

# Calculation and Study of Urban Building Energy Consumption in Shandong Province

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**Abstract:** Since China put forward the "double carbon" goal, reducing the energy consumption level of urban buildings has become an important component of energy conservation and emission reduction work. To realize the effective control of the energy consumption level of urban buildings and carry out accurate building energy consumption is the key foundation. However, at present, from the perspective of China's provinces, there is still a lack of authoritative relevant statistical data release and calculation. Based on this, this study takes Shandong Province of China as an example, explores the calculation method of building energy consumption based on energy balance table, and calculates and analyzes the corresponding urban building energy consumption, and obtains the urban building energy consumption of Shandong Province of China during 2012-2022. The analysis results show that the calculation method of building energy consumption based on energy balance table is suitable for the calculation of building energy consumption in Shandong Province, and it clearly describes the overall energy consumption, the proportion of energy consumption of various types of buildings and the energy consumption per unit area of buildings, and can provide a useful reference for the formulation of relevant building energy conservation and emission reduction policies.

**Keywords:** Shandong Province; Building Energy Consumption Calculation; Energy Consumption Analysis

## 1. Problems and Difficulties in Calculating Building Energy Consumption

### 1.1 Problems Faced in the Calculation of Urban Building Energy Consumption

Reducing building energy consumption is a key

link in the current energy conservation and emission reduction work. Although many areas in China have carried out building energy conservation and emission reduction work for many years, due to the lack of effective statistical data, the calculation of building energy consumption still faces two prominent problems. On the one hand, there is a serious shortage of statistics on building energy consumption. In terms of energy consumption in buildings, the lack of authoritative statistical data published makes it difficult to accurately assess energy consumption in towns and cities. Especially for the provincial and municipal building energy consumption data, there is a lack of unified understanding, which makes it difficult to formulate effective energy-saving policies and measures. For example, Jinan, Shandong Province, as a city that has been implementing building energy efficiency work for a long time, still lacks authoritative and accurate building energy consumption data publication, which indicates that even in the case of long-term relevant work, the data is still insufficient to support the implementation and evaluation of relevant policies. On the other hand, the reliability of some energy consumption statistics is insufficient. In terms of building energy consumption statistics, even if some data is available, its reliability is often doubted. Especially in the energy consumption survey report of civil buildings, there is a problem of insufficient reliability. This may be due to insufficiently scientific data collection methods, insufficiently comprehensive data reporting, or insufficiently reliable data sources. The lack of reliable data will make it difficult for governments and decision makers to accurately assess the current situation and predict future development trends when formulating policies, which will affect the effectiveness and sustainability of energy conservation and emission reduction efforts.

### 1.2 Difficulties in the Calculation and

## **Statistics of Urban Building Energy Consumption**

For the current urban building energy consumption calculation and statistics work, its main difficulties lie in two aspects. On the one hand, it is difficult to obtain the original data of building energy consumption, and on the other hand, the existing statistical standards are relatively backward.

The difficulty in obtaining raw data of building energy consumption is mainly due to the fact that building energy consumption is not counted separately in the energy consumption statistical system. In China's energy balance sheet, terminal energy consumption is divided into seven categories, but building energy consumption is not independently listed as one of them, but is dispersed and mixed in the energy consumption data of various industries. This method of decentralized statistics makes it difficult to obtain and accurately count the data of building energy consumption, which leads to the missing and incomplete data of building energy consumption. Specifically, since building energy consumption is not counted separately as a class of energy consumption, energy consumption data in the construction field are often scattered in the data of various related industries, such as industry, transportation, and service industries. Such statistics make it difficult to obtain energy consumption data for the building sector directly from the statistics, because building energy consumption is not identified separately, but is mixed with energy consumption data for other industries. Therefore, it is very difficult to obtain accurate building energy consumption data. This problem of data acquisition not only brings difficulties to the government's energy policy and planning, but also brings challenges to academic research and enterprises' energy conservation and emission reduction work. The lack of accurate building energy consumption data will make it difficult for the government to comprehensively evaluate energy consumption in the building sector when formulating energy conservation policies, which may lead to the formulation of policies that are not targeted and effective. At the same time, for academic research and enterprises, the lack of accurate building energy consumption data will also affect their research results and the implementation of energy-saving programs, because there is no reliable data as the basis, it

is difficult to carry out scientific analysis and decision-making.

