Research on Energy Consumption Quota Index System for Chinese Public Institutions and Its Application

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Abstract. Energy consumption quota has been widely used in various fields as an important means and technical support for energy conservation. As an important field of energy conservation in the whole society, energy conservation of public institutions shall also require an energy consumption quota method to manage energy consumption. Based on the zoning and classification of public institutions, through analyzing the energy usage characteristics of public institutions such as heating, cooling, ventilation, lighting, office and cooking, this article studied the core indexes and reference indexes of public institutions with or without heating systems, proposed the energy consumption quota index system for public institutions, and provided single-index and multiple-index evaluation schemes.

1. Background

As a long-term and important strategic task in economic and social development of China, great importance has been attached to energy conservation and emission reduction since the “11th Five-year Plan”. Playing a leading role in energy conservation of the whole society, energy conservation of public institutions strongly promotes the development of energy conservation in China. As of 2018, there were about 1.67 million public institutions in China, and the total energy consumption of these public institutions was about 182.78 million tons of standard coal. Since the “12th Five-year Plan” was initiated, China relaxed the relevant standard to manage energy consumption of public institutions. With the comprehensive transformation of energy conservation technologies, the use of high-efficiency and energy-saving products, and the improvement of management levels of public institutions, energy consumption has been greatly reduced, yielding a good result of energy conservation. However, with the expansion of public services and further increase in the building area, energy-consuming equipment and the number of energy users of public institutions, the demand for energy consumption has continued to increase, resulting in public institutions prone to energy conservation bottlenecks. Although the relevant standard is relaxed, it is difficult to achieve good results with such management method. Methods suitable for energy conservation of public institutions shall be urgently developed. Energy consumption quota management is to achieve the standard of reasonable energy consumption for the production of a unit product or the completion of unit workload under certain conditions. Energy consumption quota management has been widely used in energy consumption management of industrial enterprises, and realized remarkable effects. Similar to the energy consumption of buildings, the energy consumption of public institutions mainly includes the energy consumption of the building environment (such as heating, cooling, ventilation, and lighting) and various activities within the building (such as office and cooking), which is very suitable for energy consumption quota management. In 2019, the National Government Offices Administration issued the Guidelines for the Preparation and Application of Energy Consumption Quota Standards for
Public Institutions (for trial implementation), requiring all regions to prepare energy consumption quota standards for public institutions and promoting the preparation of energy consumption quota standards for public institutions in regions at the policy level.

Through research on the quota standards for public institutions at home and abroad, according to the characteristics of zoning and classification of energy usage of public institutions, this article built an index system respectively for public institutions with or without a heating system, and provided an evaluation method for index system. Energy consumption quota standard systems are established for various public institutions, so that the energy usage management of public institutions can be evaluated based on evidence, which will promote the market demand for energy conservation of public institutions, tap the potential of energy conservation, actively promote the improvement of energy efficiency of public institutions, and lay a foundation for energy conservation of Chinese public institutions in the “14th Five-year Plan” period.

2. Domestic and overseas research status

2.1 Overseas research status

Building energy management in government offices are studied in terms of policies and regulations, management, and building energy conservation standards.

**Energy conservation policies and regulations:** European and American countries have issued relevant laws and regulations on energy conservation in public institutions. In order to promote the energy conservation of government institutions, America proposes requirements for energy conservation of government institutions in the Resource Conservation and Recovery (RCRA), National Energy Conservation Policy Act (NECPA), Comprehensive Omnibus Budget Reconciliation Act (COBRA), Federal Energy Management Improvement Act (FEMIA) and other laws [1]. Australia, Japan, Germany and other countries promulgate and implement government energy conservation procurement policies, implement energy consumption statistics reporting systems for government institutions, implement energy audit systems and other related policies, and guide government institutions in energy conservation.

