IOP Conf. Series: Materials Science and Engineering **382** (2018) 052009 doi:10.1088/1757-899X/382/5/052009

Research on Comprehensive Evaluation System of Urban Energy Data Based on AHP Method

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Abstract: This paper aims at establishing a new system to evaluate the level of urban energy development. With the continuous progress of urban energy transformation, it is an urgent problem to make effective use of urban energy data to evaluate the development of urban energy. By summarizing the characteristics of urban energy data and analyzing the application demand of energy management departments such as electric power enterprises at present, the basic principles of selecting energy data evaluation index are determined. Through the study of the classification of energy data, the evaluation indexes are initially selected. Then, based on the analytic hierarchy process, optimize the evaluation indexes. Finally, this paper establishes a comprehensive evaluation system which can reasonably describe the energy development model, as we see from the example of Suzhou.

1. Introduction

Energy is an important material basis for protecting human production and living activities, and is also an important force to promote the development of human civilization [1].However, the utilization of energy on the one hand has created a lot of social material wealth. On the other hand, it has also caused huge consumption of resources, as well as air, soil and water pollution. Among them, the city is not only the high intensity area of energy consumption, but also the most concentrated area of environmental pollution as well as global population. Therefore, for the sustainable development of the economy and society, the construction of an "energy saving and intelligent management" city has become a top priority. As an important issue of building new energy city, how to evaluate the level of urban energy development has become the key issue of energy policy formulation and urban sustainable development.

There are a large number of literature at home and abroad to study the comprehensive evaluation system of urban energy data. They are mainly concentrated in two aspects. On the one hand, it is the selection of the evaluation index of energy data. It is reported in [2] that taking the construction of low carbon city as the goal, the distribution structure of carbon emissions is analyzed from three viewpoints (energy structure, economic structure, urban and rural structure), then, the paper analyzes the main influencing factors of carbon emission from the view of population, economy and energy by establishing the evaluation index system which includes 16 composite indexes from five aspects of quantity, structure, strength, efficiency, carbon sequestration construction. Document [3] aims at improving energy efficiency. By analyzing the research status of energy efficiency at home and abroad, this paper finds out the pros and cons of single factor method for energy efficiency analysis, and find out the input and output indicators of the total factor method for evaluating energy efficiency, and makes a comparative analysis of them. Most of the existing urban energy data evaluation indicators focus on one goal, which can't meet the need of building "green, efficient and sustainable" new city. On the other hand, the research is mainly focused on the construction of the evaluation model. Document [4] summarizes and analyzes the current situation of energy efficiency evaluation method, then adopts TOPSIS method to comprehensively evaluate the distributed energy system of natural gas, and constructs a comprehensive evaluation system including energy efficiency, economic and environmental indicators. Document [5] establishes a sustainable urban construction and evaluation index system with "driving force - pressure - state - impact response" (DPSIR) as a conceptual model. Most of the existing evaluation system cannot achieve the unification of subjectivity and objectivity when determining index weight, and it is more difficult to get the actual value of the indicators. Besides, the comprehensive evaluation steps are too complicated to realize.

This paper analyzes the characteristics of city energy data, and summarizes the application demand of energy management department. Choosing the construction of international energy transformation model city [6] as the goal, we firstly select the evaluation index which are widely used and representative, and then in order to lower the dimension of energy evaluation index, we use analytic hierarchy process (AHP) to optimize evaluation indexes, and then use AHP to establish the comprehensive evaluation system of city energy data. Finally, the data [7] of 12-14 years in Suzhou is selected as an example to describe how the system works.

2. Analysis on the Characteristics and Demand of Urban Energy Data

2.1 Analysis of Urban Energy Data Characteristics

The basic features of existing energy data include:(1)The proportion of data noise is larger; (2)The overlap of data is serious; (3) Data acquisition is not standard; (4) The data is poor in real time.

Faced with these problems, if we want to establish a perfect energy evaluation system, we need to try to select the evaluation index which is easy to get and accumulates smaller errors.

2.2 Demand analysis of urban energy data application

The applications of the evaluation index are reflected in the following aspects:

1) Describe and reflect the level or condition of the development of all aspects of the urban energy supply at any time point (or period);

2) Evaluation and monitoring of the trend and speed of ecological development in various aspects of urban energy supply in a certain period of time;

3) The degree of coordination between different areas of urban energy supply is comprehensively measured, so that the government can decide the priority of urban energy ecological supply process, and provide effective information tools for decision-makers to understand the city's energy supply.

3. Establishment of energy data evaluation index system based on AHP method

3.1 The selection of the evaluation index of energy data

In the energy data framework system, data types include four aspects:

1) System class data, including dispatching automation data, transmission network data, distribution network data, intelligent meter data, geographic information system data;

2) Equipment data, including energy consumption equipment terminal data, gas network, heating network and so on, are commonly used, such as energy storage equipment, internal combustion engine, steam turbine, air source heat pump, solar energy, biomass energy, electric vehicle pile and so on;

3) Macro policy and economic data and environmental climate data, such as GDP, GNP, temperature and wind index, environment and pollution index;

4) Other data information.

