Research on Evaluation Index System of Urban Energy Internet Development

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Abstract. At present, urban energy development faces problems such as energy resources shortage, low utilization efficiency and serious environmental pollution. The urban energy Internet is considered to be an effective means to solve urban problems. In order to effectively evaluate the development of urban energy Internet, this paper has established a detailed evaluation index system from four aspects: clean and low carbon, safe and efficient, flexible and intelligent, and open sharing of urban energy development, and given some data of foreign developed countries. reference. The evaluation indicator system can be used as a pre-guided and evaluation indicator for urban energy Internet development planning.

1. Introduction
In order to promote the large-scale development of renewable energy, enhance the efficiency of traditional one-time energy use, achieve sustainable development of social energy, and build a development-oriented society, the urban energy Internet came into being. The urban energy Internet can achieve “multi-energy complementarity and coordinated optimization” among multiple energy subsystems [1-2]. In order to effectively assess the development of urban energy Internet, it is necessary to establish a corresponding evaluation index system as a pre-guide for the development of urban energy systems. For the distribution network level, some researchers start from the multi-energy coupling characteristics and studies the reliability evaluation method of single energy hub[3]. However, the current evaluation of the urban energy Internet is biased towards the internal energy system, but lacks the coupling of economy, society and environment. In this paper, a detailed evaluation index system from four aspects was established.

2. Urban Energy Internet Development Evaluation Index System
The urban energy Internet has become the only way to adapt to the changes in the urban energy sector and to ensure the safety of society and long-term security. The core of the urban energy Internet is to integrate the sources, networks and depths of various types of energy through means of information and communication, and promote the consumption of renewable energy through multi-energy complementary synergy and energy cascade utilization to achieve clean and efficient supply of energy. Therefore, it is necessary to establish a relevant evaluation system for urban energy Internet development, reflecting its low-carbon and high-efficiency core characteristics and other advantages
over traditional sub-supply energy systems, helping to eliminate renewable energy and reduce non-renewable energy consumption. In this paper, an evaluation index system for urban energy Internet development was established, which is evaluated from four aspects: clean and low carbon, safe and efficient, flexible and smart, open and sharing.

2.1 Clean and Low Carbon

2.1.1 Renewable energy installed capacity. This indicator is the proportion of renewable energy in the power resource structure, which is an important part of energy development [4-5]. The formula can be written as below. Here, \( v \) is the proportion of installed capacity of renewable energy (%); \( C_r \) is the installed capacity of renewable energy (MW); \( C_p \) is the total installed capacity (MW).

\[
v = \frac{C_r}{C_p} \times 100\%
\]  

(1)

2.1.2 Renewable energy generation penetration rate: examples. This indicator is the proportion of the annual renewable energy generation to the total power generation of the system in the energy and power planning program.

\[
p = \frac{W_r}{W} \times 100\%
\]  

(2)

Where: \( p \) is the renewable energy generation penetration rate (%); \( W_r \) is the renewable energy generation capacity (MWh); \( W \) is the total power generation (MWh) of the power system.

2.1.3 Renewable energy consumption rate: Due to the incomplete matching of renewable energy output and system load and the operation and control of the system, some renewable energy generation cannot be accepted by the system. This indicator reflects the system's renewable energy acceptance standard. Here, \( r \) is the renewable energy consumption rate (%); \( W_r \) is the renewable generation capacity (MWh); \( W_g \) is the total renewable energy generation (MWh).

\[
r = \frac{W}{W_g} \times 100\%
\]  

(3)

2.1.4 Electrification level: Electrification is the only way to achieve clean and low-carbon. On the one hand, the use of electricity is clean and pollution-free. On the other hand, power generation is the most important form of clean energy. This indicator is the proportion of power consumption in the terminal energy.

\[
e = \frac{1.23 \times 10^{-4} \cdot W_e}{C} \times 100\%
\]  

(4)

Where: \( e \) is the level of electrification (%); \( W_e \) is the terminal energy consumption (kWh); \( C \) is the total energy consumption (tce).

