Research on environmental benefits of waste incineration power generation project

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Abstract. With the acceleration of China's urbanization process and the improvement of people's living standards, the total amount of household garbage is also increasing. For the garbage disposal, the traditional landfill disposal method not only leads to the waste of land resources, but also causes environmental pollution. The waste incineration power plant adopts advanced technology and equipment to minimize the environmental pollution caused by the discharged gases and pollutants, and generates a large amount of electric energy while harmlessly treating the garbage, which can effectively alleviate the city's electricity shortage, truly realize the resource treatment of urban waste and in line with the social concept of sustainable development. Therefore, it is necessary to pay attention to the research on the waste disposal method of waste incineration power generation, so as to generate greater environmental and energy benefits.

1. Introduction
Due to the dual benefits of environmental protection and energy generated by waste incineration power generation, the proportion of domestic waste incineration power generation in China is increasing year by year, while the proportion of landfill is decreasing year by year. As a result, incineration power generation is fast becoming the dominant direction of waste treatment. Waste incineration power plants are being promoted throughout the country. In 2016, the government explicitly requested that new waste incineration power generation projects be “mandatory” to apply the PPP model. In addition, the No. 92 document of the Finance Office of 2017, it was clearly pointed out that the government paid or the feasibility gap subsidy method was used to obtain returns, but the projects that did not establish project output with performance-linked payment mechanisms are not allowed to be placed in the database. Pay-for-performance is the key to achieve value for money and improve project operation efficiency [1]. Pay-for-performance should be established on the basis of a scientific and reasonable indicator system [2]. As there is no relatively complete indicator system for waste incineration power generation PPP projects at present, it is of great significance to carry out this study for the government to effectively supervise the operation of waste incineration power generation PPP projects and realize the maximization of environmental benefits.
2. Establish a performance evaluation index system for waste incineration power generation PPP projects

2.1. Principles of indicator system construction
This paper draws on the “3E” concept in the international government's performance evaluation of government financial funds: 3E is Economy, Effectiveness and Efficiency [3]. Today, considering the social level of our PPP waste incineration project and its close connection with environmental protection, the 5E principle is formed by supplementing Equity and Environmentalism on the basis of performance indicators. Fairness refers to the fairness of project output distribution among stakeholders, which reflects the ability of PPP projects to meet citizens' welfare and improve social benefits. Environmental protection refers to the ecological benefits closely related to the environment, such as pollution control and environmental protection. The second-level performance evaluation indicators of the waste incineration power generation PPP project are shown in figure below:

![Image](image.png)

**Figure 1.** The second-level indicators of the waste incineration power generation PPP project

2.2. Method of indicator system construction
Key Performance Indicators (KPI) combines the idea of quantitative assessment and target management. KPI closely focuses on the Performance goals of PPP projects, studies the goals so that the evaluations won't deviate from the strategic goals, accurately measures the overall project Performance and plays a role of quality evaluation. The core idea of KPI key performance indicator method comes from the "28 principle", which believes that nearly 80% of the workload of an enterprise is completed by the 20% critical behaviors that play a decisive role in the enterprise behavior [4]. In this paper, the selection of performance indicators of the waste incineration power generation PPP project is based on the KPI theory. According to the characteristics of the waste incineration power generation PPP project and the purpose of pay-for-performance, a decisive and relatively large index is selected to build the index system. Firstly, the initial indicators were selected by checking the literatures, and then analyzed, screened and scored by experts. Then, a key performance evaluation index system was constructed for the operation stage of the PPP project of waste incineration power generation based on the pay-for-performance goal.

2.3. Process of indicator system construction

2.3.1. Initial indicator set. In order to fully select the key performance indicators of the pay-for-performance oriented PPP project of waste incineration power generation, this article first related documents to the state, national and local budget performance evaluation index in common documents and relevant national provincial garbage incineration power plant operation management performance evaluation standards, the performance evaluation report (performance appraisal standards), technical specifications, pollution control standards and garbage disposal evaluation standard, Through careful
reading and summarization of relevant literatures of experts and scholars. Then, the three-level performance evaluation indexes of 51 waste incineration power generation PPP projects are preliminarily identified by the Literature check method.

