

Comprehensive Benefit Evaluation of Energy-saving Technologies for Typical Energy Intensive Enterprise

Chaoyang Xu, Kaibin Wu, Zejing Qiu

NARI Group Corporation Nari (Wuhan) Electrical Equipment & Engineering Efficiency Evaluation Center Wuhan 430074, China

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Abstract. On the basis of the typical common energy-saving technologies in the energy intensive enterprises researched and assessed, the comprehensive benefits of six typical high energy-saving technologies were selected and researched. In this paper, with Analytic Hierarchy Process (AHP), by setting energy efficiency indexes, economic indexes, life cycle indexes, comprehensive benefit evaluation system was formed, thus the comprehensive benefit evaluation model was established. The comprehensive benefit evaluation of six energy-saving technologies in the typical energy intensive enterprises was evaluated by evaluation index and model. The results showed that: the evaluation and assessment model constructed in this paper can scientifically evaluate the overall efficiency of energy-saving technologies in energy intensive enterprises, providing a reference for the preferred energy-saving technologies.

1. Introduction

At present, with energy-saving boom, energy-saving technologies promoted after another, but the lack of a complete & comprehensive evaluation system and assessment model to evaluate the practical energy saving effect and potential impact of energy-saving technologies^[1-2], leading there are some obstacles to select energy-saving technologies for the energy services company, and affected the actual project effect in the implementation of energy-saving process.

To solve the above problems, high-energy common energy-saving technologies were Preliminarily select for energy conservation needs of users, considered the energy efficiency, economic and environmental benefits of energy-saving technologies, studied the comprehensive evaluation system, and built the comprehensive evaluation model with mathematical modeling theory and comprehensive evaluation theory of energy-saving technology^[3-4], The quantitative assessment methods and models were Provided for the integrated assessment of energy-saving technologies, so as to promote the rational use of energy-efficient technologies.

Based on the thorough combing the state's key energy-saving technologies promotion directory, the Ministry of Science and Technology Support Program 11 energy saving advanced technology industry directory, as well as domestic and international professional bodies and other sources of energy-saving technology, the high-energy saving technologies for typical users was selected: frequency control system to optimize energy-saving technology, rare earth permanent magnet disc coreless motor technology, low temperature and low voltage aluminum cell structure optimization^[5], the new energy-saving technologies aluminum reduction cell cathode structure, Controlled auto-regulating distribution transformer capacity, dynamic harmonic suppression and reactive power compensation comprehensive energy-saving technologies.

2. Evaluation Index of typical high-energy user energy-saving technologies

2.1 Typical high-energy user technical indexes

To be able to carry out scientific and reasonable benefit evaluation of typical high efficiency energy saving technologies, The energy efficiency indicators, economic indicators^[6-7], the life-cycle indicators were selected as level indexes, and energy saving potential, reductions, savings income, reductions income, payback period, current and 2017 technology penetration were selected as secondary indexes, the meaning and the calculation of the indicators were given in Table 1.

Table 1 Typical high energy users technical indexes

| Secondary indexes | Formula | Scholium |
|--------------------------------|--|--|
| Energy saving potential | $G_j = (G_z \times \eta_j) \times \eta_m$ | Where: Gj defined as energy saving potential, tce/a; Gz defined as energy consumption, tce/a; η_j defined as Saving rate, %; η_m defined as current technology penetration, %. |
| Reductions | $P_n = E_{ice} \lambda_n$ | Where: Pn defined as pollutant emission reductions, t; En defined as energy savings, tce; λ_n defined as pollutant emission coefficients, t/tce. |
| Savings income | $Inc_f = E_1 c_1 + E_2 c_2 + E_3 c_3 + \dots E_n c_n$ | Where: En defined as Various energy savings, t; Cn defined as Various energy prices, ten thousand/t. |
| Reductions income | $Inc_{T_{xx}} = T_1 \gamma_1 + T_2 \gamma_2 + T_3 \gamma_3 + \dots T_{xx} \gamma_{xx}$ | Where: TXX defined as Revenue reductions, ten thousand; PXX defined as Gas emission reductions, kg; γ_{XX} defined as A gas price reductions, yuan/kg; XX defined as A gas. |
| Payback period | $P_t = Inv / (Inc - Cos)$ | Where: Inv defined as System initial investment; Inc defined as Annual income; Cos defined as Annual costs. |
| Current technology penetration | $\eta_m = n_g / n_z$ | Where: η_m defined as current technology penetration, %; n_g defined as Number of current technology pervasive devices; n_z defined as Current number of applications Equipment Technology. |
| 2017 technology penetration | $\eta_{2017} = n_g / n_z$ | Where: η_{2017} defined as 2017 technology penetration, %. |

2.2 Typical high energy user energy-saving technologies specification system

The hierarchy of High energy user comprehensive energy evaluation system were positioned on three main evaluation factors: energy efficiency indicators, economic indicators, life cycle indicators of the typical high energy user.