2.1.5 GHG emissions (emission intensity). Consumption of fossil energy will produce greenhouse gases, including carbon dioxide (CO\(_2\)), methane (CH\(_4\)), nitrous oxide (N\(_2\)O) and sulfur hexafluoride (SF\(_6\)). The indicator value is the amount of GHGs produced by the unit of energy consumed.

\[
o = \frac{G}{C}
\]  

(5)

Where: \( o \) is the greenhouse gas emissions per unit of energy consumption (mg/tce); \( G \) is the total greenhouse gas emissions (mg); \( C \) is the total energy consumption (tce).
3. Safe and Efficient

Energy and equipment utilization and energy consumption per unit of output reflect the overall efficiency of the urban energy Internet, while power quality and energy supply reliability reflect the safety of the unique energy system. Therefore, this study selected the following indicators for analysis.

3.1 Energy comprehensive utilization efficiency. There is a loss in the process of converting the energy input into the terminal energy. This indicator is the ratio of the total energy consumption of the terminal to the total input of the energy system, that is, the total energy consumption.

\[ \eta = \frac{W_t}{2.93 \times 10^4 \cdot C} \times 100\% \]  

Where: \( \eta \) is the energy comprehensive utilization efficiency (%); \( C_t \) is the total energy consumption (kJ); \( C \) is the total energy consumption (tce).

3. Unit GDP energy consumption. In order to avoid rough development, energy consumption per unit of GDP is an important reference indicator for sustainable development. This indicator is the ratio of the total annual energy consumption of the region to the annual GDP.

\[ c_0 = \frac{C}{GDP} \]  

Where: \( c_0 \) is the energy consumption per unit of GDP (tce/10,000 yuan); GDP is the regional GDP.

3.3 Energy supply reliability. The system reliability is evaluated from the reliability of the power supply system, the reliability of the heating system, and the reliability of the cooling system, and the system failure rate \( \lambda \) is selected as the evaluation index.

4. Flexible and Smart

The original intention of developing urban energy internet systems is to provide high-quality, efficient, flexible and smart energy services, generate greater social benefits, and optimize energy use channels and experiences. Therefore, the following indicators were chosen for analysis.

4.1 User-side energy quality. The energy quality of the user terminal mainly includes energy quality such as electric energy, heat energy and gas. The power quality is mainly measured by voltage fluctuation, flicker and harmonic quality, while the thermal energy quality is mainly expressed by the thermal energy grade factor. It can be defined by the combustion value of the gas and the composition of the hydrocarbon compound. The quality of the user's energy directly determines the user's energy experience.

4.2 User comfort. User comfort is the direct feeling of users participating in energy interaction and is a direct reflection of the degree of system intelligence. In the fixed period, the user survey questionnaire is used to collect the opinions, thus the users’ satisfaction and reasonable suggestions for energy consumption during this period can be obtained, and the data should be fed back to the background center, which is important for improving the user's energy construction significance.

4.3 Active peak load. The proportion of users actively participating in peak load reduction reflects the construction level of demand side response and the enthusiasm of users to participate, and is an important indicator of system flexibility.

4.4 Smart meter popularity. As a smart terminal managed by the demand side, the smart meter has the functions of user information data storage, multi-rate bidirectional metering, and user terminal control in addition to the energy metering function of the conventional meter. The popularity of smart meters can reflect the perfection of user response to demand, and represents the development process of intelligent and integrated energy systems.
5. Open and Sharing
The open sharing of urban energy Internet systems is the open sharing of system data, that is, the open sharing of data between different energy systems and systems, and the open sharing of system energy services.

5.1 Proportion of information disclosure equipment. The indicator refers to the proportion of equipment available in the energy system and other information to the total number of equipment in the system, which reflects the open sharing of energy system data.

5.2 Data accessibility. Data accessibility is used to comprehensively evaluate the degree of open sharing of system data, mainly from the aspects of whether the data is open, whether the data is free, whether the data is complete, and whether the data is open in time.

