Comparative Study on Development, Application and Benefit of Typical Electric Heating Projects in China

Baoguo Zhao¹, Yan Xie¹, Jian Zhang¹, Xin Lu², Liang Yue³* and YongLi Wang⁴

¹State Grid Tianjin Electric Power Company, Tianjin, 300000, China
²State Grid (Tianjin) Integrated Energy Service Co., Ltd., Tianjin, 300000, China
³Beijing Zhongdian Feihua Communication Co., Ltd., Beijing, 102200, China
⁴North China Electric Power University, Beijing, 102200, China
*Corresponding author’s e-mail:m15210225501@163.com

Abstract. In recent years, the continuous severe fog and haze weather in China has caused serious damage to people's health. In order to make the public aware of the characteristics of electric heating, this paper first analyzes the technical scheme of electric heating and provides suggestions for the choice of electric heating mode. Then, taking a project in a certain area of North China as an example, from the aspects of annual cost, energy consumption, pollutant discharge, etc., the application of electric heating and other heating methods to analyze the economic, environmental and social benefits, and the overall benefit of electric heating is quantitatively evaluated. According to the evaluation results, some suggestions for the healthy development of electric heating are provided, which has important practical reference significance for the implementation of electric heating.

1. Introduction

Many scholars at home and abroad have also analyzed the benefits of electric heating replacement. Glassley and William E[1] and others have evaluated the economy of ground source heat pump system by studying the deployment of ground source heat pump systems in 30 large cities in the United States. Oliver David[2] conducted thermo-economic analysis by establishing an economic evaluation method for renewable energy technologies.

The economies of scale of renewable energy technologies such as ground source heat pump are demonstrated. Blum Philip[3] analyzed the technical and economic factors affecting the ground source heat pump system, and found that the economic benefits of the ground source heat pump system can only be realized when the system scale reaches a certain level. Zhang Yinping, Liu Xin and others [4~7] conducted an empirical study on the technology and economy of all-weather operation of phase change material electric panel heating using low-energy electricity. Sun Yi and Xu Peng [8] conducted in-depth analysis and exposition on the new technical background of "internet plus" smart energy and the alternative development route of electric energy under the market environment.

2. Theories and methods

The traditional project comprehensive benefit evaluation mostly adopts analytic hierarchy process. This research combines fuzzy set theory and analytic hierarchy process theory, uses fuzzy comprehensive evaluation method to evaluate and analyze the social benefits of electric heating, and
uses analytic hierarchy process (AHP) to determine the weight value of each index, i.e. uses expert consultation method to construct a two-two comparison judgment matrix, obtains the matrix feature vector and root, and carries out consistency test to obtain the weight of each index.

1) constructing a judgment matrix

According to the 1-9 scale method to construct the judgment matrix, the scale method is as follows: In the constructed judgment matrix \( A = (a_{ij})_{n \times n} \), elements \( a_{ij} \) represent the ratio of the relative importance of elements i and j, and they have the following relationships:

\[
\begin{align*}
1) & \quad a_{ii} = 1; \quad 2) \quad a_{ij} \neq 0; \quad 3) \quad \frac{1}{a_{ij}} = a_{ji} (i, j = 1, 2, \ldots, n).
\end{align*}
\]

2) Carry out consistency check (first calculate weight)

The calculation steps are as follows:

Step 1. Calculation of the product \( M_i \) of elements in each row of the judgment matrix.

\[
M_i = \prod_{j=1}^{n} a_{ij}, i = 1, 2, \ldots, n
\]

Step 2. calculation of \( \bar{W}_i \) that is n-th root of \( M_i \):

\[
\bar{W}_i = \sqrt[n]{M_i}
\]

Step 3. Normalization of Vector

\[
\bar{W} = \left[ \bar{W}_1, \bar{W}_2, \ldots, \bar{W}_n \right]^T
\]

Step 4. Calculation of Maximum Characteristic Root \( \lambda_{\text{max}} \) of Judgment Matrix

\[
\lambda_{\text{max}} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i}, \text{among } (AW_i) \text{ represents the } i\text{-th element of vector } AW.
\]

Step 5. Consistency Test of Judgment Matrix

During the inspection, consistency index CI and consistency ratio CR shall be calculated:

\[
\text{CI} = (\lambda_{\text{max}} - n)/(n-1)\quad \text{(2-3)}
\]

\[
\text{CR} = \text{CI}/ R\quad \text{(2-4)}
\]

When CR is less than or equal to 0.10, it is considered that the judgment matrix meets the consistency, and single sorting can be performed. When CR is more than 0.10, it is considered that the consistency deviation of the judgment matrix is too large and needs to be corrected until the judgment matrix has satisfactory consistency.

3) Delphi method is adopted to ensure the objective, fair and accurate evaluation results as much as possible by consulting experts. an expert questionnaire on social impact evaluation of electric heating is designed, and \( n \) experts (n is generally an integer of \( N>30 \)) are invited to grade the indexes in the questionnaire. The evaluation set is defined as \( E=(E_1, E_2, E_3, E_4, E_5)= \) (very large, large, medium, small, very small).

Assuming that \( n \) questionnaires are actually collected and the results of the \( n \) questionnaires are statistically analyzed, the membership matrix of the secondary index to the comment set is obtained, and the expression is as follows:
Fuzzy comprehensive evaluation needs to comprehensively consider the influence of all factors to obtain the correct evaluation result.

