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Cost-benefit analysis on green building energy efficiency technology application: A case in China

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ABSTRACT

In order to initiate economic evaluation of green buildings and foster their development, this article conducts the cost–benefit evaluation of energy efficiency technology application (EETA) on green buildings in China. Based on the economic evaluation theory of construction project (EETCP), the authors first establishes the theoretical framework system of cost–benefit evaluation of the EETA on green buildings and then develops the analysis methods of incremental costs and quantitative calculation formula of incremental benefits of the EETA on green buildings. Using these theories and methods, this article takes the Wanke City project in China as a study case, conducts the cost–benefit empirical analysis of the EETA on green buildings, and draws the following important conclusions: (1) the incremental costs of the EETA account for a large proportion of total incremental costs of green buildings, which are more than 50% in this case; (2) the EETA on green buildings can bring incremental economic benefits, as well as environmental benefits; (3) if only consider the incremental economic benefits of the EETA on green buildings, the financial evaluation indexes show green buildings do not have market investment potential; (4) among all the factors influencing the financial evaluation results of the EETA on green buildings, power price is the most sensitive factor, followed by the unit incremental costs, and the lifetime has the smallest influence.

1. Introduction

Developing green buildings is an important strategic way to realize sustainable development, save resource and energy, and protect environment. In order to promote the healthy development of green buildings, many countries issue green buildings evaluation standard, such as BREEAM of the UK, CASBEE of Japan, GBTool of Multinational Cooperation and LEED of the USA, which all aim to evaluate the “environment performance grade” of green buildings [1–3]. In 2006, China issued “Evaluation Standard for Green Building (ESGB)”, which is the first multi-objective and multi-level comprehensive evaluation standard of green building “environment performance grade” in China [4]. In 2008, China began to implement the green building evaluation label system. There are 10, 20, 82 new buildings acquiring green building evaluation labels in 2008, 2009 and 2010, respectively [5]. By the end of 2012, there are total 742 new buildings acquiring green building evaluation labels in China, and total building areas had reached 75.43 million m^2 [6]. This shows that the development of green buildings have kept rapid momentum in China. However, compared by the new building areas of nearly 2 billion m^2 each year, the development scale of green buildings is still very small in China.

Analyzing the international existing green building evaluation systems, it can be found that these evaluation systems do not involve the economic evaluation of green buildings. For instance, BREEAM, LEED, CASBEE and ESGB do not contain such economic evaluation. Although the GBTool system, as an evaluation framework, proposes to evaluate cost benefits, it does not provide specific evaluation contents and methods. Currently, many people’s awareness about green buildings is not enough comprehensive and accurate, they think that green buildings require high investment and high cost, and do not want to develop or purchase green buildings, which hinders the development of green buildings in China. Hence, it is very necessary to construct the theoretical method system of green building cost–benefit analysis from a technical and economic point of view, which has important theoretical value and practical significance for the healthy development of green buildings.

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Table 1
Level of green standard and average green cost premium.

Level of green standard	Average green cost premium (%)
Level 1—Certified	0.66
Level 2—Silver	2.11
Level 3—Gold	1.82
Level 4-—Platinum	6.50
Average of 33 buildings	1.84

2. Literatures review

At present, many scholars at home and abroad are focusing on the research about economic performance resulted by green buildings, which mainly covers the following three aspects:

(1) Analysis on economic, environmental and social benefits generated by the green building technology application [7–11]. For instance, Nalewaik and Venters [7] think green buildings can bring tangible and intangible benefits; besides, with the increase of resources and energy's price, cost saving of resources and energy will make green buildings generate significant economic benefits. Ries et al. [8] takes new green plant as a case, and analyzes quantitatively economic and environmental benefits brought by the green plant, which mainly includes increasing working efficiency and human health, decreasing energy consumption, operating and maintenance costs; Specifically, the case study shows that working efficiency is increased by 25%, and energy is saved by 25%. Kats [9] thinks that the benefits brought by green buildings include saving energy and water, decreasing waste discharge, increasing indoor environment quality, employee's satisfaction and work efficiency, as well as decreasing health costs, equipment operation costs and maintenance costs.