2.3.2. Screening indicator set. Because this article research results-oriented index system is established, and the research goal is to link a pay-for-performance program for performance evaluation and the government, according to the assessment results, a pay-for-performance program. Therefore, some indicators such as unclear purpose, non-quantitative and feasible indicators in the initial indicator set can be further deleted, and comprehensively analyze the performance evaluation index system of the waste incineration power generation PPP project. The direction of perfect analysis mainly includes three aspects: 1 the purpose of performance indicators is clear; 2 the repeatability of performance indicators; 3 the difficulty level of obtaining performance indicators.

2.3.3. Final indicator set. This study investigated whether the experts in the industry agreed to the indicators after the improvement, and scored the importance of the indicators through the 5-level Likert scale to select the most important indicators. Analysis by SPSS software shows that the reliability of the data in this study meets the requirements, indicating that the survey is consistent and the results are reliable. Finally, the evaluation indicators with an average score of less than 3.5 were excluded, and five dimensions and 22 performance evaluation indicators were determined.

2.3.4. Comparison and selection of indicator weighting methods. In the evaluation indicator system, the influence degree of each indicator is different. In order to accurately carry out project evaluation and decision-making, it is necessary to evaluate the importance of each indicator and determine its weight. Weight is an attribute that can objectively reflect the indicator itself, and it is also the result of subjective and objective comprehensive measurement. Whether the weight is reasonable will directly affect the quality of evaluation. Entropy method, Delphi method, analytic hierarchy process (ahp) and principal component analysis (pca) are commonly used to determine the weight [5]. Since the entropy method is an objective valuation method, and the evaluation results are highly objective, the entropy method is selected for the performance evaluation system of the PPP waste incineration power generation project in this paper for the objective indicator weighting.

2.3.5. Using entropy method to determine indicator weight.
2.3.5.1. Calculation steps of entropy method
Entropy method is a kind of mathematical method to judge the degree of indicator dispersion. American mathematician and information theory founder shannon first put forward the "information entropy" theory in 1948, and gave the information entropy formula [6]. In the information theory, entropy is a
measure of uncertainty. The more information there is, the less uncertainty there is and the less entropy there is. Conversely, the smaller the amount of information, the greater the uncertainty and the higher the entropy. Entropy value can be used to determine the randomness of events, the degree of disorder and the degree of indicator dispersion. The greater the degree of indicator dispersion is, the greater the influence on the comprehensive evaluation will be, and the greater the weight will be. The entropy method is an objective weighting method, and the calculation steps to determine the indicator weight by the entropy method are as follows:

1. Assume that there are a total of m dimensions, and there are n indicators in each dimension. Calculate the proportion of the jth indicator in the i-th dimension

\[ P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, (i=1,2,...,m; j=1,2,...,n) \]  

2. Calculate the entropy of the jth indicator:

\[ e_j = -k \sum_{i=1}^{m} P_{ij} \ln P_{ij}, (k = 1/ \ln m, k \geq 0, e_j \geq 0) \]  

3. Calculate the entropy redundancy:

\[ d_j = 1 - e_j, (j=1,2,...,n) \]  

4. Calculate indicator weights:

\[ W_j = \frac{d_j}{\sum_{j=1}^{n} d_j}, (j=1,2,...,n) \]  

2.3.5.2. Weight calculation of performance evaluation indicator for waste incineration power generation PPP project

When the performance evaluation indicator system of waste incineration power generation PPP project uses the entropy method to determine the indicator weight, the dimension of the influencing factors of performance evaluation is first coded. In order to determine the weight of each indicator, this study issued a score table for five authoritative academics in the academic field, and used the entropy method to process the data obtained from the interview. The score sheet is scored in a form with a score of 10 points. First, experts are asked to score the performance of the five dimensions of the familiar PPP project, and then compare the refined indicators of the five dimensions of the familiar PPP project with each other. Experts believe that the five dimensions of economy, efficiency, effectiveness, environmental protection and Equity of waste incineration power generation PPP projects are equally important, each accounting for 20%. In addition, through the statistics of the score table, the statistical table of the performance evaluation refinement indicator of the waste incineration power generation PPP project is obtained, as shown in Table 1 below.
Table 1. Expert scoring statistics table under entropy method

