Economic Analysis of Energy-Saving Reconstruction Based on Life-Cycle for Existing Buildings

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Abstract

At this stage, the energy consumption of a large number of existing buildings has exceeded the national energy-saving standards, and it is unable to meet the requirements of energy-saving 65% and energy-saving 75%. It is urgent to save energy for existing buildings. This paper will focus on the energy-saving renovation of existing buildings, based on the life cycle assessment (LCA) method, select the actual cases of existing energy-saving retrofits, and focus on the analysis and evaluation of energy consumption at all stages of the building life cycle.The results show that the energy consumption of the life cycle of the building is very huge, and the potential for energy-saving renovation of existing buildings is huge, and the economic benefits are considerable.Hope to provide some references for the energy conservation reconstruction of existing buildings in China.

Keywords

Existing buildings, energy-saving renovation, life cycle assessment, actual case.

1. Introduction

Energy shortages are increasingly becoming the focus of attention around the world, excessive use of energy exacerbates global warming and poor environmental quality. From the perspective of sustainable development of human society, the use of energy conservation has become a prerequisite for development. According to the statistics of the "People's Republic of China 2018 National Economic and Social Development Bulletin" [1], China's total energy consumption in 2018 was 4.64 billion tons of standard coal, an increase of 3.3% over the previous year. Adhere to energy conservation and promote energy-saving reconstruction, which is conducive to better development.

Building energy consumption is an important part of the society's energy consumption, including building construction processes and energy consumption during building operations. Due to the large number of existing buildings being high-energy buildings, the envelop enclosure used in the construction process is poor in thermal insulation performance, and the heating performance is low during operation. Many reasons lead to poor energy-saving effects of existing buildings, resulting in waste of energy. Every stage of the building life cycle consumes energy. From design and construction to use and demolition, there are also many wastes of energy in the link. Analysis of building energy consumption from the perspective of the whole life cycle is conducive to energy-saving reconstruction of existing buildings.

2. Research status at home and abroad

Foreign research on building LCA began earlier. From the beginning of the application of LCA to building energy conservation, there have been a lot of research results in theory, simulation and so on. Domestic research on building LCA began around the mid-1990s and started late. It is still difficult to meet the evaluation of building energy efficiency.

The UK government revised its building codes in 2002, 2006 and 2010 to achieve more stringent energy efficiency standards and ultimately achieve the 2016 “zero carbon” new homes [2]. In 2008, Timothy Carter [3] conducted a cost-benefit analysis of the life cycle of a residential green roof system and found that the net present value (NPV) of green roofs was 10% to 14% higher than that of traditional roofs, and construction costs were reduced by 20%. In 2015, Norbert Harmatia and Zoltán Magyar [4] reduced the window-to-wall ratio (WWR) from 50% to 25%~30% through the renovation of the 10-story office building envelope 83% of heating energy demand.

Compared with foreign countries, some domestic research results appear later.In 2009, Liu Yuming[5] analyzed the cost-benefit of a certain district in Baotou City, and optimized the scheme of heat source heat network transformation. The results show that the static investment recovery period of the scheme is 7.31 years, and the internal benefit rate is 12.35%. Zhou Zhiyu[6] analyzed the cost-effectiveness of Tsinghua University's northwest residential renovation project in 2014. The results show that the project can reduce CO_2 emissions by more than 500 tons and SO_2 tens of tons during the whole life cycle of the project, and the emission reduction effect is remarkable. In 2016, Zhao Jinming[7] applied the cost-benefit analysis and evaluation model of the existing building energy-saving renovation in the whole life cycle to the benefit evaluation of the Qingdao transformation project. After the transformation, the energy-saving rate reached 57%.

3. Life Cycle Assessment (LCA)

3.1 Definition of LCA

China's 2008 Environmental management-Life cycle assessment-Requirements and guidelines (GB/T 24044-2008)[8], a standard interpretation of LCA: "Life cycle analysis is the life cycle input to a product system, output and its potential environmental impact compilation and evaluation." The so-called from the cradle to the grave.

