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ARTICLE

Overcoming the barriers for the development of green building certification in China

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Abstract This study investigates the major barriers in the development of China's green buildings and the ways to overcome these barriers. By survey, statistical analysis, and interview, we find that the high-incremental-cost and the immature green technologies are the two major barriers to the comprehensive and balanced development of green buildings in China. By analyzing the main causes of high incremental costs, solutions such as choosing the general or preferred items in different order and enhancing the incremental cost efficiency of green technology are proposed. Moreover, we show the green technology applications are still in early stage in China. Three strategies for improving the use of green technologies and development of highly cost-effective green technologies are also proposed. The present study provides recommendations to overcome the barriers, which could facilitate the rapid and full-scale development of green buildings in China.

Keywords Incremental cost · Green technologies · Green building evaluation system (GBES) · Leadership in energy and environmental design (LEED) · Green certification

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1 Introduction

China faces enormous resources, energy, and environment pressures, where there is a large number of building stocks and new buildings are continuously built (Wu 2011). As a result, green building has become a widely investigated construction topic (Tian et al. 2012). The development of green buildings is the most effective way to alleviate the resource, energy, and environment pressures (Zhang et al. 2011).

Green building assessment systems, such as LEED and CASBEE, have been vigorously developed in other countries/regions (Newsham et al. 2009; Binh et al. 2011). Binh et al. (2011) have shown that currently the LEED standards are relatively comprehensive and influential. The Chinese certification standards on green building were initiated much later and the whole development progress can be categorized into three stages: the release of China's Eco-house technical evaluation handbook based on LEED in 2000; the release of green building assessment system for the Beijing Olympics based on CASBEE in 2002; and the release of national Green Buildings Evaluation System (GBES) based on LEED in 2006 (Geng et al. 2012). The GBES is the most comprehensive national standard for the multi-level and multi-objective evaluation of a green building (Du 2006).

Many buildings designed under LEED and GBES have now been occupied in China. It is reasonable to ask whether these certified green buildings save energy and resource. Take energy as an example, Newshan et al. (2009) indicated that on average, LEED buildings use 18–39 % less energy per floor area than their conventional counterparts. Baylon and Storm (2008) found that the mean energy use per floor area for the 12 LEED buildings was 10 % lower than that for the 39 similar non-LEED buildings. Peng (2012) indicated that on average, GBES buildings use 13–38 % less energy than their conventional counterparts. These studies suggested that LEED and GBES certification systems indeed contribute to substantial energy savings.

However, promoting green building will increase the cost of construction, and mainly due to that some items of LEED or GBES need high-incremental-costs technologies to apply, such as the "optimize energy performance" in LEED-NC and the "renewable energy" in GBES-RB. Although green buildings are justified in energy savings, Jin et al. (2009) pointed out that the incremental cost of energy-saving technology is high, and the efficiency of incremental cost is so low that building owners would rather waste electricity in operation than adopt energy-saving technology.

Therefore, exploring ways to reduce the incremental cost and enhance the efficiency of a green building is urgently needed. Incremental cost is the cost increase resulted from the technology solutions for land, water, energy, and material conservations and for indoor environment, under the goal to construct green building in line with the green certification requirements. Based on the certification items in LEED, Miranda et al. (2005) studied ways to accomplish LEED projects with lower incremental cost. Tatari and Kucukvar (2011) pointed out that among the six certification categories of LEED, the incremental cost for energy and atmosphere shows the highest sensitivity; therefore, the incremental cost efficiency may be enhanced by targeting this category.

Moreover, green technologies are critical to implement in green certification buildings. As shown by Liu et al. (2012), lack of green technologies largely hinders the success in green building certification. Zhang et al. (2011) revealed that the active technology covering multiple new techniques results in a high incremental cost, which may be reduced by targeting the active technology. Yin (2012) indicates that the technologies with low incremental cost, such as "envelope Insulation and Low-E exterior window" also have significant impact on the improvement of environment. The industrialization and creativity of technology is important to achieve environment protection with low incremental cost (Ma et al. 2010).