The existing statistical standards are relatively backward, which mainly shows that the statistical system and the means of information disclosure are relatively backward. In terms of statistical system, the current building energy consumption statistical data system is mainly based on the "Civil Building Energy Consumption and energy saving information Statistical Report System" issued in 2010, but the system requires that the basic information and energy consumption information of civil buildings in the form to reflect limited. Only basic information such as time of construction completion, building type, number of building floors, building area, cooling and heating methods are included. This makes it impossible to fully understand the situation of building energy consumption, and also limits the scientific assessment and analysis of building energy consumption. In terms of information disclosure system, although the "System" requires civil building energy consumption statistics to be once a year, the announcement of relevant building energy consumption information is very limited. As a result, the public cannot fully understand the situation of building energy consumption, and it also prevents relevant research institutions from doing further research based on building energy consumption information. The lack of disclosure also limits public and stakeholder oversight and participation in energy consumption.

## **2. Evaluation and Selection of Urban Building Energy Consumption**

### **2.1 Review of Main Calculation Methods of Urban Building Energy Consumption**

At present, there are three mainstream methods for the calculation of urban building energy consumption, one is based on statistical yearbook calculation, the second is based on energy intensity calculation, and the third is based on terminal energy consumption model calculation.

Based on the energy statistical yearbook, the method of calculating the energy consumption of urban buildings is mainly to analyze the building related energy consumption from the annual energy statistical data, and calculate the building energy consumption accordingly.

Although this method is simple and easy to use, and the data source is authoritative, it is suitable for the construction administration to calculate the energy consumption of buildings in the region, but the data of the Energy Statistical yearbook need to be adjusted and interpreted appropriately to ensure accuracy and reliability. The advantage of this method is that it is easy to operate and the data source is reliable, but it needs to be adjusted and interpreted appropriately according to the limitations of the data to ensure the accuracy and reliability of the obtained building energy consumption data.

The method based on the calculation of energy consumption intensity provides a simple and effective way to evaluate the energy consumption of urban buildings. By calculating the energy consumption intensity of different types of buildings, the energy consumption of different regions and building types can be compared and analyzed, and then provide a reference for energy planning and policy formulation. This method is connected with the energy consumption report system of civil buildings and has high applicability. However, the implementation of this method needs to carry out a wide range of building energy consumption statistics and surveys to ensure the accuracy and comprehensiveness of the data, which poses a certain challenge to the relevant institutions and departments. Therefore, although the energy intensity measurement method has potential in the assessment of urban building energy consumption, it needs to overcome the difficulties in data acquisition and statistical investigation in practical application to give full play to its role.

The method of calculating the energy consumption of urban buildings based on the terminal energy consumption model is to subdivide the terminal energy consumption of buildings and gradually summarize the energy consumption of buildings from the bottom. This method goes deep into the technical level, and can analyze the impact of technical or policy factors on building energy consumption, so as to facilitate the scenario analysis of building energy consumption, prediction and evaluation of building energy saving potential or energy saving. However, this method requires a large amount of data, some of which are difficult to obtain, and the final calculation

results need to be checked by authoritative data such as statistical yearbooks. Due to the complexity of the calculation process, it is only suitable for professional research institutions to conduct building energy consumption research. In this study, the calculation method based on statistical yearbook is adopted. Considering that the data source of this method is authoritative and easy to analyze the trend of building energy consumption, the accuracy of calculation and analysis is improved.

## **2.2 Calculation Model of Urban Building Energy Consumption based on Energy Balance Sheet**

Through the analysis of the existing urban building energy consumption measurement methods, it can be seen that although all kinds of methods can get the urban building energy consumption measurement results, there are some shortcomings. Based on this, a model based on energy balance sheet is proposed.