**Building energy conservation standards:** Developed European and American countries have developed standards related to public buildings to regulate and promote energy conservation in the field of public buildings. Based on actual energy consumption data from the American business building energy consumption survey, American ENERGY STAR Benchmarking Tools establishes the energy consumption benchmark combined with mathematical statistics, uses a multiple linear regression fitting method to compare multiple combination, screening and fitting results of impact factors for multiple times, and then develop a method of determining energy consumption benchmark to judge the level of building energy consumption [2]. The German standard VDI 3807 divides government office buildings into the highest federal agencies, parliaments, administrative buildings, work centers, and public security bureaus; the sub-item energy consumptions are summed up to form building energy consumption, and the power consumption is divided into lighting, ventilation, and air conditioning and refrigeration according to energy usage purpose. Through establishing rated operating time and rated correlation coefficient, buildings and building energy consumption are divided in detail with energy consumption index values provided [3]. The British standard Energy Performance in the Government’s Civil Estate divides office buildings into four types: luxury air-conditioned buildings, standard air-conditioned buildings, naturally ventilated office buildings with open floor plan, and naturally ventilated ordinary office buildings. Through introducing the method of judging compound office buildings and correcting application days, target values and standard values of energy conservation are provided for these four types of office buildings [4].
2.2 Domestic research status

Although the energy conservation of domestic public institutions has entered the development stage, the research on energy conservation of public institutions, especially the quota of energy conservation and energy consumption, is still in its primary stage.

**Energy conservation policies and regulations in public institutions:** In 2007, the Standing Committee of the National People’s Congress, based on the promulgated Energy Conservation Law of the People’s Republic of China [5], proposed that relevant departments shall formulate energy consumption quota for public institutions in accordance with management authority, and the financial department shall develop the criteria for energy consumption expenditure based on the quota. In 2008, the Regulations on Energy Conservation by Public Institutions [6] issued by the State Council of the People’s Republic of China proposed specific requirements for the preparation of energy consumption quota: energy consumption quota shall be developed according to the comprehensive level and characteristics of energy consumption for public institutions in different industries and different systems. In 2016, the 13th Five-year Plan on Energy Conservation of Public Institutions [7] issued by the National Government Offices Administration and the National Development and Reform Commission improved the requirements for preparing energy consumption quota and encouraged the implementation of energy consumption quota management.

**Building energy conservation standards:** The Standard for Energy Consumption of Building (GB/T 51161) gives constraint value and guidance value of public building energy consumption index based on climatic region, building functions and classification; when the actual use intensity is higher than the standard use intensity, the constraint value and guidance value can be corrected according to the actual use time of the building [8]. In the Design Standard for Energy Efficiency of Public Buildings (GB 50189-2005), the 50% energy conservation target of public buildings for the “benchmark building” was proposed, and the design was controlled by using the prescriptive method and performance method [9]. Wuhan issued the Guidelines for Energy Consumption Quota of Civil Buildings in Wuhan in 2014, which includes three parts: building energy consumption quota, public building energy consumption quota, and civil building air-conditioning heating energy consumption index. Quota standards for comprehensive energy consumption and power consumption of state organ office buildings in Guangxi, Shanghai, Shandong, and Shenzhen, etc.

3. Energy consumption quota index system

To build an energy consumption quota index system for public institutions, first sort out the classification of public institutions, and determine the energy consumption quota index according to the classification characteristics and the collection and analysis of the energy consumption quota data of each public institution.

3.1 Classification of public institutions

For party and government organs, due to the different economic levels and business requirements of province-level, city-level, county-level and township-level party and government organs, the energy consumption for province-level, city-level, county-level and township-level party and government organs generally decreases. The party and government organs may be further classified into the province-level, city-level, county-level and township-level party and government organs. Due to the trend of centralized office of party and government organs, the classification of party and government organs can also be refined according to the building area.

According to national economic industry classification in China, educational institutions are classified into pre-school education, primary education, secondary education, higher education, special education and other education in the process of developing energy consumption quota. However, if the energy consumption of accommodation exists in both primary and secondary education institutions in certain area, primary education institutions and secondary education institutions can be combined into primary and secondary education institutions. Higher education institutions can also be refined into
liberal arts, sciences, and engineering according to the characteristics of the school such as scientific research capabilities, research funds, and test equipment with high energy consumption.