However, there are few reports on the impact of incremental cost of applied certification systems, which are the major applied green technologies in China. Especially, limited studies have focused on the introduction, implementation, barriers and solutions for LEED and GBES in China. The present study aims to identify barrier in the adoption of green building and propose ways to overcome these barriers. This report is organized in the following sections: Sect. 2, research methods are developed; Sect. 3, LEED and GBES, the two equally practiced systems in China, are analyzed; Sect. 4, current status of green projects certified by LEED and GBES, and the main barriers for the promotion of green buildings in China are discussed; Methods and strategies to solve the barriers and facilitate the rapid and full-scale development of green building certification in China are proposed. The conclusions are drawn in Sect. 5.

2 Research methods

2.1 Research and data collection

To investigate the existing barriers for China's green building certification development, GBES and LEED were taken as the foundation of this study, since vast majority of green buildings in China were certified by these two certification systems.

The related data in this study were collected from the website of Green Building Certification Institute (GBCI) (LEED project directory 2013) and the website of Ministry of Housing and Urban–Rural Development of the People's Republic of China (2013), a variety of literatures (Wang et al. 2012; Tian et al. 2012; Kats et al. 2003; Issa et al. 2010; D'Antonio 2013; Li and Sun 2013; Xu and Zhao 2012), research reports (Green Building Council 2013; China Academy of Building Research 2013; Yin 2012), and 138 green certification projects across 27 Provinces in China (China Green Real Estate Network 2013; Chinese Green Building Evaluation Label 2013).

2.2 Data analysis and processing methods

The data collected from all these sources were analyzed statistically by organizing in Excel to generate new sets of results. In order to validate and improve the original results that are derived from all the sources and gather further comments and interpretation of the original results, face-to-face interviews were conducted. The author selected 20 interviewees randomly from the project managers, designers, engineers, contractors, and suppliers who have the experience for green building in China. The data (information) collected from face-to-face interviews were processed by Excel based on the original results, note: if above 60 % interviewees did not agree with the original results, the original results were replaced with the reasonable (average) results proposed by interviewees.

2.3 Study process and methods

The study process and corresponding study method includes four steps as follows:

Step 1 Analysis of LEED and GBES. We firstly comparatively analyzed the certification categories, prerequisites, certification levels, and rating method, as well as certification authority and process of LEED and GBES, aiming to provide theoretical basis for better understanding the certification systems, and then providing the foundation for this paper

Step 2 Discussion of the practice of LEED and GBES green buildings, and determination of the major barriers for the development of green buildings. According to the statistical analysis of the data collected from GBCI (LEED project directory 2013), the website of Ministry of Housing and Urban–Rural Development of the People's Republic of China (2013) and China Green Real Estate Network (2013), and literature (Wang et al. 2012) about the green building certification projects in China, we first elaborated the original results including current regional distribution, annual number of LEED-certified and GBES-certified projects, and the major barriers for the development of green buildings.

The original analysis results were validated and improved by the face-to-face interviews. The interviews include two main steps: (1) the interviewees were given the original analysis results proposed in this step; (2) Based on the experience, the interviewees should answer what are the major barriers in the balanced development of green buildings. Finally, the present barriers in the development of green buildings in China are determined.

Step 3 Methods and suggestions are proposed for overcoming one of the major barriers—high incremental cost. In order to determine the main reasons that cause the high incremental cost and propose the solutions, the relationships between the green technologies and the evaluation items in LEED and GBES were firstly proposed. Based on the statistical analysis of the data from literatures (Tian et al. 2012; Kats et al. 2003; Issa et al. 2010; D'Antonio 2013; Li and Sun 2013), research reports (China Academy of Building Research 2013; Green Building Council 2013) about the incremental cost of green technologies, we investigated the incremental cost (no/low/relatively high/high) for realizing each LEED and GBES evaluation item and for different LEED and GBES certification levels in China.

The original results were validated and improved by face-to-face interview. The interviews include two main steps: (1) the interviewees were provided with the original results proposed in this step; (2) Then, the interviewees should answer the questions, such as "Do they agree with the relationship between the green technologies and the evaluation items in LEED-NC and GBES-RB? Do they agree with the extent of incremental cost of green technologies (for realizing each evaluation items)? Do they agree with the range of incremental cost for each LEED-NC and GBES-RB certification level in China? If they do not agree, what is their opinion?" Finally, the main reasons that cause the high incremental cost were determined, and methods to overcome the high incremental cost were proposed.

