Study on Improving Energy Saving for Old Buildings with Daily Energy Conserving Index

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Abstract. Energy conservation and carbon reduction have become the emphasis of governance in countries of the world as global warming is increasing quickly. This study assessed building energy efficiency, proposed plans for enhancing building energy efficiency, and assessed the effectiveness of enhancement; in order to comply with the green building specification and save energy for sustainable development. The target building was assessed according to the major items in the Energy Conservation Target of Taiwan's system for Ecology, Energy saving, Waste reduction, and Health (EEWH) and Ecotect. These included the Efficiency of Lighting (EL), Efficiency of Air-Conditioning (EAC), and building Enclosure Energy-efficient Value (EEV). Buildings must pass these three items in order to pass the energy conservation assessment.

Keywords: Green Building, EEWH, Ecotect, Energy Saving, BIM

1 Introduction

The condition of the earth has been deteriorating in recent years as witnessed by the continuing extreme climates, ice meltdown in the Arctic and Antarctic, forest fire, and ozone layer damage. Global warming and high oil prices were a threat to the whole human race. One of a solution is to reduce energy consumption of building.[1] Realizing the future impact of climate change, the Taiwanese Government began advocating energy conservation and carbon reduction and launched the green building specification in 1999.

It is important to evaluate Building Life Cycle Energy Consumption which is the key problem of building energy-saving. [2] About 97% of buildings in Taiwan are older buildings, and most did not pass the Green Building Mark (GB mark) accreditation. Throughout the lifespan of buildings, as energy consumption when buildings are in use is about 93% [3], energy conservation can help enhance the substantive economic efficiency of old buildings. The most important decisions regarding a building's sustainable features are made during the design and preconstruction stages. [4] In order to obtain the GB Mark, buildings must pass at least four out of the said nine targets, and "energy conservation" and "water conservation" are the required targets. This study mainly investigated the "energy conservation" target. The main issues of this target include building enclosure energy-saving design, air-conditioner energy-saving design, and lighting efficiency. These issues are closely related to energy consumption.

In this study, the College of Architecture and Planning of Chung Hua University was selected as the subject to assess if the building was qualified for the energy conservation assessment of Taiwan's GB mark accreditation. The research objectives of this study include: (1) To investigate the methods for enhancing energy conservation in green buildings, (2) To build the BIM and implement Ecotect to simulate and analyze the assessment items of energy conservation, and (3) To propose improvement plans for non-conforming items and estimate the projected benefits of improvement.

2 Literature Review

2.1 Energy Conservation

Energy-efficient design for buildings is a vital step towards building energy-saving. [5] The lifespan of buildings is about 50-60 years. When the building is in use, air-conditioning, lighting, elevator service, etc will consume most part of the energy throughout the lifespan of the building. In summer, air-conditioning consumes about 40-50% of energy, and lighting about 30-50%. Therefore, discussing building energy conservation in terms of air-conditioning and lighting will be the most effective [6]. The construction industry is increasingly interested in designing green buildings that can provide both high performances while saving on costs. [7]

2.2 Building Information Modeling

Building information modeling. Building information modeling (BIM) is a three-dimensional value technology. BIM can provide a range of information about a building. [8] The concept of BIM necessary for the design of green building can provide the characteristics and performance of design concepts. [9] It integrates the data of all related information of a construction project. That is to say, it is the quantitative expression of construction projects. BIM is also a valuation method applied to design, construction, and management. By applying it to the central management of construction projects, constructors can enhance the overall project efficiency and reduce project risk [10].

In general, BIM is considered as a digital 3D geometric model of buildings. BIM provides a cooperative work platform for building designers and engineers, which is beneficial for them to effectively achieve energy saving, pollution reduction, costs saving of a project. [11] The information is expressed in different dimensions of a building, such as the layout, façade, cross section, detailed drawing, 3D view, perspective, BOM, the lighting effect of individual rooms, the required ventilation of air-conditioning, material price, and purchasing information. Therefore, BIM builds a virtual building in the computer by means of digitization and provides a complete, consistent, and logical building database [12].