According to functions and diagnosis and treatment patients, Chinese medical institutions are divided into comprehensive hospital, specialty hospital, special hospital, sanatorium, and rest home, etc. According to the diagnosis and treatment objects and scale, Chinese medical institutions are divided into three levels: large, medium and small, and the regional hospitals are divided into three levels: city, district and community. According to the nature, the level of diagnosis and treatment and the number of beds of hospitals, the hospitals are also divided into grades 1, 2 and 3. In the process of developing the actual energy consumption quota, hospitals are generally classified according to grades 1, 2, and 3. In some developed regions with fully equipped large-scale medical equipment at all levels of hospitals, the hospitals can also be classified into comprehensive hospital, specialty hospital, special hospital, sanatorium, and rest home, etc., so as to better distinguish the energy consumption of hospitals.

Due to economic, transportation, number of people and other factors, the situation of venues varies greatly. Venue institutions can be further classified into the culture, sports, and science and technology venues according to social service functions and energy usage levels. The necessity for developing the quota of venues can be determined based on the number and usage of venues in various regions.

Most of the other institutions are related to the public security organs, procuratorial organs and people’s courts, and can be further classified into the province-level, city-level, county-level and township-level institutions according to economic level and other factors.

According to the nature of public institutions, public institutions are classified into the state organs, medical institutions, educational institutions, venue institutions and other types of public institutions.

3.2 Construction of index system

Due to unique climatic environment in China, heating energy consumption varies greatly in different regions, and central heating is implemented in some regions. Therefore, when constructing the energy consumption quota, the public institutions in all provinces in the country are classified according to the institution with or without heating system. According to the requirements of the Statistical System for Energy Consumption of Public Institutions and Guidelines for the Preparation and Application of Energy Consumption Quota Standards for Public Institutions (for trial implementation), the “energy consumption per unit building area” is the main assessment index for the regions without heating system, and “non-heating energy consumption per unit building area” and “heating energy consumption per unit heating area” are the main assessment indexes for the regions with heating system. For the public institutions with heating system, indexes such as power consumption per unit building area, non-heating energy consumption per capita, non-heating energy consumption per student, and non-heating energy consumption per hospital bed are selected; for the public institutions without heating system, indexes such as power consumption per unit building area, comprehensive energy consumption per capita, comprehensive energy consumption per student, and comprehensive energy consumption per hospital bed are selected; energy usage effectiveness (EUE) is selected for the data center room; fuel consumption per 100 kilometers per vehicle and other reference indexes are selected for official vehicles. See the indexes in the table below.

Combined with the energy consumption characteristics of various types of public institutions, comprehensively develop an energy consumption quota index system of public institutions, as shown in Table 1:

| Region       | With heating system | Without heating system |
|--------------|---------------------|------------------------|
| Non-heating energy consumption per unit building area | Energy consumption per unit building area |
Non-heating energy consumption per capita | Comprehensive energy consumption per capita
---|---
Party and government organ | Power consumption per unit building area | Power consumption per unit building area
Educational institution | Non-heating energy consumption per student | Comprehensive energy consumption per student
Medical institution | Non-heating energy consumption per hospital bed | Comprehensive energy consumption per hospital bed
Venue institution | Power consumption per unit building area | Power consumption per unit building area
Other types of public institutions | The above indexes are selected according to the actual energy consumption per unit |
Data center room | Energy usage effectiveness (EUE) | Energy usage effectiveness (EUE)
Official vehicle | Fuel consumption per 100 kilometers per vehicle | Fuel consumption per 100 kilometers per vehicle

Note: The regions with heating system refer to the regions where a heating system consisting of three main parts, that is, heat source (heat medium preparation), heat cycle system (pipe network or heat medium delivery) and heat dissipation equipment (heat medium utilization), is used to centrally supply heat to the room, which are usually the heating areas in the north in winter. The regions without heating system refer to the regions where a heating system isn’t available in winter.

It can be seen from the above table that energy consumption per unit building area (kgce/m²) and power consumption per unit building area (kWh/m²) are important indexes for the assessment of energy consumption quota.

