A Three-level Sustainability Evaluation Framework for Electric Energy Substitution Project

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Abstract. By establishing sustainability evaluation framework suitable for electric energy substitute project, combining technical & economic analysis methods and analytic hierarchy process, the sustainability of electric energy substitute project could be quantified and measured. The sustainability of the electric energy substitute project is analyzed, and then the key factors that affect the sustainability of the electric energy substitute project is found out. Based on this, a three-level sustainability evaluation framework including 12 indicators is established and the analytic hierarchy process is adopted to calculate the weight of sustainability evaluation index of electric energy substitute project. Our proposed framework can be applied to quantitatively evaluate the sustainability of electrical energy substitution projects.

Introduction

The theory of "sustainable development" has received wide attention since it was put forward. Sustainable development is a kind of growth mode that pays attention to the long-term development of economy and society, and it is one of the basic requirements of the scientific development view of China [1]. The application of the theory can be divided into the sustainable development at the macro level and the sustainable development at the micro level.

The sustainable development of the project is a more microcosmic application of sustainable development theory. The sustainable development of the project integrates the concept of sustainable development into the whole life cycle of the project including phase preparation, establishment, design and construction, making the economic effect of the project sustainable and effective, coordinating with the natural environment and resources, and adapting to the social development [2].

The electric energy substitution uses the electric energy to replace the scattered coal, the fuel oil energy consumption way in the terminal energy consumption link. The electric energy substitution includes the electric heating, the ground energy heat pump, the industrial electric boiler (kiln), the agricultural electricity drainage irrigation, the electric automobile, port shore power, the airport bridge loading equipment, the electric storage energy regulation and so on [3]. Electric energy has the advantages of being clean, safe and convenient. The implementation of electric energy substitution is of great significance to promoting the revolution in energy consumption, implementing the national energy strategy and promoting the development of clean energy, and is an effective measure to increase the proportion of electric coal, control the total amount of coal consumption and reduce air pollution.

The sustainability evaluation of electric energy substitute project (SEEESP) evaluates the internal competitiveness, external environment and social benefits of the electric energy substitute project from the point of view of sustainable development, and evaluates the state of sustainability of the
project and the strength and weakness of sustainability. Different from the traditional techno-economic evaluation, the SEEESP can evaluate the sustainable competitiveness of the project, the ability of continuous development, the ability of coordination with resources and environment and the sustainable ability of social benefits at any stage of the whole life cycle [4]. By establishing sustainability evaluation framework suitable for electric energy substitute project, combining technical and economic analysis method and fuzzy comprehensive evaluation method, the sustainability of electric energy substitute project is measured.

Related Work

The SEEESP is a new research direction, so there is very few related studies. The healthy development of electric energy substitute project can promote the adjustment of energy structure and protect ecological environment effectively in China. It is very important to evaluate the sustainability of electric energy substitute project from the perspective of sustainable development.

(1) SEEESP is conducive to improving the economic efficiency and competitiveness of electric energy substitution projects. SEEESP is used to evaluate the internal management capability and technical competitiveness of electric energy substitution projects, analyze and demonstrate the economic and technological rationality and sustainability of the projects [5]. It is conducive to improving the technical advanced level and the scientific level of management of electric energy substitution projects during their operation, improving the ability to use advanced electric energy substitution technologies, optimizing the use of investment funds, so as to achieve the long-term sustainable economic competitiveness of electric energy substitution projects.

(2) SEEESP is beneficial to clarify the external sustainability status of electric energy substitute projects and improve the coordination degree of electric energy substitute projects and resources, ecological environment and power grid construction [6]. The external sustainability of electric energy substitute projects plays a vital role in ensuring the continuous effectiveness of the project. By measuring the degree of harmony between energy substitution projects in terms of resources and environment, the degree of coordination with other energy use modes in local areas, and the compatibility with the development of local power grids, the factors that are detrimental to sustainability are found, so as to improve the sustainability of electric energy substitution projects and external environment, and promote the healthy and benign development of electric energy substitution projects.

(3) SEEESP is beneficial to improve the social benefits of electric energy substitute projects. The social benefits evaluation of electric energy substitute projects is to evaluate the various net benefits brought to the society by electric energy substitute projects. The social benefits include the improvement of local residents’ income level, the promotion of living environment in the region and the improvement of employment situation, etc. The construction of electric energy substitute projects has an important pulling effect on the economic and social development of the local areas, bringing significant social benefits to local society. To evaluate the social benefits of energy substitution projects from the perspective of sustainable development can ensure that the social benefits of electric energy substitution projects continue to be effective.

Constructing Sustainable Evaluation Framework

The sustainable evaluation framework constructs from three aspects: the sustainability of internal competitiveness, the sustainability of external environment and the sustainability of social benefits. The electric energy substitute project with strong internal competitiveness has strong self-development ability, core competence and the ability of continuous development. The electric energy substitute project with strong external environment sustainability has strong external coordination ability. The sustainability of social benefit make the electric energy substitute project have strong sustainability in future operation and development.