3.2 Advantages of LCA

Energy consumption has an extremely important impact throughout the life of the building and is an important factor that cannot be ignored. The life cycle assessment (LCA) method has become a widely used method for building sustainability evaluation in the international arena due to its long-term comprehensive evaluation perspective and scientific quantitative calculation methods[9]. Introducing the evaluation method into the field of building energy conservation will help to analyze the economic efficiency of building energy.

3.3 Main stages and calculation methods of LCA

The life cycle of a building is divided into five stages: the mining of raw materials, the production and processing of building materials and equipment, the construction of the site, the operation and maintenance of the building, and the demolition and disposal [11]. Among them, the production of materials and the operation of buildings are the most energy-intensive and should be the focus of research.

In the 1990s, some Western scholars began to introduce life cycle theory into the field of architecture. Through a series of studies, a more unified evaluation model for the energy consumption of the building life cycle was established[10].

$$Q_{Life\text{-}Cycle}=Q_{manuf}+Q_{Erect}+Q_{Occup}+Q_{Demol}+Q_{Disp} \tag{1}$$

Here,Q_{manuf} means the total energy consumed by the building system during the material preparation phase;Q_{Erect} means the total amount of energy consumed by the building during the construction phase;Q_{Occup} means the total amount of energy consumed by the building during its use phase;Q_{Demol} means the total amount of energy consumed by the building during the demolition phase;Q_{Disp} means the total amount of energy consumed by the building during the disposal of waste building materials.

4. Actual case

(1).In order to quantitatively evaluate the impact of building energy conservation and comprehensive environment in China, Gu Daojin and Zhu Yingxin[11] of Tsinghua University proposed a life cycle assessment method suitable for China's national conditions in 2006.The analysis and simulation calculation of the energy consumption of a multi-storey building in Beijing shows that the building energy consumption accounts for 20% of the total building energy consumption in the 50-year life cycle, and the heating energy consumption in the running period accounts for 40%. The ratio of energy consumption to operating energy consumption in the production of building materials and equipment is close to 1:4; comparison of building energy consumption of insulation material (polystyrene board) thickness is found to be energy-saving when the thickness exceeds 100 mm. The effect is minimal, after 120 mm,there is no energy saving effect.

(2). Wei Xiaoqing[12] of Hunan University established a life cycle energy consumption model for a comprehensive building in Changsha City in 2010. The energy consumption of each stage of the 50-year life cycle of the building was calculated and evaluated, and the total life cycle was calculated. The energy consumption is about 4.2×10^9MJ, of which the energy consumption in the operation phase accounts for 79.39%, followed by the energy consumption of building materials production and demolition and waste building materials processing. These two stages should be the focus of the building life cycle research; 50 years life cycle, the CO_2 emission in the internal operation stage reaches 1.22×10^7kg, which has a great impact on the environment.

(3). In 2017, Liu Lu[13] of Tianjin University selected the Hongshunli area of Hebei District in Tianjin to analyze the life cycle of the building. Using Revit to build the pre-reformed and reconstructed building model, select the Revit plug-in – Tally built the life cycle of the building. Evaluate and calculate the material usage, energy consumption, global warming potential and cost of typical buildings per unit area under different energy conservation goals, and calculate the life cycle cost(LCC) of the building based on the information of Tianjin construction cost. Provided a good data sample for energy efficiency retrofits in existing buildings in the area.

5. Conclusion

This paper focuses on the energy-saving renovation of existing buildings from the perspective of life cycle. Based on the literature research, the energy consumption of existing buildings is analyzed. The results show that the energy consumption of existing buildings is very huge at present, from the perspective of life cycle. It is found that the energy consumption of many buildings does not meet the building energy consumption standards of China, which is very unfavorable to the development of China; the cost-effectiveness of the energy-saving renovation of existing buildings is analyzed. The results show that the energy-saving renovation can not only obtain energy consumption. It has been greatly reduced, and its benefits are also considerable.

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