5.3 Proportion of Regional shared devices. This indicator refers to the ratio of the number of devices that provide cross-region shared services to the number of devices in the region, which reflects the sharing of services across devices in the region.

5.4 Equipment external service rate. This rate refers to the average value of the external service rate in the region, which is the average value of the original equipment.

6. Typical indicator benchmark
The benchmarking in this paper is based on the data of some foreign indicators.

6.1 Utilization of renewable energy
The utilization of renewable energy can reduce the consumption of fossil fuels and pollutant emissions. At present, many cities have set targets for renewable energy utilization.

| Region     | Target                                                                 |
|------------|------------------------------------------------------------------------|
| Bergen     | Renewable energy supply reaches 95%, replaces oil-based heating (14% of GHG emissions) |
| Copenhagen | By 2025: 100% renewable energy supply                                  |
| Dubai      | Renewable energy generation reaches 5% in 2030                        |
| Frankfurt  | Reachable energy supply rate of 100% in 2050                           |
| Helsinki   | Renewable energy accounts for 20% of energy production by 2020 (7% in 2013) |
| Hong Kong  | By 2020, reduce coal to less than 10% of power generation; by 2030, eliminate existing coal |

6.2 Greenhouse gas emission reduction
It can be expected that with the further development of China’s economy and society, carbon emission constraints will increase. Currently, countries and cities have developed responsive greenhouse gas reduction targets.

![Figure 1. Typical city greenhouse gas emission reduction targets](image-url)
6.3 Electrification standard

Electrification is an important means of energy efficient transformation. Electrical energy can be efficiently converted into mechanical energy, thermal energy and light energy, so the level of electrification can effectively reduce energy consumption. From 1990 to 2015, China's electrification level increased by an average of 1 percentage point, and energy intensity decreased by 3.6%. During the period from 2016 to 2030, the electrification level is expected to increase by an average of 1 percentage point, and the energy intensity will decrease by 2.6%. The proportion of power generation in power generation is mainly characterized by the fact that developed countries are generally higher than developing countries and countries with poor fossil energy resources are relatively high. The proportion of power generation in developed countries has entered a stable stage in the 1980s and 1990s after experiencing a rapid improvement phase. In recent years, affected by the shale gas revolution, economic crisis, and nuclear abandonment policy, the proportion of power generation in developed countries has fluctuated slightly. The proportion of power generation in developing countries has been in a rising stage. In particular, the BRICS countries including China have sustained rapid economic and social development, and the supply-side electrification level has rapidly climbed to the level of OECD countries. In terms of the proportion of terminal electrical energy, it shows the slowdown in electrification level growth in developed countries and the rapid increase in emerging market countries. The overall level of electrification in developed countries has slowed down. Affected by the continuous adjustment of industrial structure and the enhancement of competitiveness of alternative energy sources, the electrification level of developed countries in the late stage of industrialization fluctuated around 20%-25%. The rapid increase in the level of electrification driven by the industrialization process in developing countries is the main driving force for the steady rise of electrified water in the world. Among the BRICS countries, China's electrification level is only lower than that of South Africa.

![Figure 2: Electrification level, energy intensity changes](image1.jpg)

![Figure 3: Power generation ratio (major economies)](image2.jpg)

7. Conclusion

In this paper, a detailed evaluation index system is established from four aspects of urban energy Internet development, and some data of developed cities in foreign countries are given as reference. Finally, relevant suggestions are as follows: Firstly, supply side urban energy Internet supply system. Urban energy Internet systems are highly cost-competitive. Usually, these systems use energy from industrial waste heat/cold and have high energy efficiency. Secondly, remote energy conservation and alternative technologies on the consumer side. Carry out a variety of electric energy substitution work, accelerate the promotion and application of drying technology, heat pump, electric kiln and other technologies. Finally, promote innovation in the business model of integrated energy services. Promote integrated energy development through the construction of services such as cooling and heating triple supply and waste heat utilization, two-stage demand side response management, and a combination of distributed energy and storage.

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