(2) Study on incremental costs of green buildings technology application [9,12–18]. Through comparative study on the costs of 33 green buildings and conventional buildings of the same type, Kats [9] finds that the average incremental cost is only $3–5 per square foot, and the average cost increasing rate is only 1.84%, which is shown in Table 1.

By collecting the construction cost data of 221 buildings (including teaching buildings, laboratories, libraries, community centers and so on) and comparing the unit construction cost, Morris [13] finds that the difference of construction cost is very big even among the same type of buildings, which mainly depends on the type of property, no matter whether the green buildings get the LEED certification or not. Zhang et al. [14] examines the costs and barriers in applying the green elements to the process of developing property projects, they find that the passive design strategies are comparatively inexpensive to apply as opposed to the active design strategies and the major barriers, the higher costs have hindered the extensive application of green technologies in China. By statistically analyzing the incremental costs of 18 projects participating the green building certification label (9 public green buildings, 9 residential green buildings), Sun et al. [15] find that the major factors influencing on the incremental costs are: renewable energy application (48.20%), saving energy of envelope structure (23.20%), building intelligent (16.10%), indoor environment control (7.5%), water utilization and rainwater collection (2.60%). Chen [16] applies two indexes of "unit area incremental cost" and "incremental cost ratio" to analyze the incremental costs of green buildings, and gets that unit area incremental cost is 6.01$/m^2 for one-star green building label, 16.28$/m^2 for two-star green building label and 35.48$/m^2 for three-star green building label, and that unit area incremental cost ratio is 1.0% for one-star green building label, 2.2% for two-star green building label and 3.4% for three-star green building label.

(3) The cost–benefit evaluation of green building technology application [8,9,19–24]. Ries et al. [8] conducts a financial evaluation on the new green plant project utilizing three financial indexes of the net present value (*NPV*), breakeven period and B/C, which shows that investing new green plant is a correct decision from financial benefits aspect. Kats [9] analyzes on the present value of incremental benefits and costs of 33 green buildings obtaining the LEED certification in 20 years of study period, which indicates that total financial benefits of green buildings are over ten times the average initial investment required to design and construct a green building, and energy savings alone exceed the average incremental costs associated with building green, and building green is cost-effective and make financial sense (see Table 2). Li and Tian [19] constructs an incremental cost–benefit model of green buildings in the whole life cycle, proposes that the comprehensive benefits of green buildings in the whole life cycle can be reflected by two indexes, one is the *NPV* of comprehensive benefits, the other is the incremental cost–benefit ratio, and through case analysis, she draws a conclusion that green buildings have economic feasibility.

Table 2
Financial benefits of green buildings summary of findings (per ft^2).

Item	Category	20-year *NPV*
1	Energy value	$5.79
2	Emissions value	$1.18
3	Water value	$0.51
4	Waste value(construction only)-1 year	$0.03
5	Commissioning O&M value	$8.47
6	Productivity and health value (certified and silver)	$36.89
7	Productivity and health value (gold and platinum)	$55.33
8	Less green cost Premium	$4.00
9	Total 20-year *NPV* (certified and silver)	$48.87
10	Total 20-year *NPV* (gold and platinum)	$67.31

In brief, the literatures above-mentioned mainly study on economic, environmental and social benefits of green buildings, and cost–benefit evaluation of green technology application on green public buildings and green plant buildings from the view of qualitative and quantitative point. However, there are a few of articles on the cost–benefit evaluation of green technology application on large-scale residential area in China. In this paper, taking the large-scale green residential area in China as a study case, the authors would systematically carry out the cost–benefit analysis on energy efficiency technology application (EETA) on green buildings.

3. Analysis methodologies

3.1. Evaluation method

According to the EETA on proposed green construction project, green building energy efficiency scheme (GBEES) will first be set up; then this project's virtual baseline building energy efficiency scheme (BBEES) which can meet both the national and local compulsory energy efficiency standards will also be set up; finally, based on the GBEES and BBEES, economic evaluation theory of construction project (EETCP) would be applied to analyze the cost–benefit of the EETA on green buildings [25]. The basic flow of cost–benefit analysis on the EETA of green buildings is shown in Fig. 1.