4. Assessment and application of index system

4.1 Evaluation of single index
When evaluating the single index for the evaluation object, the level of index quota shall be divided and the score of quota levels shall be calculated through combining the *Energy Consumption Quota Standards for Public Institutions*. The specific evaluation methods are found in Table 2.

| Actual value of quota index | E₁≤Eᵢ | E₁<Eᵢ≤E₂ | E₂≤Eᵢ≤E₃ | Eᵢ>E₃ |
|-----------------------------|-------|----------|-----------|-------|
| Quota index level           | A     | B        | C         | D     |
| Score of level (Sᵢ/point)   | 100 (E₁)/(Eᵢ) | 80+20 (E₂-Eᵢ)/(E₂-E₁) | 60+20 (E₃-Eᵢ)/(E₃-E₂) | 60 (E₃)/(Eᵢ) |

Note: Eᵢ is the actual value of the single index of the evaluation object; E₁ is the guidance value of the single index specified in the *Energy Consumption Quota Standards for Public Institutions*; E₂ is the reference value of the single index specified in the *Energy Consumption Quota Standards for Public Institutions*; E₃ is the constraint value of the single index specified in the *Energy Consumption Quota Standards for Public Institutions*.

4.2 Evaluation of multiple indexes
Obtain the score of each index by adopting the single index evaluation method in 2.2.1, establish a weight coefficient for each index, and calculate a comprehensive score of multiple index quota levels. The specific evaluation method is found in formula (1):
$S_n = \sum_{i=1}^{n} S_i \times I_i$ \hspace{1cm} (1)

Where,
- $S_n$ – Comprehensive score of multiple index quota levels;
- $S_i$ – Score of single index level;
- $I_i$ – Weight coefficient of single index.

Note: In the $\sum_{i=1}^{n} I_i = 1$, the weight coefficient of each index is determined by the evaluation unit.

[For example] Single index evaluation and comprehensive evaluation of multiple indexes are conducted for these three indexes: the energy consumption per unit building area of party and government organ A in XX province is 18kgce/m$^2$, comprehensive energy consumption per capita is 600kgce/p, and power consumption per unit building area is 120kWh/m$^2$. The energy consumption quota level and index weight coefficient of party and government organ A in XX province are shown in Table 3.

| Energy consumption index                        | Guidance value | Reference value | Constraint value | Weight coefficient of index |
|------------------------------------------------|----------------|----------------|-----------------|----------------------------|
| Energy consumption per unit building area (kgce/m$^2$) | 10             | 16             | 28              | 0.35                       |
| Comprehensive energy consumption per capita (kgce/p) | 450            | 725            | 1283            | 0.3                        |
| Power consumption per unit building area (kWh/m$^2$) | 75             | 110            | 210             | 0.35                       |

Evaluation of single index:
The energy consumption per unit building area of party and government organ A is 18kgce/m$^2$, $E_2=16< E_i=18 \leq E_3=28$, the quota level is C; $S_1=60+20 \times (28-18)/(28-16)=76.67$. The power consumption per unit building area of party and government organ A is 120kWh/m$^2$, $E_2=110< E_i=120 \leq E_3=210$, the quota level is C; $S_2=60+20 \times (210-120)/(210-110)=78.00$. The comprehensive energy consumption per capita of party and government organ A is 600kgce/p, $E_1=450< E_i=600 \leq E_2=725$, the quota level is B; $S_3=80+20 \times (725-600)/(725-450)=89.09$. Comprehensive evaluation of multiple indexes:
$S_3=S_1 \times I_1+S_2 \times I_2+S_3 \times I_3=76.67 \times 0.35+78 \times 0.3+89.09 \times 0.35=81.42$.

5. Summary
This article built a quota index system for energy consumption of public institutions. Main indexes for the regions with heating system are non-heating energy consumption per unit building area and heating energy consumption per unit heating area; the main index for the regions without heating system is energy consumption per unit building area; energy consumption quota reference indexes are determined for the party and government organs, educational institutions, medical institutions, venue institutions and other institutions. At the same time, single index and multi-index evaluation schemes are proposed in the application of the index system. The construction of an energy consumption quota index system in public institutions will effectively guide public institutions in all regions to prepare energy consumption quota standards, improve energy efficiency, promote the progress of energy conservation technologies in the field of public institutions, and promote the development of energy conservation and emission reduction of public institutions.

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