Starting from this three aspects, the implementation and future energy-saving expected of the typical high energy users measures were comprehensive evaluated by measuring the energy efficiency, economic benefits, life cycle of energy-consuming enterprises.

Based on the evaluation of qualitative and quantitative analysis, Each indicator also broken down by specific indicators of evaluation to achieve accurate, scientific, systematic evaluation of the target. The comprehensive evaluation index system of the typical high energy saving technology was shown in Figure 1.

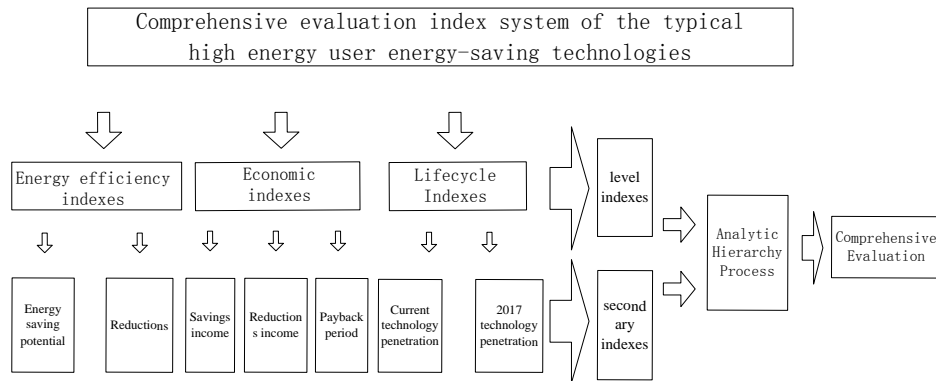


Figure1 Comprehensive evaluation index system of the typical high energy user energy-saving technologies

3. Comprehensive Assessment Model of the typical high energy user energy-saving technologies

3.1 Principle of Analytic Hierarchy Process

Analytic Hierarchy Process model was established substantially according to the following four steps: (1) establishment of a hierarchical structure model; (2) construct all levels in all judgment matrix; and (3) single-level sorting and consistency check; (4) the total level sorting and consistency check.

To compare the effect of n factor $X = \{x_1, x_2, \dots, x_n\}$ of a factor Z size, how to compare for credible data? Saaty et al suggestions could be taken to establish a pairwise comparison matrix approach by pairwising comparison factor. That is, each taking two factors x_i and x_j , a_{ij} represent the impact ratio of x_i and x_j on Z , The comparison matrix $A = (a_{ij})_{n \times n}$ represent all the results, and A called paired comparison judgment matrix between Z and X . Judgment matrix A corresponding to the feature vector W of maximum eigenvalue λ_{\max} , A factor in the relative ranking of importance weights were normalized to the same level after the previous level for the corresponding factor.

On how to determine the value of a_{ij} , Saaty, etc. Suggested citation of numbers 1-9 and the reciprocal as scale. the meaning of the 1-9 scale was listed in Table 2:

Table 2 the meaning of the 1-9 scale

| Scale | Meaning |
|------------|---|
| 1 | |
| 3 | Represents the two factors that are of the same importance |
| 5 | The former is slightly more important than the latter for the two factors |
| 7 | Compared with the two factors, the former is significantly more important than the latter |
| 9 | Compared to the two factors, the former is more important than the latter. |
| 2,4,6,8 | The former is more important than the latter in the two factors. |
| Reciprocal | The intermediate value of the adjacent judgment If the importance ratio of factor i and j is a_{ij} , then $a_{ji}=1/a_{ij}$. |