The three-level sustainability evaluation framework including 12 indicators is showed as table 1.
Table 1. Three-Level Sustainability Evaluation Framework.

<table>
<thead>
<tr>
<th>Level I indicators</th>
<th>Level II indicators</th>
<th>level III indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1: The sustainability of internal competitiveness</td>
<td>I21: Management Capability</td>
<td>I31: Total Assets Turnover Rate</td>
</tr>
<tr>
<td></td>
<td>I22: Technical Competitiveness</td>
<td>I32: Total Labor Productivity</td>
</tr>
<tr>
<td></td>
<td>I23: Power Supply Capacity</td>
<td>I33: Unit Cost</td>
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<td></td>
<td>I24: Power Grid Coordination</td>
<td>I34: Technical Advancement</td>
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<td></td>
<td>I25: Social Environmental Benefits</td>
<td>I35: Equipment Utilization Hours</td>
</tr>
<tr>
<td>I2: The sustainability of external environment</td>
<td>I36: Regional Electricity Consumption Growth Rate</td>
<td>I36: Regional Electricity Consumption Growth Rate</td>
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<td></td>
<td>I37: Policy Environment</td>
<td>I37: Policy Environment</td>
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<tr>
<td></td>
<td>I38: Grid Matching Degree</td>
<td>I38: Grid Matching Degree</td>
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<tr>
<td></td>
<td>I39: Grid Dispatching Capacity</td>
<td>I39: Grid Dispatching Capacity</td>
</tr>
<tr>
<td>I3: The sustainability of social environmental benefits</td>
<td>I3A: Environmental Protection Publicity Effect</td>
<td>I3A: Environmental Protection Publicity Effect</td>
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<td></td>
<td>I3B: Environmental Benefit</td>
<td>I3B: Environmental Benefit</td>
</tr>
<tr>
<td></td>
<td>I3C: Living Environment Improvement</td>
<td>I3C: Living Environment Improvement</td>
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**Internal Competitiveness**

The management ability is the basic index to measure the internal competitiveness. The electric energy substitute project with strong management ability has strong operation ability and profit ability, can better integrate resources and make rational use of them, what determine the development ability of the electric energy substitute project. The technical competitiveness is the internal core competitiveness of the electric energy substitute project, and the higher technical level can guarantee the sustained and effective competitiveness of the electric energy substitute project.

*Total Assets Turnover Rate:* the turnover ratio of total assets refers to the ratio of total operating income to average total assets in a given period of time (one year). The index can evaluate the operation quality and efficiency of all assets of electric energy substitute projects. The higher turnover ratio of total assets indicates that the electric energy substitute projects have fast turnover speed of total assets, high utilization ratio of assets, strong operation ability and competitiveness.

*Total Labor Productivity:* total labor productivity refers to the value of the products produced by each employee in a certain period (one year). This index reflects the level of labor productivity and technical proficiency of employees, and it is an important index to measure the human resource management ability of electric energy substitution projects. Since electric energy substitution projects usually reduce the number of employees compared with their predecessors, total labor productivity can well reflect the technical level and professional quality of employees in electrical energy substitution projects, and evaluate the human resource management ability of projects from the perspective of measuring output.

*Unit Cost:* unit cost refers to the cost per unit of product used. This index reflect the cost management capability of electrical energy substitute project. In the whole life cycle of electrical energy substitute project, it can effectively reflect the cost change, make the project strengthen the cost management and improve the competitiveness. In the comparison between electrical energy substitute projects, the project with low unit cost has better internal competitiveness.

*Technical Advancement:* the better the advance of electric energy substitute technology, the stronger the internal competitiveness of the electric energy substitute project. For the qualitative analysis and evaluation of the advance of electric energy substitute technology, we should not only evaluate the total power of the electric energy substitute project, but also combine the technical level, the adaptability, the performance of grid-connection and the maintenance cost.

*Equipment Utilization Hours:* the utilization hours of equipment refer to the utilization hours of equipment under the condition of full load operation in a certain period of time (one year). Since there is no comparison between different electric energy substitute projects, the utilization hours of equipment can well characterize the utilization rate of equipment, which shows whether the electric energy substitute projects are competitive or not.
**External Environment**

The external environmental sustainability evaluation indexes for electric energy substitute projects can be divided into power supply capacity and grid coordination degree. Good power supply capacity and excellent grid coordination degree reflect that power consumption for electric energy substitute projects can be satisfied smoothly, avoiding the risk of power shortage. So electric energy substitute projects can be developed in coordination with the grid at the same time.

*Regional Electricity Consumption Growth Rate:* the growth rate of regional electricity consumption reflects the annual growth of electricity consumption in the load center area of the electrical energy substitution project. If the growth rate of electricity consumption is high, the power supply capacity is strong; if the growth rate of electricity consumption is small or even negative, the growth rate of regional electricity consumption is slow and the power supply capacity is weak.