Firstly, the evaluation matrix $R_k$ of each sub-factor layer index $C_{ki}$ is subjected to fuzzy matrix operation to obtain the subordinate direction $B_k$ of the main factor layer index $C_k$ to the comment set:

$$B_k = W_k \cdot R_k = (W_{k1}, W_{k2}, \ldots, W_{kn})$$

(2-6)

4) Fuzzy Comprehensive Evaluation Analysis

Single factor fuzzy evaluation only reflects the influence of one factor on the evaluation object. Fuzzy comprehensive evaluation needs to comprehensively consider the influence of all factors to obtain the correct evaluation result.

Firstly, the evaluation matrix $R_k$ of each sub-factor layer index $C_{ki}$ is subjected to fuzzy matrix operation to obtain the subordinate direction $B_k$ of the main factor layer index $C_k$ to the comment set:

Fuzzy comprehensive evaluation can be expressed as:

$$B_k = W_k \cdot R_k = (W_{k1}, W_{k2}, \ldots, W_{kn})$$

(2-6)

3. Case analysis

With the continuous expansion of residential buildings, people's requirements for the environment are getting higher and higher, and the demand for room heating in winter is increasing year by year. North China, Northwest China and Northeast China, north of Qinling Mountains and Huaihe River, have always been traditional main heating areas. Heating in winter in these areas is a necessary condition for residents' production and life.

### Table 3-1. Evaluation Index of Comprehensive Benefits of Electric Heating

| Target | Classified evaluation index | Individual evaluation index | Electric heating users | Community residents along the line | Peer experts | Heating department managers | Commercial users along the line |
|--------|-----------------------------|-----------------------------|-----------------------|-----------------------------------|-------------|---------------------------|-----------------------------|
| Social equity C1 | Social efficiency index C | employment effect C11 | 0.0483 | 0.5154 | 0.3822 | 0.0444 | 0.0097 |
| | | income distribution benefit C12 | 0.0444 | 0.4537 | 0.3842 | 0.0869 | 0.0309 |
| | | per capita income growth rate of residents C13 | 0.290 | 0.4357 | 0.4054 | 0.1063 | 0.0328 |
| | | regional competitiveness C14 | 0.1680 | 0.5000 | 0.3031 | 0.2015 | 0.0039 |
| | | social Engel coefficient C15 | 0.0232 | 0.4131 | 0.3880 | 0.1313 | 0.0444 |
| | | Gini coefficient C16 | 0.0193 | 0.4595 | 0.3983 | 0.1062 | 0.0212 |
| | | social security rate C17 | 0.0598 | 0.4459 | 0.4170 | 0.0376 | 0.0097 |
| Social justice C2 | Improving quality of life C21 | balance of payments C24 | 0.0888 | 0.4537 | 0.3919 | 0.0425 | 0.0232 |
| | | access to resources C25 | 0.0483 | 0.4050 | 0.4247 | 0.0656 | 0.0376 |
Firstly, the fuzzy matrix operation is performed on the evaluation matrix $R_{kj}$ of the sub-factor layer index $C_{kj}$, because the comprehensive evaluation of all factors of the overall social impact evaluation should be considered. The synthesis operation here adopts the multiplication operation suitable for the common matrix to obtain the membership vector of the main prime layer index $C_k$ for the comment $B_k$ set:

$$B_1 = (0.0543, 0.4727, 0.3836, 0.0699, 0.0196)$$

$$B_2 = (0.0648, 0.4183, 0.4113, 0.0755, 0.0293)$$

$$B_3 = (0.0870, 0.4392, 0.4078, 0.0491, 0.0170)$$

$$B_4 = (0.0959, 0.4110, 0.4461, 0.0372, 0.0101)$$

$$R = \begin{bmatrix}
B_1 \\
B_2 \\
B_3 \\
B_4
\end{bmatrix} = \begin{bmatrix}
0.0543 & 0.4727 & 0.3836 & 0.0699 & 0.0196 \\
0.0648 & 0.4183 & 0.4113 & 0.0755 & 0.0293 \\
0.0870 & 0.4392 & 0.4078 & 0.0491 & 0.0170 \\
0.0959 & 0.4110 & 0.4461 & 0.0372 & 0.0101
\end{bmatrix}$$

Then the fuzzy matrix operation is carried out on $r$. The membership vector $B$ of the target layer index $C$ to the comment set is obtained.
Evaluation results: Therefore, we can conclude that the fuzzy membership degree of the project belongs to (very large, large, medium, small, very small) is:
\[ B = (0.0858, 0.4319, 0.4173, 0.0489, 0.0160) \]

Fuzzy comprehensive evaluation method is used to evaluate the social impact of electric heating project. According to the principle of maximum membership degree, it is finally shown that the typical electric heating project can achieve better social benefits. After the implementation of electric heating, the degree of social fairness and justice is higher, which is conducive to the sustainable development of society. Its promotion brings new development opportunities to relevant industries in the region, has more significant promotion effect on the region, and is conducive to the harmonious development of society.

4. Conclusion
In order to enable the public to better understand the advantages of electric heating and accept and adopt this new type of heating form, this paper analyzes the technical scheme of electric heating, and makes an in-depth comparative study between electric heating and heating methods such as coal burning and gas burning from the angles of economy, environment and social benefits, and draws the following conclusions:

1) The main domestic electric heating technologies are classified, the characteristics of various electric heating technologies are introduced, and suggestions are provided for the electric heating application technologies of various heating objects according to the characteristics of various electric heating technologies.
2) In comparison, direct electric heating of electric boilers is not economically feasible.
3) Electric heating replacement has remarkable social benefits.

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