Step 4 Strategies for overcoming the major barriers in applying green technologies were proposed. The green technologies for realizing LEED and GBES evaluation item are significant to the certification systems (projects). Based on the statistical analysis of the information acquired from official websites (Ministry of Housing and Urban–Rural Development of the People's Republic of China 2013; China Green Real Estate Network 2013; Chinese Green Building Evaluation Label 2013), literatures (Wang et al. 2012; Xu and Zhao 2012; Li and Sun 2013), and reports (China Academy of Building Research 2013; Yin 2012) about the green technologies and its incremental cost in China, the major applied technologies for realizing items in each certification category of LEED and GBES as well as their average incremental cost are analyzed as original results.

The original results were validated and improved by face-to-face interview. The interviews include two main steps: (1) the interviewees were given the original results proposed in this step; (2) Then, the interviewees should answer the questions, such as "Do they agree with the original results? If they do not agree, what is their opinion? What green technologies are applied in each certification category for achieving each evaluation item of LEED and GBES and its incremental cost (no/low/relatively high/high)?" Finally, some strategies for the improvement of green technologies are proposed, aiming to enhance the incremental cost efficiency, and promote the adoption of green buildings.

3 Analysis of LEED and GBES

LEED contains multiple sub-certification systems. LEED-NC (new construction) is most basic and common, which includes six certification categories: (1) sustainable sites (SS), (2) water efficiency (WE), (3) energy and atmosphere (EA), (4) materials and resources (MR), (5) indoor environmental quality (EQ), and (6) innovation and design process (ID).

Each certification category in a LEED-NC system consists of two types of evaluation items: prerequisite items (prerequisites) and general items (credits). Prerequisites are required items, or green building strategies that must be included in any LEED-NC-certified project. General items (credits) are optional elements, or strategies that projects can select to adopt to gain points toward LEED-NC certification. LEED-NC prerequisite items and general items work together to provide a common foundation of performance and a flexible set of tools and strategies to accommodate the circumstances of individual projects. (About LEED 2014).

In LEED-NC, the total number of prerequisite items is seven, while the total scores of general items are 69 points. Taking the evaluation items of EA in LEED-NC certification system as an example, the meaning of items and numbers is shown in Table 1.

GBES has two sub-certification systems, GBES-RB (for residential buildings) is most widely applicable and contains six certification categories: (1) land saving and outdoor environment (LO), (2) water conservation and utilization of water resources (WU), (3) energy saving and utilization (EU), (4) material saving and utilization (MU), (5) indoor environmental quality (EQ), and (6) operation and management (OM).

Each certification category in a GBES-RB system consists of three types of evaluation items: prerequisite items, general items, and preferred items. Prerequisite items are required items that must be included in any GBES-certified project. General items and preferred items are optional elements, or strategies that projects can select to adopt to gain points toward GBES certification.

Table 1 The evaluation items for EA

The type of evaluation items	Description of items	Points
Prerequisite items	Fundamental building systems commissioning	Prerequisite
	Minimum energy performance	Prerequisite
	CFC reduction in HVAC&R equipment	Prerequisite
General items	Optimize energy performance	10 points
	Renewable energy	3 points
	Additional commissioning	1 point
	Ozone protection	1 point
	Measurement and verification	1 point
	Green power	1 point
Total number of prerequisite items for EA		3 items
Total points of general item for EA		17 points
Total number of all prerequisite items		7 items
Total points of all general item		69 points

All evaluation items of LEED-NC certification system are available at USGBC (2005)

In GBES-RB, the total number of prerequisite items is 25, while the total number of general and preferred items is 49. Using the evaluation items of EU in GBES-RB certification system as an example, the items and numbers are explained in Table 2.

3.1 Comparative analysis of the certification categories in LEED and GBES

GBES has similarities with LEED; the certification categories 1–5 in GBES-RB are similar with those in LEED-NC; however, the certification category 6 in GBES-RB differs from that in LEED-NC.

According to the analysis of the proportions of the numbers (points) of each certification category to the total numbers (points) of the six categories for LEED and GBES (Fig. 1), the weighing proportion of the six certification categories varies between GBES-RB and LEED-NC. Figure 1 reveals that LEED-NC pays more attention to EA, MR, and EQ, whereas statistics from the Ministry of Water Resources of the People's Republic of China indicate that more than 400 out the 669 China cities have insufficient water supply, and 110 of them suffer from serious water shortages. Therefore, China's GBES-RB pays more attention to WU.