The following basic principles should be met in the selection of the energy data evaluation index:

(1) the principle of representativeness; (2) the principle of dynamic nature; (3) the principle of operability; (4) the principle of ecological civilization.

According to the basic framework of energy data, indexes should not only reflect the characteristics of the energy scale and energy efficiency, but also should be closely related to the embodied energy and economic and social development. According to the principle of selecting the evaluation index, the primary indicators should be comprehensive and easy to obtain.

3.2 Dimensionality reduction of energy data evaluation index based on AHP method

Drop index system dimension can help the workers quickly and accurately determine the energy audit results, thus making the process of benchmarking management system more simple. The steps to reduce the dimension of the index are as follows:

1) Establishment of hierarchical structure

Analysis of the need to solve the problem, the problem can be decomposed into different factors, grouped according to the relationship between the factors, and each group is divided into top layer, the middle layer, the lowest layer and corresponding level indicators, two indicators, three indicators. The highest level is to achieve the overall objective. The middle layer is the intermediate link for the realization of the top goal to take measures to the lowest level is taken to solve the problem Measures.

2) Structural judgment matrix

When determining the weight between different levels, it is not easy to be recognized if it is only a qualitative result. The judgment matrix can compare all the factors of this layer to the relative importance of a certain factor on the upper layer. The element of judgment matrix a_{ij} can be described by 1-9 scale method.

Table 1 Judgment Matrix Scale

Scale	Scale interpretation
1	a_i and a_j is equally important
3	a_i is a little more important than a_j
5	a_i is more important than a_j
7	a_i is a lot more important than a_j
9	a_i is the most important element in this layer
2,4,6,8	The intermediate values of the above criteria
$a_{ij} = 1/a_{ji}$	Contrary to the above meaning

3) Hierarchical single ordering and consistency check

Hierarchical single ranking is based on the judgment matrix, which calculates the weight of the order of importance for each factor of a layer for a certain factor on a previous level. The single rank can be reduced to the problem of computing the eigenvalue and eigenvector of the judgment matrix, that is, the judgment matrix B. The component of the maximum characteristic root $\lambda_{max}$and the eigenvector w_i by $\mathrm{BW} = \lambda_{max}W$ is the single sort weight of the corresponding factor. In order to test the consistency of the matrix, it is necessary to calculate the consistency index CI, When CI=0, the judgment matrix is completely consistent. The larger the CI is, the worse the consistency. In order to check whether the matrix has good consistency, we need to compare CI with the average random consistency index RI, which is recorded as $\mathrm{CR} = CI/RI$, When the CR is less than or equal to 0.1, has a good consistency of the judgment matrix, otherwise it should be adjusted to the judgment matrix.

Table 2 1-9 Order RI Matrix

Order	*RI*
1	0
2	0

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3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45

4) Screening weak weight index

According to the actual situation of city energy data, index choice weights are screening indicators byξ.

If the comparison matrix satisfies the consistency requirement, it shows that the estimator has little deviation in the cyclic comparison, and the relative weights of normalized indicators are all [0, 1] in the range of the determined real number. According to the difference between the number of indicators and the weight values of each relative index, we choose index weight to select index. When the weight is less than the weight of the index, we will discard the evaluation index.

3.3 The establishment of a comprehensive evaluation index system for energy data

After reduce the dimension, we reconfirm the weight of the evaluation index. Then we rank the single rank and consistency check for each layer, then carry out the general ranking and consistency check of the layers, and finally calculate the comprehensive evaluation index, and make a comprehensive evaluation of the energy development.

The level of total order refers to the use of the same level in all single level sequencing results for a level of the layer of all factor importance weights. The level of total order from top to bottom layer order, second for the top layer below, the single level sequencing is a total order, consistency the results of the evaluation of the level of total order, and the need to calculate the single level sequencing test a similar amount.

The formula for calculating the consistency of the total ranking is as follows:

$$\mathrm{CI} = \sum_{i=1}^{n} a_i CI_i \tag{1}$$

The average random consistent formula is as follows:

$$\mathrm{RI} = \sum_{i=1}^{n} a_i RI_i \tag{2}$$

In the formula， CI_i is the consistency index of the corresponding level of a_i. RI is a random consistency index of the corresponding level of a_i. When $\mathrm{CR} = CI/RI \leq 0.1$, the consistency is good, otherwise the judgment matrix RI_i should be adjusted.

Then the calculation of the comprehensive evaluation index is carried out, the following steps are as follows:

1) The calculation of the third level index value

If the data gets better with the increase,

$$C_i = 1 - \frac{S_i - C_i}{S_i - Min} \tag{3}$$

If the data gets worse with the increase，

$$C_i = 1 - \frac{C_i - S_i}{Max - S_i} \tag{4}$$

S_i is the reference value of a certain third level index; C_i is the actual value of a third level index, Min is the data of the minimum value of the third level index divided by 1.05;Maxs the data of the maximum value of the third level index divided by1.05.