| Annual waste incineration treatment rate (%) | first expert | second expert | third expert | fourth expert | fifth expert |
|---------------------------------------------|--------------|---------------|--------------|---------------|--------------|
| X_{11}                                      | 10           | 10            | 10           | 6             | 10           |

| Internet power up to standard rate X_{12}   | 6            | 10            | 6            | 6             | 2            |

| Each incineration line operates for hours per year X_{13} | 10 | 6 | 3 | 4 | 3 |

| Incinerator slag heat reduction rate X_{14} | 6 | 9 | 4 | 1 | 9 |

| Furnace temperature X_{15} | 10 | 3 | 6 | 1 | 3 |

| Equipment integrity rate X_{21} | 9 | 9 | 8 | 9 | 9 |

| Garbage reduction rate X_{22} | 6 | 9 | 5 | 5 | 9 |

| Unit investment employment effect X_{23} | 9 | 5 | 5 | 6 | 7 |

| Effective complaint settlement rate X_{24} | 6 | 9 | 3 | 2 | 1 |

| The contribution of labor productivity X_{25} | 9 | 5 | 1 | 5 | 1 |

| Flue gas treatment up to standard X_{31} | 9 | 10 | 8 | 9 | 9 |

| Fly ash handling up to standard X_{32} | 6 | 9 | 3 | 5 | 3 |

| Treatment of permeate X_{33} | 9 | 5 | 9 | 9 | 5 |

| Noise control compliance X_{34} | 8 | 9 | 1 | 4 | 3 |

| Odor control X_{35} | 5 | 2 | 1 | 1 | 1 |

| Safe operation rate X_{41} | 9 | 10 | 8 | 8 | 9 |

| The project promotes local social, economic and environmental (sustainable) development X_{42} | 4 | 9 | 6 | 4 | 6 |

| Stakeholder satisfaction X_{43} | 9 | 5 | 6 | 2 | 3 |

| Internal rate of return X_{51} | 9 | 9 | 8 | 8 | 9 |

| Reasonable risk sharing mechanism X_{52} | 9 | 8 | 9 | 10 | 9 |

| Operating cost savings rate X_{53} | 6 | 10 | 9 | 8 | 9 |

| The present value ratio of benefits to costs X_{54} | 5 | 9 | 8 | 7 | 10 |

(1) From the above table, the evaluation matrix A between the four indicators of the efficiency indicator dimension is obtained, and X_{ij} in the evaluation matrix represents the score of the i-th expert on the j-th indicator.

\[
A_1 = \begin{bmatrix}
10 & 6 & 10 & 6 & 10 \\
10 & 10 & 6 & 9 & 3 \\
10 & 6 & 3 & 4 & 6 \\
6 & 6 & 4 & 1 & 1 \\
10 & 2 & 3 & 9 & 3 
\end{bmatrix}
\]

Using formula (1), we get
\[
P_1 = \begin{bmatrix}
0.2174 & 0.2 & 0.3846 & 0.3103 & 0.4348 \\
0.2174 & 0.3333 & 0.2308 & 0.3103 & 0.1304 \\
0.2174 & 0.2 & 0.1154 & 0.2069 & 0.2069 \\
0.1304 & 0.2 & 0.1538 & 0.1379 & 0.1304 \\
0.2174 & 0.0667 & 0.1154 & 0.0345 & 0.0435 
\end{bmatrix}
\]

Using formula (2), the indicator entropy matrix e1 = (1.4497, 1.3766, 1.3583, 1.3122, 1.5655)

Using formula (3), entropy redundancy d1 = (-0.4497, -0.3766, -0.3583, -0.3122, -0.2565)

Formula (4) is used to refine the weight vector of the indicator in the efficiency indicator dimension W1= (0.26, 0.21, 0.20, 0.18, 0.15).