3.2 Comparative analysis of the prerequisites in LEED and GBES

Prerequisites (prerequisite items) are mandatory conditions (required elements or green building strategies) for green building certification, representing the green building entry requirement. All prerequisites must be included in any LEED- or GBES-certified project. In other words, any certification level of LEED or GBES buildings must include prerequisites.

As shown in Fig. 2, LEED-NC has a relatively low-entry requirement (seven prerequisite items), and hence more easily acceptable in China; however, all the prerequisites of GBES-RB directly address significant environmental/resource problems in China, and GBES-RB is thus more suitable to meet the reality of China.

Table 2 The evaluation items for EU

The type of evaluation items	Description of the item
Prerequisite items	Thermal performance meet relevant standards, such as JGJ 26-2010 (Design standard for energy efficiency of residential buildings in severe cold & cold zones); JGJ 134-2010; and JGJ 75-2003
	The energy efficiency ratio of heating & cooling equipment should meet the requirement of GB 50189 (design standard for energy efficiency of public buildings)
	Adjust room temperature and heat metering device
General items	Make good use of natural ventilation and natural lighting
	Select the high efficiency of energy-using equipment
	Apply the heating & cooling equipment with higher energy efficiency ratio
	Lighting power density (GB 50034)
	Energy recovery system
	Renewable energy
Preferred items	The energy consumption of heating & cooling equipment is lower than the requirement data of standards by 80 %
	The proportion of renewable energy and total energy consumption by buildings is more than 10 %
Total number of prerequisite items for EU	3 items
Total number of general items for EU	6 items
Total number of all prerequisite items	25 items
Total number of all general and preferred items	47 items

All evaluation items of GBES-RB certification system are available at Chinese Green Building Evaluation Label (2013)

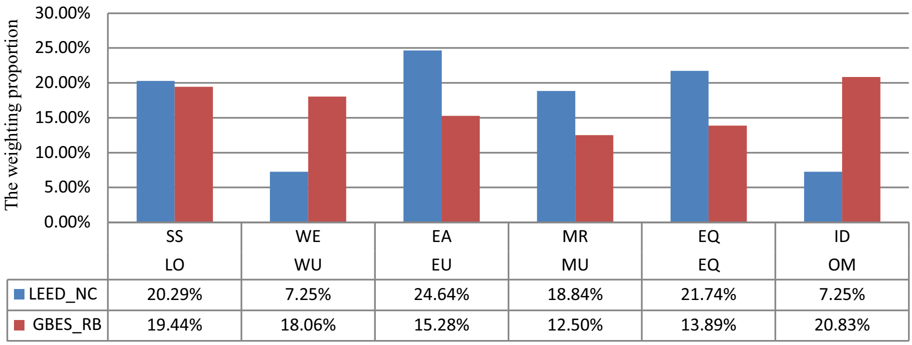


Fig. 1 Certification categories and point distribution of GBES-RB and LEED-NC

As prerequisite items for LEED or GBES certification, buildings are required at least to meet ASHRAE90.1 or regulation, standard, and document in China, such as Urban Greening Regulation, a requirement that did not exist for all non-LEED or non-GBES buildings. Taking energy as an example, although a LEED building is receiving zero

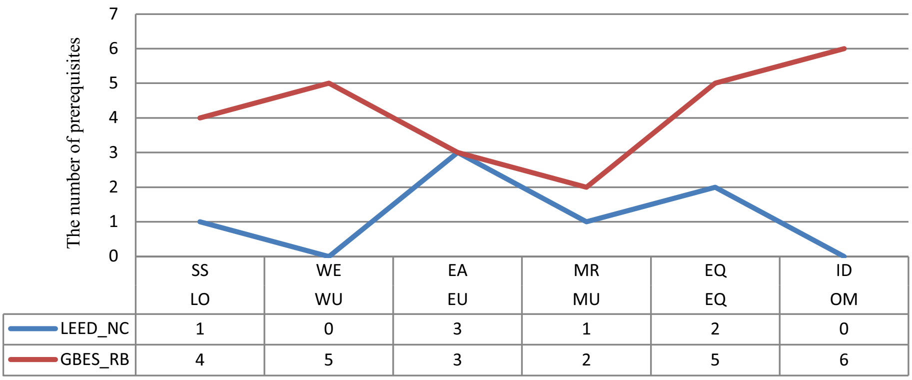


Fig. 2 The number of prerequisite items in GBES-RB and LEED-NC

general items for EA (zero energy points), its energy consumption can be 14 % lower than the CBECS mean (Newshan et al. 2009).