2) The calculation of the second level index value

$$B_i = \sum_{i=1}^{n} C_i X_i \tag{5}$$

In the formula，B_i is the second level index value; C_i is the value of the third level index included in the second level index; X_i is the weight of the third level index; n is Number of items containing the second indicators of the third indicators.

3) The calculation of the first order index value

$$A_i = \sum_{i=1}^{m} B_i Y_i \tag{6}$$

In the formula，A_i is the second level index value; B_i is the value of the second level index included in the first level index; Y_i is the weight of the second level index; m is Number of items containing the first indicators of the second indicators.

4) The calculation of the comprehensive energy development index value

The index is multiplied by the values of the first level index by adding and obtaining each weight. The formula is as follows:

$$DI = \sum_{i=1}^{u} A_i Z_i \tag{7}$$

In the formula，A_i is the second level index value; Z_i is the weight of the second level index; u is the number of the first level index,DI is the comprehensive energy index value.

4. Example analysis

4.1 The pre-selection of the evaluation index of urban energy data

This paper selects 7 indicators from 3 aspects of energy scale, energy intensity and energy sustainability as the second level. 18 indicators are selected as primary indicators, reflecting the connotation of cleanliness, efficiency and sustainability from different aspects. Primary indicators are shown in Table 3.

Table 3 Evaluation Index of Urban Energy Data

First level index	Second level index	Third level index
Energy scale	Scale of production	Primary energy production ratio Two energy production ratio Annual per capita generating capacity
	Consumption scale	Coal accounts for the proportion of energy consumption The proportion of oil to energy consumption
Energy intensity	Energy consumption intensity	Energy consumption of 10,000 Yuan Electric power consumption of 10,000 Yuan Per capita energy consumption
	Energy level	Energy efficiency

Energy sustainability	Economic indicators	Power consumption elasticity coefficient
		Energy consumption ratio of the second industry
		Energy consumption ratio of the third industry
	Environmental indicators	Relative energy consumption index
		Per capita CO_2 emissions
		Construction of laws and regulations
	Pollution index	SO_2 annual mean concentration
		PM2.5 annual mean concentration
		NO_2 annual mean concentration

4.2 The comprehensive evaluation index of energy data in Suzhou

According to the calculation procedure of Section 3.2, the pre-selection indexes can be optimized. Select ξ=0.15, sift the third level indexes. According to the calculation procedure of Section 3.3, establish the judgment matrix to the first level indexes and second level indexes, calculate the relative weight value, determine the consistency of the evaluation index drop; after the dimension, calculate its weight. Then， choose The corresponding data of Suzhou energy data from 2012 to 2014 to calculate the comprehensive evaluation index.

Table 4 Optimal Results of Urban Energy Data Evaluation Index

Primary selection index	Primary weight	Final weight	Primary selection index	Primary weight	Final weight
Primary energy production ratio	0.4286	0.02355	Power consumption elasticity coefficient	0.201	0.07828
Two energy production ratio	0.1429	0	Energy consumption ratio of the second industry	0.0776	0
Annual per capita generating capacity	0.4286	0.02355	Energy consumption ratio of the third industry	0.5205	0.1566
Coal accounts for the proportion of energy consumption	0.5	0.07065	Relative energy consumption index	0.201	0.07828
The proportion of oil to energy consumption	0.5	0.07065	Per capita CO2 emissions	0.75	0.0783
Energy consumption of 10,000 Yuan	0.7022	0.02025	Construction of laws and regulations	0.25	0.0261
Electric power consumption of 10,000 Yuan	0.1170	0	SO2 annual mean concentration	0.8847	0.2087
Per capita energy consumption	0.7022	0.02025	PM2.5 annual mean concentration	0.4423	0.1044
Energy efficiency	1	0.081	NO2 annual mean concentration	0.1474	0

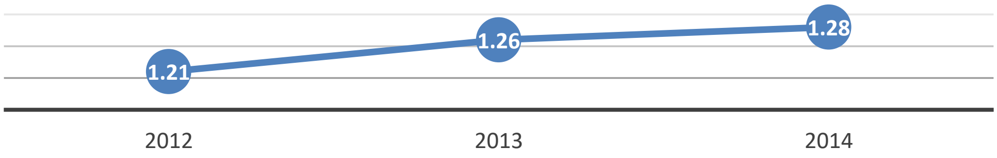

Figure 1 The Comprehensive Evaluation Index of Suzhou From 2012 to 2014

5. Conclusion

According to the application demand of city energy data for energy management department, the principles of selecting the evaluation index are determined. Based on the city energy data framework and the AHP method, this paper selects and optimizes the indexes of energy evaluation, after which, the comprehensive evaluation system of urban energy data is established. According to the results, we can see that the comprehensive energy development index value of Suzhou from 12 to 14 kept increasing, which means the level of energy development in Suzhou met the development expectations. As we can see, the system can reasonably describe the development of city energy situation, thus providing references for the city to achieve the adjustment of energy structure and sustainable development.

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