Ecotect. Ecotect uses a flexible and perceptual 3D information model simplifies complex geometric conceptualization, and completely abandons the complex modeling method of conventional CAD. It includes six analysis functions: thermal environment, light environment, sound environment, daylight, economic and environmental effects, and visibility analyses. These analyses cover the major factors affecting architectural design [13] and can accurately simulate the corresponding surroundings of a building in the four seasons. It also includes the interior environment analysis of buildings. This package allows us to spend the least time to simulate and experiment architectural design in the greatest detail. In energy conservation, it further analyzes information relating to daylight length, thermal environment, air-conditioning, and lighting equipment to reduce energy consumption of buildings for energy conservation.

3 Present Status and Analysis of Target Buildings

3.1 Assessment of Energy Conversation Indicators of the Target Building

The College of Architecture and Planning of Chung Hua University was the target of this study aiming to investigate if the building was qualified for “energy conservation”. In Table 1, the failed items include “horizontal light penetration window solar radiation shade” and “Building envelope energy efficient value (EEV)”. As EEV is the required assessment item, these results showed that the target building is not a qualified green building.

Table 1. Energy conservation indicator assessment sheet of the target building.

Item	Standard	Result	Pass	Fail
(a) Glass visible light refraction rate	Gri<0.25	Gri = 0.09	V	
(b) Horizontal light penetration window solar radiation shade	HWs<HWsc	HWs = 0.71 HWsc = 0.308		V
(c) Roof average penetration rate	Ur<1.0(w/m²˙k)	Ur = 0.724	V	
(d) Building envelope energy efficient value (EEV)	EEV≤0.8	EEV = 1.24		V
(e) Unit capacity efficiency (HSC)	HSC≤1.35	HSC = 0.438	V	
(f) Efficiency of Air Conditioning System (EAC)	EAC≤0.8	EAC = 0.75	V	
(g) Efficiency of Lighting (EL)	EL≤0.7	EL = 0.657	V	
Failed in energy conservation when any of the following items fails: EEV, HSC, EAC or EL				V

3.2 Analysis of Building Enclosure Energy-Efficient Value

The calculation of the energy conservation efficiency of the horizontal sunshade, vertical sunshade, and grid sunshade of windows was the focus of EEV analysis. When assessing enclosure energy conservation efficiency, we usually calculate the average window solar gain (AWSG). The AWSG of the target building is 198, which is higher than the standard at 160. Therefore, it failed. For this reason, the enclosure energy conservation efficiency of the target building should be reviewed. Most openings of the target building face east and west, including 47% facing east and 36.3% facing west. Although grid sunshades are installed on the building, as they are too shallow (approx. 15-25cm), and there are too many openings on the east and west, the AWSG value is much higher than the standard EEV value for green buildings. Therefore, we suggest the owner to increase the depth of the sunshade and change all sunshades into grid sunshades. This way, there will be a greater change to pass the assessment.

4 Energy Efficiency Analysis

This study applied Ecotect to simulate and analyze "lighting energy conservation" and "enclosure energy conservation". After creating a 3D module based on the target building's present status, related values are input for space energy analysis. Classrooms A307 and A324 on the third floor of the target building were the targets of spatial simulation. The following energy conservation items were analyzed:

4.1 Verification of Lighting Energy Conservation

We verified the lighting energy conservation of Classrooms A307 and A324. T8 (Tube 8/8 inches) fluorescent lamps were equipped in room A324. The equipment capacity included 12 sets of T8 fluorescent lamps, each 40W x 3 tubes. In room A307, T5 (Tube 5/8 inches) fluorescent lamps were equipped. The equipment capacity included 12 sets of T5 fluorescent lamps, each 28W x 2 tubes. As the luminous efficacy of the T8 fluorescent lamp is 52.5Lm/W each tube, the radiant flux of each set is 6,300Lm. Also, the luminous efficacy of the T5 fluorescent lamp is 89.29Lm/W each tube, the radiant flux of each set is 5,000Lm.