Therefore, prerequisite items can guarantee certain improvement in environment/resource sustainability, which has little correlation with certification level of the building, or the number of points (items) achieved by the building in design.

3.3 Certification levels and rating method of LEED and GBES

Both LEED and GBES use grading evaluation method to carry out the certification; however, the difference is that GBES certification system has three certification levels as 1, 2, and 3 stars, while four certification levels (certified, silver, gold, and platinum) are used in LEED system.

The rating method of each LEED certification level is as follows: Other than required for mandatory prerequisite items, each LEED certification level only looks at the total scores of all general items, i.e., it does not require breakdown scores for each particular general item among the six certification categories (SS, WE, EA, MR, EQ, and ID).

Compared with LEED, the rating method of GBES guarantees the balanced improvement of environment performance among six categories for different certification levels. Each GBES certification level not only requires realization of prerequisite items, but also requires the project to meet the total number of preferred items and the total number of general items. Moreover, the number of certain general items is specified, i.e., for the six certification categories (LO, WU, EU, MU, EQ, and OM), both total number of general items and number of general items in certain category are needed to meet the requirement for corresponding certification levels.

3.4 Certification authority and procedure of LEED and GBES

USGBC is in charge of the LEED. The certification procedures include registering the project begin the LEED certification process, preparation and submission of application, review process, and certification.

The governmental department in charge of GBES is the Ministry of Housing and Urban–Rural Development (MOHURD). Certification procedures of GBES include submission of application, formal examination, expert committee evaluation, public hearing, and notification.

4 Results and discussion

4.1 Practice and barriers of green building certification in China

According to the analysis of current status of China's green projects certified by LEED and GBES, this section investigates the major barriers for the development of green buildings in China.

4.1.1 Overall status of LEED-certified projects in China

LEED certification started to enter Chinese market in 2005. According to the statistics released on the GBCI website (LEED project directory 2013), as of October 31, 2012, there are 288 LEED-certified projects in China. Their features are analyzed as follows:

(1) Regional distribution

The regional distribution of LEED-certified projects in northern and southern China has been shown in Figs. 3 and 4. China has 34 provincial administrative regions, and LEED-certified projects cover 22 Provinces (or autonomous regions, municipalities, and SAR). About 73 % LEED-certified projects are in southern China. Beijing and Tianjin located in northern China and Shanghai, Guangdong, Jiangsu, and Zhejiang located in southern China are the economically more developed six regions, with top-ranked GDP in the nation, and have high degree of openness and internationalization, as well as high degree of recognition of LEED, where the market of LEED certification has been developed maturely. The proportion of LEED-certified projects in these six regions accounts for 86 %.

Guizhou is relatively less developed in economy, and it has two LEED-certified projects, indicating that green building has begun to spread to economically developing regions. But due to the low development level of economy and green technologies, compared

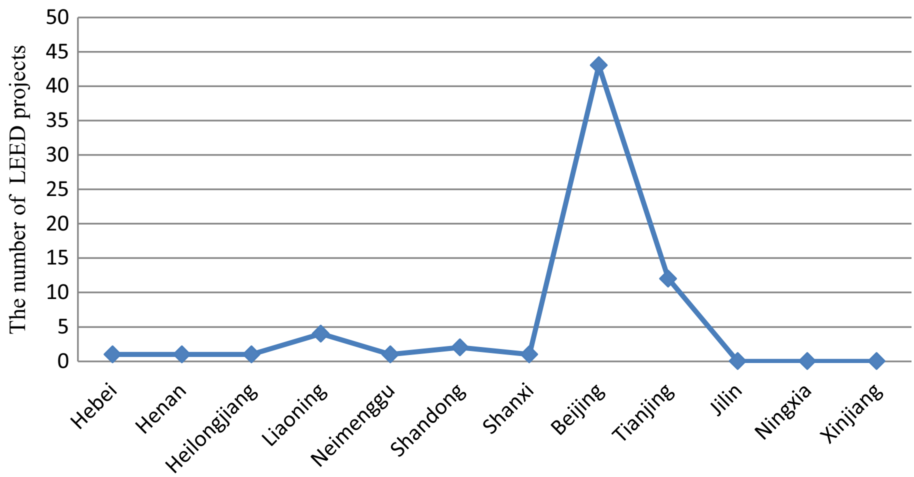


Fig. 3 Distribution of LEED-certified projects in northern China

with that in the six economically developed regions, the number of LEED-certified projects in other regions remains few.