The method of calculating the energy consumption of urban buildings based on the energy balance sheet involves obtaining the building energy consumption data from the energy balance sheet and analyzing it according to the end energy consumption department in the energy balance sheet. In China's energy balance sheet, building energy consumption is mainly distributed in wholesale, retail and accommodation, catering, other and residential life sectors. Therefore, the analysis of building energy consumption usually involves a comprehensive analysis and induction of energy consumption data in these sectors. First of all, it is necessary to clarify the source and caliber of the data of the energy balance sheet to understand the accuracy and reliability of the data. Then, the relevant data of building energy consumption can be obtained from the statistical yearbook and other channels, and the calculation and analysis can be combined with the final energy consumption department in the energy balance sheet. This analysis method can help to understand the distribution and trend of building energy consumption, and provide a reference for formulating relevant policies and measures. However, it should be noted that since there is no single list of building energy consumption in the energy balance sheet, it is necessary to comprehensively consider the energy consumption data of multiple departments when calculating building energy

consumption, and pay attention to the accuracy of the data and the reliability of the data sources to ensure the accuracy and credibility of the measurement results.

In this study, the energy balance method is mainly used to analyze the energy consumption of urban buildings in Shandong Province, and the main data comes from the energy balance table (physical quantity) of Shandong Province. In the specific calculation process, since the original data is the physical amount of energy consumption, it needs to be converted to the standard amount. The specific conversion standard is as follows. In terms of calculation caliber, according to the total energy consumption caliber, electricity is calculated according to the coal consumption of power

generation. The specific calculation formula is: urban building energy consumption = basic amount of urban building energy consumption - transportation energy consumption deduction + building energy consumption of other departments. Among them, the basic amount of building energy consumption refers to wholesale, retail and accommodation, catering, other, residential energy consumption.

### 3. Calculation Results and Analysis

Based on the introduction of the above methods, the study calculated the urban building energy consumption in Shandong Province from 2012 to 2022. First, the research calculated the total building energy consumption data of Shandong Province, and the results are shown in Table 1.

**Table 1. Total Building Energy Consumption in Shandong Province from 2012 to 2022**

Unit: 10,000 tce

	Total building energy consumption	Energy consumption of public buildings	Urban residential building energy consumption	Rural building energy consumption
2012	1332.98	323.25	422.15	587.58
2013	1468.61	353.64	495.22	619.75
2014	1530.89	346.44	480.55	703.90
2015	1576.82	403.51	481.25	692.07
2016	1624.12	525.73	532.22	566.17
2017	1672.84	609.08	501.52	562.24
2018	1638.05	627.05	489.61	521.39
2019	1687.19	693.27	531.30	462.63
2020	1689.09	712.96	554.53	421.60
2021	1739.76	729.31	724.09	286.36
2022	1703.57	668.82	529.56	505.18

Further, combined with the total energy consumption data, the proportion of various

types of energy consumption was calculated, as shown in Table 2.

**Table 2. Proportion of Energy Consumption of Urban Buildings in Shandong Province from 2012 to 2022**

Year	Total energy consumption of buildings as a proportion of total energy consumption	The proportion of energy consumption of public buildings to total energy consumption of buildings	The proportion of energy consumption of urban residential buildings to total energy consumption of buildings	The proportion of rural building energy consumption to total building energy consumption
2012	17.35%	24.25%	31.67%	44.08%
2013	11.84%	24.08%	33.72%	42.20%
2014	10.49%	22.63%	31.39%	45.98%
2015	11.25%	25.59%	30.52%	43.89%
2016	12.33%	32.37%	32.77%	34.86%
2017	11.18%	36.41%	29.98%	33.61%
2018	11.65%	38.28%	29.89%	31.83%
2019	11.89%	41.09%	31.49%	27.42%
2020	13.38%	42.21%	32.83%	24.96%
2021	12.89%	41.92%	41.62%	16.46%

2022 14.94% 39.26% 31.09% 29.65%

In addition, the research calculated the energy consumption per unit area of each type of building according to the situation of various building areas in each year, and the results are shown in Table 3.

