be further expanded.

(2) The method of data acquisition needs to be further expanded. The ESEP management evaluation information in this paper mainly comes from the social responsibility report, sustainable development report, CSMAR database and company website issued by listed companies, which may lead to incomplete ESEP management information.

(3) The rationality of the evaluation results needs to be further verified. As some companies have adopted non-disclosure or selective disclosure in ESEP management, the evaluation results of this study may not fully represent the ESEP management level of these companies, and more comprehensive information can be collected by further combining questionnaire survey and other methods in subsequent research.

Table 6. Analysis of representative companies at each level.

Cloud Level	Representative Enterprise	Major Features etc.
V level	China Shenhua (2017)	(1) Perfect ESEP management system; Systematic energy conservation and environmental protection department; Environmental Protection Council; Attach great importance to environmental protection; Abundant energy conservation and environmental protection education activities; Implement ISO14001 environmental management; Systematic ESEP management system; Normative ESEP provisions; (2) Green procurement of raw materials; Environmentally friendly production; Clean production audit specification; Effective implementation of waste water, waste gas and solid waste reduction management, effective recycling of water resources, effective comprehensive utilization of solid waste; Diversification of energy efficiency measures, perfect implementation, diversification of climate change measures, effective management of greenhouse gas emissions, diversification of measures to reduce ecological environment damage, very effective restoration and governance of ecological environment, diversification of measures related to green office; (3) A large number of ESEP-related awards/honors/patents/papers with great influence; Ten thousand yuan output value environmental protection/high energy saving investment; (4) Participation in ESEP public welfare projects is general;
IV level	China Yangtze Power (2017)	(1) The institutional system, management culture, management system, terms and policies are relatively perfect; (2) Procurement of raw materials, product production, clean production, emission reduction of waste, water resources and solid waste recycling are all environmentally friendly, while energy efficiency improvement, tackling climate change and ecological environment recovery need to be further improved; (3) ESEP influence and ESEP investment are relatively weak; (4) Participation in ESEP public welfare projects needs to be improved;
III level	Datang International Power Generation (2017)	(1) The institutional system, management culture, management system, terms and policies are relatively perfect; (2) Procurement of raw materials, product production, clean production, emission reduction of waste, water resources and solid waste recycling are all environmentally friendly, while energy efficiency improvement, tackling climate change and ecological environment recovery need to be further improved; (3) ESEP influence and ESEP special investment are relatively weak; (4) Participation in ESEP public welfare projects needs to be improved;
II level	Guozhong Water (2017)	(1) Poor institutional system, management culture, management system and other aspects, and generally perfect terms and policies; (2) The procurement of raw materials, product production, clean production, emission reduction of three wastes, recycling of water resources and solid wastes are poor, and the implementation of energy efficiency improvement, tackling climate change and ecological environment restoration measures is mediocre; (3) There is no explanation of ESEP's influence and ESSP's input; (4) Poor participation in ESEP public welfare projects.
I level	Fuling Electric Power (2017)	C1-C20 are less disclosed, only indicating strict compliance with laws and regulations, implementation of some energy conservation and emission reduction measures, etc.

4. Conclusions and Suggestions

4.1. Conclusions

(1) The analysis results of the status quo of ESEP information indicate that the amount of ESEP information released shows a steady increasing trend, but the release rate is still low. Only 42.44% (N = 59) of energy enterprises released ESEP-related information reports (S = 378) from 2006 to 2017. The different nature of the industry leads to a great difference in the release rate of ESEP information, among which the release rate of the gas production and supply industry is the lowest (25.57% on average in recent 3 years). ESEP information content still has huge deficiencies in comparability, systematization and standardization. ESEP information content covers a wide range of areas, but quantitative information disclosure is less common.