(2) Annual number of LEED-certified projects

Since entering the Chinese market in 2005, LEED system has developed rapidly and obtained a relatively high recognition. The trend of yearly changes in the number of LEED platinum, gold, silver, and certified projects, as well as projects that failed LEED certification, has been shown in Fig. 5, indicating that the number of LEED-certified projects increased each year from 2005 and displayed a trend of rapid growth during 2009–2012 from 31 to 93. LEED gold projects increased faster than others and accounted for 58.68 % of the total number of LEED-certified projects.

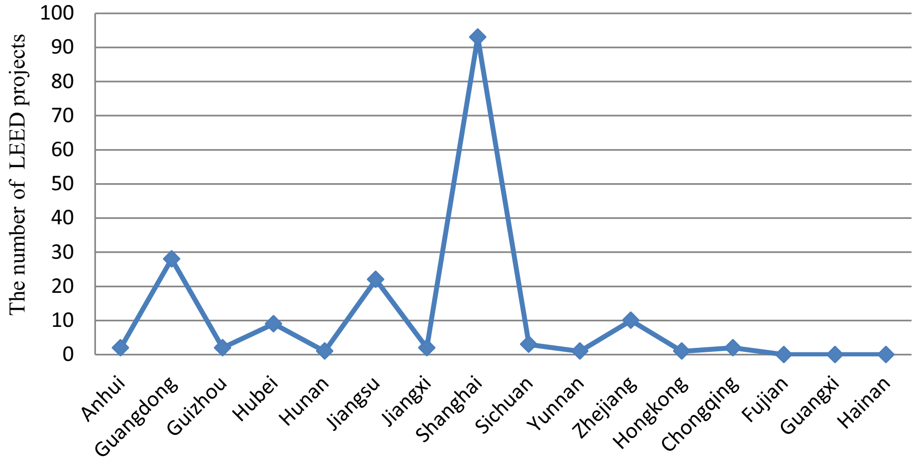
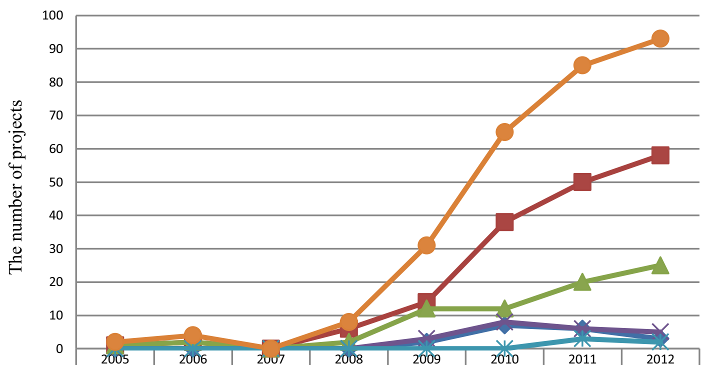


Fig. 4 Distribution of LEED-certified projects in southern China



	2005	2006	2007	2008	2009	2010	2011	2012
The number of LEED platinum projects	0	0	0	0	2	7	6	3
The number of LEED gold projects	1	2	0	6	14	38	50	58
The number of LEED silver projects	1	2	0	2	12	12	20	25
The number of LEED certified projects	0	0	0	0	3	8	6	5
The number of LEED denied projects	0	0	0	0	0	0	3	2
The number of LEED-certified projects	2	4	0	8	31	65	85	93

Fig. 5 Number of LEED-certified projects at different levels changing with years

The development of LEED certification in China accelerated most rapidly in 2012; from January 1, 2012 to December 31, 2012, 93 construction projects obtained LEED certification. Mainly because LEED certification system has a relatively low-entry requirement, it is easier to promote its application. There are another 487 constructed, constructing, or proposed projects that will pass LEED certification (China Green Real Estate Network 2013), suggesting a vast space for the development of LEED in China.