*Policy:* the policy environment of electric energy substitution is a qualitative index, which refers to whether there are definite policies and measures in the target area to promote the proportion of electric energy substitution in the energy consumption structure and to encourage the development of electric energy substitution and to expand the absorptive capacity of electric energy substitution projects.

*Grid Matching Degree:* The degree of grid matching refers to the degree of matching between the transmission equipment provided by the power grid for electric energy substitution projects, which is a qualitative index. Whether the grid is stable and advanced will affect the degree of coordination between the increase of power consumption in the load area of electric energy substitution projects and the grid. If power grid matching lags behind the development of electric energy substitution projects, it will limit the power consumption of electric energy substitution projects, thus affecting the sustainability of electric energy substitution projects.

*Grid Dispatching Capacity:* power dispatching refers to the management means that, in order to ensure the safe and stable operation of power grids, the operating parameters of power grids are adjusted in real time according to the load level on the demand side of power grids. Reliable transmission and supply of electric power are guaranteed through the adjustment of voltage, current, frequency and load. Powerful dispatching capability of power grid can complete the dispatching work of power supply for electric energy substitution projects and ensure the operation of electric energy substitution projects.

**Social Benefits**

The social environmental benefit index refers to the contribution and influence that the electric energy substitute project brings to the local social environment during its development, construction and operation. The social environmental benefit index is difficult to be evaluated by quantitative analysis, so three qualitative indexes are used to evaluate the social environmental benefit of the electric energy substitute project.

*Environmental Protection Publicity Effect:* through the local construction of electric energy substitution projects, it is possible to publicize the use of clean energy and the importance of energy restructuring. Good environmental protection publicity enable people to understand clean energy, attach importance to clean energy, use clean energy and reduce environmental pollution, thus supporting the development of electric energy substitution projects, forming a virtuous circle and ensuring the sustainable and effective social benefits of electrical energy substitution projects.

*Living Environment Improvement:* the index of improvement degree of living environment reflects the degree of improvement of local living environment during the operation of electric energy substitute project. The operation of electric energy substitute project brings about the improvement of local electrification level and brings convenience and cleanliness to people's life.

*Environmental Benefit:* the environmental benefit index is a comprehensive qualitative index including the benefit of emission reduction and the saving of kerosene resources. The electric energy substitute project with good environmental benefit can be coordinated with the natural environment and enhance the sustainability of the environment.
Implementation of Sustainability Evaluation

This paper uses AHP to determine the weight of sustainability evaluation index for electric energy substitute project.

(1) We compare the first-order index of sustainability evaluation for electric energy substitute project and constructs a judging matrix of the comparison between the two indexes.

<table>
<thead>
<tr>
<th>Level I indicators</th>
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<th>I2</th>
<th>I3</th>
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<tbody>
<tr>
<td>I1</td>
<td>b11</td>
<td>b12</td>
<td>b13</td>
</tr>
<tr>
<td>I2</td>
<td>b21</td>
<td>b22</td>
<td>b23</td>
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<tr>
<td>I3</td>
<td>b31</td>
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<td>b33</td>
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(2) Consistency test of Judgment matrix. It should not appear the contradictory situation to each index relative important degree judgment. If the judgments of several experts are contradictory, experts should be organized to re-judge the importance of the indicators. The steps of the consistency test are as follows. First, the maximal characteristic root $\hat{\lambda}_{\text{max}}$ of the judgment matrix is obtained; secondly, extent of deviation from consistency is calculated, $CI = \frac{\hat{\lambda}_{\text{max}}-P}{P-1}$; and finally, the stochastic consistency ratio CR, $CR=CI/RI$ is calculated, in which $RI$ is a constant parameter related to the number of experts $P$. When $CR<0.1$, it can be judged to pass the consistency test, and when $CR \geq 0.1$, the judgment matrix needs to be adjusted until it passes the consistency test.

(3) Several experts assign values to elements in the matrix. $b_{ij}$ represents the comparative value of indicator $I_i$ to the relative importance of indicator $I_j$, quantifying the importance relationship between the two indicators by 1, 2, 3, 4, 5 or 1/5, 1/4, 1/3, 1/2.

(4) Sum by column and normalize the matrix to get the weights $w_i$ of indicator $I_i$

$$w_i = \frac{b_i}{\sum_{j=1}^{P} b_j} , \quad b_i = \sum_{j=1}^{P} b_{ij} .$$

(5) Repeat the above steps to obtain the second and third level indicator weights.

Summary

This paper analyzes the sustainability of the electric energy substitute project, clarifies the sustainable status of the project, finds out the key factors that affect the sustainability of the electric energy substitute project, and constructs three-level sustainable evaluation framework including 12 indicators, then uses the analytic hierarchy process (AHP) to calculate the weight of sustainability evaluation index. The method proposed in this paper can be used to quantitatively evaluate the sustainability of electrical energy substitution projects.

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