(2) The results of cloud level analysis of all companies indicate that the energy conservation and environmental protection management level of most listed companies in the energy industry belongs to "III level-transition level" and "II level-improvement level", and only 17.19% of the sample enterprises are in the "IV level-acceptable level" and "V level-claim level". Further research shows that different industries have differences in ESEP management levels. The ESEP management levels from high to low are the coal mining and washing industry, oil and natural gas extraction industry, gas production and supply industry, water production and supply industry, power and heat production and supply industry. Among them, the coal mining and washing industry, oil and gas industry, electricity, heat production and supply industry, gas production and supply industry, water production and supply industry ESEP management benchmarking enterprise respectively for China Shenhua (V), SINOPEC (IV), China Yangtze Power (IV), Shenzhen Gas (IV), Grandblue Environment (IV), etc.

(3) Analysis results of cloud level of each indicator indicate that the expectation of most energy conservation and environmental protection management indexes fluctuates from level II to Level IV. C2-ESEP management culture, C3-ESEP management system, C4-ESEP clauses and policies, C1-ESEP institutional system, C8-energy efficiency management, C9-tackling climate change and other aspects perform well (reaching the "transition level" or above). In terms of C18-ESEP influence, C17-ecological environment construction, C16-greenhouse gas emissions, C14-energy consumption situation, and C13-discharge of three wastes, the performance is relatively weak (below the "transition level"). Further research shows that C17-ecological environment construction, C16- ecological environment construction, C15-greenhouse gas emissions, C14- energy consumption situation, and C13-discharge of three wastes are the key to further improve ESEP management level of level III to level IV enterprises. C2-ESEP management culture, C3-ESEP management system, C4-ESEP clauses and policies, C1-ESEP institutional system, C8-energy efficiency management and C9-tackling climate change are the key points in the construction of I~II level enterprises.

4.2. Suggestions

Based on the research conclusions, this study proposes the following improvement strategies for ESEP management.

(1) Strengthen the standards and supervision of ESEP information disclosure. At present, there is no systematic and authoritative framework and standard for enterprise's ESEP management disclosure, which leads to poor comparability, consistency and comprehensiveness of ESEP information disclosed by listed companies. As can be seen from the above results, there are some problems in ESEP management, such as low release rate of ESEP information and less quantitative disclosure of released content. In view of this, the government should establish and improve the relevant legal system to further regulate ESEP information disclosure. For example, enterprises can further improve ESEP management by setting minimum disclosure standards, standardizing disclosure formats, introducing authentication evaluation, including information disclosure in enterprise assessment, and imposing sanctions for false information.

(2) Actively carrying out ESEP management evaluation is an important measure to improve China's ESEP management level, but at present, no institution or scholar has conducted a systematic and comprehensive evaluation of ESEP management. Therefore, it is suggested that relevant departments establish a systematic, comprehensive, scientific, standardized, forward-looking and effective ESEP management evaluation system, actively carry out ESEP management evaluation work (such as establishing an ESEP management statistics system, etc.) and regularly release the evaluation results, so as to track and analyze the overall and sub-industry ESEP management status and change trend. It is expected to provide basic support for in-depth implementation of "energy conservation and emission reduction" and continuous improvement of the sustainable development capacity of enterprises.

(3) Give play to the exemplary role of benchmarking enterprises. As benchmarking enterprise of ESEP management coal mining and washing industry, oil and gas industry, electricity, heat production and supply industry, gas production and supply industry, water production and supply industry, China Shenhua, SINOPEC, China Yangtze Power, Shenzhen Gas, Grandblue Environment to enterprise are directional leaders in ESEP management reform and development. Relevant organizations should carry out ESEP management model selection activities, actively promote the ESEP management experience of model enterprises, promote these enterprises to maintain and improve ESEP management model image, and then influence and drive enterprises to improve ESEP management levels.

(4) Guide enterprises to continuously improve key links. Governance efficiency index is the core content of ESEP management, as well as the link that is most weak and most needs to improve. ESEP information disclosure of listed companies currently, including ESEP management influence, ESEP special investment, occupational disease incidence and other aspects, is respectively weak, and these weak links should be direction of further efforts for listed companies to improve their ESEP management level in the future. In view of this, it is feasible to increase the ESEP management impact by increasing the quality and quantity of awards/honors/papers/patents and to guide enterprises to increase ESEP special investment through green credit, green securities and other economic policies.

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