4.1.2 Overall status of GBES-certified projects in China

GBES was officially promulgated in 2006; however, due to the imperfect related implementing rules, it was only formally applied from 2008. According to statistics from literatures and research reports (Wang et al. 2012; Ministry of Housing and Urban–Rural

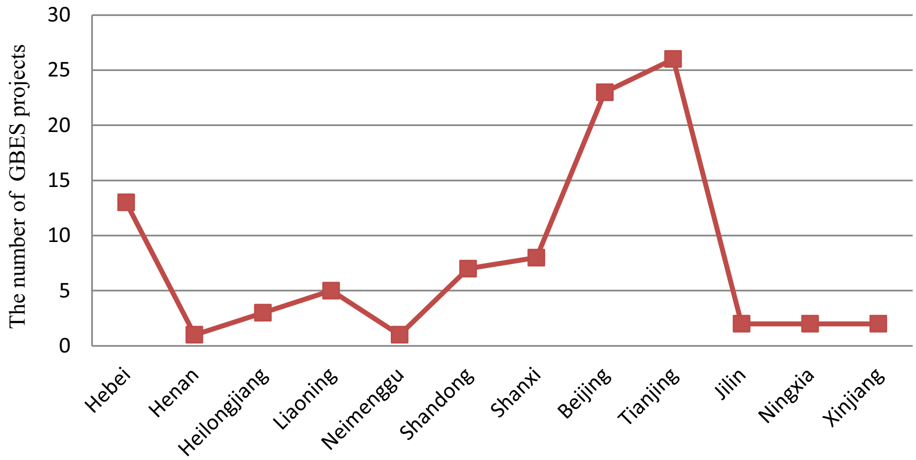


Fig. 6 Distribution of GBES-certified projects in northern China

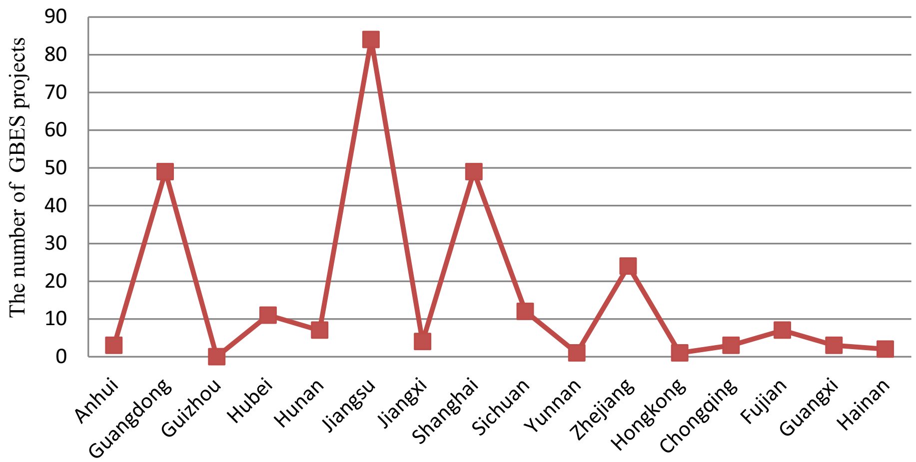
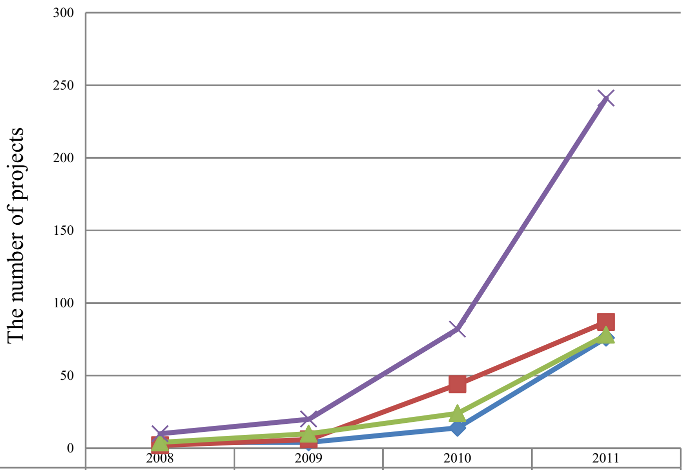


Fig. 7 Distribution of GBES-certified projects in southern China



	2008	2009	2010	2011
★ projects	4	4	14	76
★★ projects	2	6	44	87
★★★ projects	4	10	24	78
The total number of GBES-certified projects	10	20	82	241

Fig. 8 Number of GBES-certified projects at different levels changing with years

Development of the People's Republic of China 2013), as of early 2012, there were 353 projects certified by GBES in 4 years. Their features are analyzed as follows:

(1) Regional distribution

The distribution of GBES-certified projects in different regions of China has been shown in Figs. 6 and 7. GBES-certified projects cover 27 provinces (or autonomous regions, municipalities, and SAR). About 74 % GBES-certified projects are in southern China.