**Table 3 Energy Consumption per Unit Area of Urban Buildings in Shandong Province during 2012-2022**

Unit: kgce/m <sup>2</sup>			
Year	Public building	Urban residential buildings	Rural residential building
2012	12.07	11.04	3.52
2013	10.96	9.47	3.58
2014	8.65	7.60	3.56
2015	8.70	5.87	3.02
2016	14.42	6.19	3.00
2017	15.40	6.84	3.32
2018	15.85	6.27	3.18
2019	15.69	6.34	3.93
2020	18.19	6.15	4.01
2021	21.66	8.93	5.30
2022	21.44	9.69	4.88

It can be seen from the calculation results of Table 1 to Table 3 that there are several obvious characteristics of urban building energy consumption in Shandong Province. According to the total energy consumption and energy consumption ratio in Table 1 and Table 2, the total energy consumption of buildings in Shandong Province has been fluctuating upward since 2012. The main growth comes from the increase in energy consumption of public buildings and urban residential energy consumption, of which public building energy consumption has more than doubled in a decade, becoming the key to promoting the expansion of total energy consumption of buildings throughout the town. In contrast, the level of building energy consumption in rural areas did not change significantly and even decreased in some years. It can also be seen from Table 3 that the energy consumption per unit area of urban buildings in Shandong Province is much higher than that of urban residential buildings and rural residential buildings. These results also reflect that the key node of energy conservation and emission reduction in urban buildings in Shandong Province lies in the level of public buildings.

#### 4. Conclusion

Promoting energy conservation and emission reduction in buildings is crucial for achieving China's "double carbon" goal, which aims to reduce both carbon emissions and energy consumption. Shandong Province serves as a

focal point in this study, providing insights into urban building energy consumption patterns from 2012 to 2022. By evaluating various measurement methods, this research proposes an innovative urban building energy consumption calculation model based on an energy balance table, offering a comprehensive approach to analyzing energy usage in Shandong Province's urban areas.

The analysis underscores the significant role of public buildings in driving overall energy consumption in urban areas of Shandong Province. These structures often exhibit higher energy demands due to factors such as size, occupancy rates, and operational requirements. As a result, targeted energy conservation and emission reduction strategies need to be implemented specifically tailored to address the unique challenges posed by public buildings.

To facilitate green and low-carbon development in Shandong Province, the study advocates for the implementation of comprehensive energy-saving measures in public buildings. This could include retrofitting outdated infrastructure with energy-efficient systems, enhancing insulation and ventilation, optimizing lighting and HVAC (heating, ventilation, and air conditioning) systems, and promoting the use of renewable energy sources where feasible. Additionally, raising awareness among building occupants and stakeholders about energy conservation practices and fostering a culture of sustainability can further contribute to reducing energy consumption and

emissions in urban areas.

By prioritizing energy efficiency initiatives in public buildings and leveraging innovative calculation models, Shandong Province can make significant strides towards achieving its environmental goals while simultaneously promoting sustainable urban development and enhancing the quality of life for its residents.

### Reference

- [1]Shareef S , Altan H .Urban block configuration and the impact on energy consumption: A case study of sinuous morphology[J].Renewable and Sustainable Energy Reviews, 2022, 163.
- [2]Irene Mansó Borràs, Neves D , Gomes R .Using urban building energy modeling data to assess energy communities' potential[J].Energy and Buildings, 2023, 282:112791-.DOI:10.1016/j.enbuild.2023.112791.
- [3]Alamin E , Kamaruzaman N , Kamar H M .Building Envelopes Toward Energy-Savings in Hot and Humid Climates: A Review[J].Strategic planning for energy and the environment, 2023(3):42.
- [4]Fan Xiaoli, Luo Tao, ZHANG Xuewei et al. A continuous scale study on the correlation between urban spatial form and residential building energy consumption at county level: A case study of Changxing in Zhejiang Province and Lianjiang in Fujian Province [J]. Acta Ecologica Sinica, 2022, 42 (08): 3155-3166.
- [5]Zhou Wei, Mi Hong, Yu Xiaofeng et al. Research on urban building energy consumption under the influence of population structure change [J]. China Environmental Science, 2013, 33 (10): 1904-1910.
- [6]Xu Hongsheng, Wang Mingbo, Zhang Xiuman. Analysis and research on energy consumption intensity of urban civil buildings in Shandong Province [J]. Building Energy Conservation,2015,43(10):115-118+123.