After Ecotect simulation and analysis of Classrooms A324 and A307, Fig. 1 shows that the illuminance of artificial lighting by using T8 lamps for A324 is 223.71lx, meeting the CNS school indoor lighting requirements at 200-750lx. Fig. 2 shows that the illuminance without natural lighting by using T5 lamps for A307 is 215.45lx, also meeting the CNS requirements. In energy consumption, assume that these lamps are used 10 hours a day, the energy consumption is 146.4 kWh for summer months; 291.6 kWh for non-summer months. The cost for summer months is 146.4 x $3.5/kWh = $512.4, for non-summer months is 291.6 x $2.62/kWh = $764; and the total amount is $1276 x 12 sets = $15,312/year.

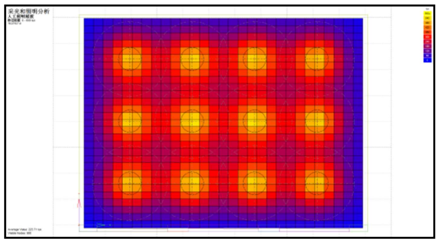

Fig. 1. Illuminance of T8 lamps (room A324, 223.71lx)

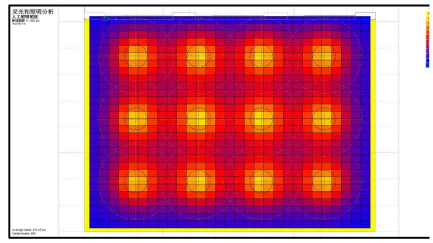

Fig. 2. Illuminance of T5 lamps (room A307, 215.45lx)

4.2 Cost Analysis of Lamp Replacement

As shown in the results, the illuminance difference between T8 and T5 lamps was very small, reduced from 223.71lx to 215.45lx. In energy consumption, however, the difference is significant, from $15,312/year to $7,152/year. That is to say, T5 lamps can save energy up to 53%. After replacing part of the lamps on the first to the fifth floors in June 2011, the changes in energy consumption of the target building from June to December 2011 was shown in Fig. 3. The results showed that T5 lamps can reduce energy consumption up to 31.7% when compared with the same period last year. These results also suggest that energy conservation performance will be more significant after replacing the lamps of the entire building to T5 lamps.

After replacing part of the T8 lamps to T5 lamps in the target building, the total capacity saved is 15,762W. Assume the consumption time is 3,650 hours, a total of 57,531 kWh and a sum of NT$172,593 of electricity bill will be saved a year. A budget of lamp replacement is NT$254,945. The estimated payback period is 15 months.

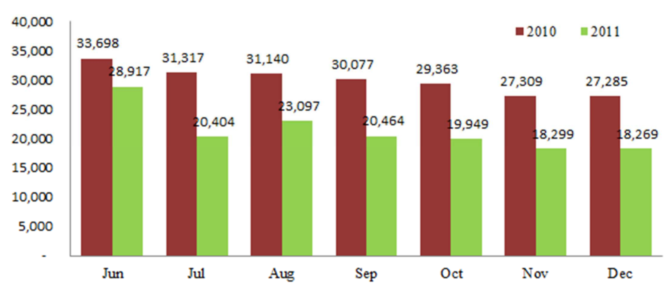

Fig. 3. Illuminance statistics 2010 and 2011 (unit: kWh)

5 Conclusions

Based on the investigation results of the target building, the effect of energy conservation is obtained after replacing part of the T8 lamps with T5 lamps. In the energy consumption of air-conditioning, conservation should begin with the enclosure design. A good building enclosure design can maximize the lighting, sun-shading, and heat-insulating effects of buildings. Consequently, the energy consumption of lighting and air-conditioning will be reduced. The author suggests the replacement of all T8 fluorescent lamps with T5 fluorescent lamps for the entire building to reduce energy consumption. In terms of building enclosure, as most openings are in the east and west, the energy conservation efficiency is limited. Therefore, the author suggests the installation of 45cm horizontal sunshades on all openings to achieve optimal energy conservation effect.

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