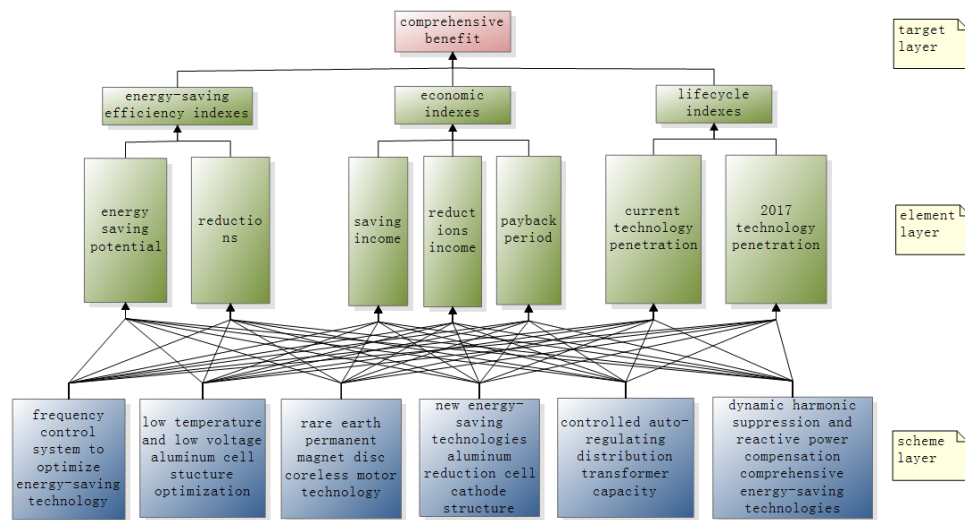


Figure 2 The Energy-saving technologies of typical high energy consumption level structure model

3.2 Comprehensive benefit evaluation model of typical high energy consuming user energy saving technologies

Based on the characteristics of analytic hierarchy process, it can be reasonably applied to the analysis and research of energy saving technologies of typical high energy consumption. According to the characteristics of the typical high energy consuming user energy saving technologies, the influence factors were classified and the criterion layer was formed. At last, According to the solution to improve the energy efficiency of the typical high energy consumption, the scheme layer in the analysis model was formed, and the hierarchical structure model was established.

Based on the typical high energy consumption user's energy efficiency indexes, economic benefit indexes, life cycle indexes using analytic hierarchy process, through the complex problem decomposed into several levels and some factors, the simple comparison and calculation, the decision-making process of the complex system was modeled and quantified. The sub index weights of three benefit were obtained, which could provide basis for the choice of best scheme by using this method. And the Yaahp software was used for modeling as shown in figure 2.

4. case analysis

Based on the data research, secondary indexes of the six kinds of typical energy saving technologies of high energy consumption were got by the application of typical high energy consumption and energy saving technology index system, it was shown in table 3.

Table 3 Secondary indexes of the typical energy saving technologies

| Project indexes | unit | Frequency control system to optimize energy-saving technology C1 | low temperature and low voltage aluminum cell structure optimization C2 | rare earth permanent magnet disc coreless motor technology C3 | new energy -saving technologies aluminum reduction cell cathode structure C4 | Controlled auto-regulating distribution transformer capacity C5 | dynamic harmonic suppression and reactive power compensation comprehensive energy-saving technologies C6 |
|--------------------------------|----------------------------|--|---|---|--|---|--|
| Energy saving potential | million tons standard coal | 10 | 35 | 30 | 100 | 65 | 8 |
| Reductions | million t | 26.31 | 92.085 | 78.93 | 263.1 | 171.015 | 21.048 |
| Savings income | million yuan | 8000 | 28000 | 24000 | 80000 | 52000 | 6400 |
| Reductions income | million yuan | 1205.4 | 4218.9 | 3616.2 | 12054 | 7835.1 | 964.32 |
| Payback period | annual | 2 | 1 | 5 | 5 | 6 | 4 |
| Current technology penetration | % | 5 | 30 | 3 | 15 | 1 | 1 |
| 2017 technology penetration | % | 10 | 60 | 8 | 30 | 5 | 15 |

The comprehensive benefit of typical high-energy user's energy-saving technologies example was evaluated in this section, namely getting the priorities of typical high-energy users energy-saving technologies according to the comprehensive benefit evaluation of energy saving technologies. Among them, the indexes of energy-saving benefit, economic benefit life cycle could be quantified. based on the analytic hierarchy process, weights were calculated by the software yaahp, and the results of the the indexes weights factor at various levels and comprehensive benefit was shown in table 3.