Using the same method, the weight vector W2= (0.26, 0.24, 0.24, 0.14, 0.12) of the indicator in the effect indicator dimension is calculated, and the weight vector W3= (0.26, 0.21, 0.24, 0.16, in the
environmental indicator dimension). 0.13), the weight vector of the refinement indicator in the fairness indicator dimension is \( W_4 = (0.37, 0.34, 0.29) \), and the weight vector of the refinement indicator in the economic indicator dimension is \( W_4 = (0.26, 0.26, 0.25, 0.22) \).

| Table 2. The weight table of performance evaluation indicators determined by entropy method |
|---------------------------------|---------------------------------|-----------------|-----------------|-----------------|
| Dimension                      | weight dimension                | refinement indicator                              | entropy value | entropy redundancy | weight |
| Efficiency indicator           | 0.2                             | Annual waste incineration treatment rate (%) \( X_{11} \) | 1.4497        | -0.4497          | 0.26             |
|                                |                                 | Internet power up to standard rate \( X_{12} \)     | 1.3766        | -0.3766          | 0.21             |
|                                |                                 | Each incineration line operates for hours per year \( X_{13} \) | 1.3583        | -0.3583          | 0.20             |
|                                |                                 | Incinerator slag heat reduction rate \( X_{14} \)   | 1.3122        | -0.3122          | 0.18             |
|                                |                                 | Furnace temperature \( X_{15} \)                    | 1.5655        | -0.2565          | 0.15             |
| Effectiveness indicator        | 0.2                             | Equipment integrity rate \( X_{21} \)               | 1.4640        | -0.4640          | 0.26             |
|                                |                                 | Garbage reduction rate \( X_{22} \)                 | 1.4323        | -0.4323          | 0.24             |
|                                |                                 | Unit investment employment effectiveness \( X_{23} \) | 1.4411        | -0.4411          | 0.24             |
|                                |                                 | Effective complaint settlement rate \( X_{24} \)   | 1.2452        | -0.2452          | 0.14             |
|                                |                                 | The contribution of labor productivity \( X_{25} \) | 1.2165        | -0.2165          | 0.12             |
| Environmental indicator        | 0.2                             | Flue gas treatment up to standard \( X_{31} \)      | 1.4627        | -0.4627          | 0.26             |
|                                |                                 | Fly ash handling up to standard \( X_{32} \)       | 1.3845        | -0.3845          | 0.21             |
|                                |                                 | Treatment of permeate \( X_{33} \)                 | 1.4314        | -0.4314          | 0.24             |
|                                |                                 | Noise control compliance \( X_{34} \)              | 1.2824        | -0.2824          | 0.16             |
|                                |                                 | Odor control \( X_{35} \)                          | 1.2372        | -0.2372          | 0.13             |
| Equity indicator               | 0.2                             | Safe operation rate \( X_{41} \)                   | 1.4617        | -0.4617          | 0.37             |
|                                |                                 | The project promotes local social, economic and environmental (sustainable) development \( X_{42} \) | 1.4214        | -0.4214          | 0.34             |
|                                |                                 | Stakeholder satisfaction \( X_{43} \)              | 1.3551        | -0.3551          | 0.29             |
| Economic indicator             | 0.2                             | Internal rate of return \( X_{51} \)               | 1.1597        | -0.1597          | 0.26             |
|                                |                                 | Reasonable risk sharing mechanism \( X_{52} \)     | 1.1592        | -0.1592          | 0.26             |
|                                |                                 | Operating cost savings rate \( X_{53} \)           | 1.1511        | -0.1511          | 0.25             |
|                                |                                 | The present value ratio of benefits to costs \( X_{54} \) | 1.1329        | -0.1329          | 0.22             |

Through calculation, the entropy value matrix, entropy redundancy, and weight are determined by entropy method. The results of 22 indicator weights of PPP project performance evaluation of waste incineration power generation are shown in Table 2 above.
3. Conclusion

With the rapid development of various aspects in China, the current waste incineration power generation project is an important infrastructure for urban sustainable development. As the leading direction of the current garbage disposal, it not only produces environmental benefits, but also brings energy benefits. Compared with traditional landfills. Buried treatment method, waste incineration power generation project is more environmentally friendly and efficient to solve the problem of domestic garbage pollution and improve the environment. This study has better waste cleaning and harmless treatment effect and environmental protection benefits for waste incineration power plant projects. It also has practical practical significance to create environmental benefits for society and the public and to improve the overall environmental quality level.

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