Table 4 Weight factors of the typical energy saving technologies

| Level indexes | weights | Secondary indexes | weights |
|---------------------------|---------|--------------------------------|---------|
| Energy efficiency indexes | 0.4206 | Energy saving potential | 0.3505 |
| | | Reductions | 0.0701 |
| | | Savings income | 0.1054 |
| Economic indexes | 0.3545 | Reductions income | 0.0581 |
| | | Payback period | 0.1911 |
| Lifecycle indexes | 0.2249 | Current technology penetration | 0.0375 |
| | | 2017 technology penetration | 0.1874 |

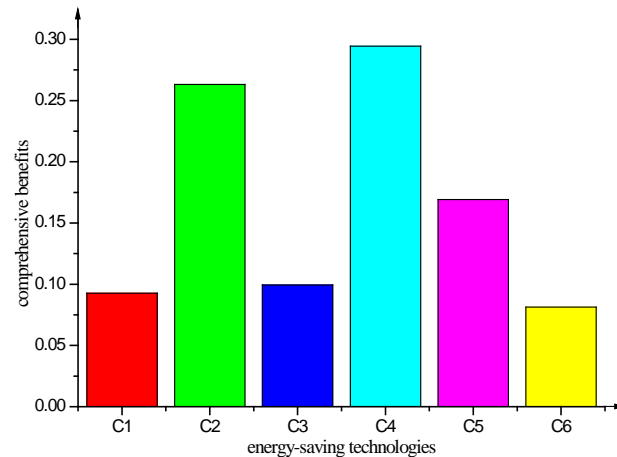
The comprehensive benefits of six kinds of energy saving technology C were Calculated on the basis of analytic hierarchy process, the result was $C_1=0.0926$, $C_2=0.2631$, $C_3=0.0993$, $C_4=0.2945$, $C_5=0.1692$, $C_6=0.0813$; The calculation results curve was shown in figure 3,

Figure 3 the comprehensive benefit comparison chart of six kinds of energy saving technologies

According to the comprehensive benefit value, the comprehensive benefit of six typical high-energy users energy-saving technologies was sorted, and the result was as followed.

$$C_4 > C_2 > C_5 > C_3 > C_1 > C_6$$

Therefore, the application sequence of the six typical high-energy users energy-saving technologies was the new energy-saving technologies aluminum reduction cell cathode structure, low temperature and low voltage aluminum cell structure optimization, Controlled auto-regulating distribution transformer capacity, frequency control system to optimize energy-saving technology, rare earth permanent magnet disc coreless motor technology ,dynamic harmonic suppression and reactive power compensation comprehensive energy-saving technologies.



As a demonstration project of the similar energy saving technology, this kind of evaluation indexes, evaluation model of the energy saving technology and the analysis of the evaluation results could provide referential basis for selective preference of the later related typical high-energy users energy-saving technologies.

5. Conclusion

Based on the overall energy intensive industries investigated and assessed, six typical energy-saving technologies in energy intensive enterprises were selected, building the evaluation indexes system of three aspects in energy-saving benefit indexes, economic benefit index and lifecycle indexes, and using the analytic hierarchy process to evaluate the energy conservation technology application benefit,

The result was that the new energy-saving technologies aluminum reduction cell cathode structure, low temperature and low voltage aluminum cell structure optimization, Controlled auto-regulating distribution transformer capacity was preferable, it could provide selective preference for energy-saving technologies in typical energy intensive enterprise and reference for energy-saving project investment.

Reference

- [1] Lohr Steve, "Energy Use Can Be Cut by efficiency, Survey Says," New York Times, November 29, 2006.
- [2] Zafer Utlua, Arif Hepbasli, A review on analyzing and evaluating the energy utilization efficiency of countries, Renewable and Sustainable Energy Reviews 11(2007): 1-29.
- [3] FENG Zhi-Bing, JIN Hong-Guang. Performance assessment of combined cooling, heating and power []. Journal of engineering thermophysics. 2005, 9(26): 725-728.
- [4] ZHAI Qin, KANG Yan-Bin, Niu bo energy efficiency administration in the US and me Enlightenment to China[J]. Energy of china, 2003, 25(7): 8-14.
- [5] Yang Zhi-Rong. Energy saving and energy efficiency management[M], China electric power press, 2009, 9.
- [6] Hu Zhao-Guang, Han Xin-Yang. Comprehensive resource strategy planning and demand side management theory and practice [M]. China electric power press. 2008, 2.
- [7] Zhou Jing-Hong. Strategic planning model theory and comprehensive energy efficiency power plant resources research [D], North China electric power university: 2011.