In Beijing, Tianjin, Shanghai, Guangdong, Jiangsu, and Zhejiang, not only the development of LEED-certified projects is relatively mature, but also the number of GBES-certified projects is also large. The proportion of GBES-certified projects in these six regions accounted for 72 %. It reflects that these economically developed and highly internationalized places, compared with the economically developing places, have certain economic and technological advantage to emphasize green building promotion and provide more opportunities for its development.

(2) Annual number of GBES-certified projects

The total number of GBES-certified projects as well as the number of projects at each GBES certification level exhibited a trend of rapid growth (Fig. 8). One decisive factor is that certain policies, such as "The implementation suggestions for promoting the development of green building in China", launched by the Ministry of Finance and the Ministry of Housing and Urban–Rural Development have boosted the spread of GBES.

The number of GBES-certified projects displayed a trend of rapid growth during 2008–2011 from 10 to 241. Projects with GBES two stars increased quicker than others and accounted for 40 % of the total numbers of GBES-certified projects. From early to the end of 2012, China had 233 constructed, constructing, or proposed building projects under GBES certification in 1 year (China Green Real Estate Network 2013).

4.1.3 Major barriers for the development of green buildings

According to the above analyses, although the number of LEED- and GBES-certified projects increased gradually through the years and there is a vast space for the development of green building in China, the development of green building in China displayed geographical differences. The number of LEED- and GBES-certified projects in the cities of southern China is far greater than that in the northern cities, and the number of LEED- and GBES-certified projects in economically developed regions, e.g., Beijing, is far greater than that in economically developing regions, e.g., Xinjiang. The results suggested that the major barrier of the balanced development of green buildings in China is the level of regional economic development.

The face-to-face interviews were conducted as described in step 2 given in Sect. 2.3. Based on the analysis of the 20 interviews, the high incremental cost of green building, the recognition of sustainable development, the degree of internationalization, the common practice of interdisciplinary research, and the lack of cost-effective technologies were also identified as the barriers, in addition to the level of regional economic development. However, about 90 % of interviewees believed the major barriers are the level of regional economic development, the high incremental cost of green building, and the lack of cost-effective green technologies.

The level of regional economic development in China is unbalanced. For most of northern regions with low economic development level (economically developing regions), high incremental cost makes many potential green building developers unwilling to pursue the green certification, which hinders the large-scale adoption of LEED and GBES within a short time. In conclusion, two major barriers existed in China's green certification project development are the high incremental cost and low development level (cost-efficiency) of applied green technologies.

To find the methods and strategies for solving the barriers is of significance for each region, especially for economically developing regions. It is the most effective means to promote a balanced development of green buildings.

4.2 Overcoming one of the major barriers—high incremental cost

Understanding the incremental costs for meeting each LEED and GBES evaluation item for different LEED and GBES certification levels will facilitate the identification of the main reasons causing high incremental costs and the targeted control of incremental cost (enhance incremental cost efficiency), and further promotion of the green certification projects in China.

Table 3 Distribution of incremental cost for technologies required for achieving different evaluation items of LEED and GBES

System	Evaluation items (number or point)	NICT	LICT	RHICT	HICT
LEED-NC	Prerequisite (7 items)	5	1	1	0
	General (69 points)	27	6	10	26
GBES-RB	Prerequisite (25 items)	8	6	9	2
	General/Preferred (47 items)	16	3	17	11

NICT items (points) can be achieved with no-incremental-cost technologies, *LICT* items (points) can be achieved with low-incremental-cost technologies, *RHICT* items (points) need to be achieved with relatively high-incremental-cost technologies, *HICT* items (points) need to be achieved with high-incremental-cost technologies

4.2.1 Analysis of the incremental cost for realizing each LEED and GBES evaluation item

The evaluation items and their numbers (points) in LEED-NC and GBES-RB (Sect. 3) listed in Table 3 (second column) provide the basis for analyzing the incremental cost of LEED-NC and GBES-RB.

In China, the average cost of developing a residential building is 1500 Yuan/m^2. Based on the extent of incremental cost, green technologies are classified into four categories as the following: (1) no-incremental-cost technology (approximately 0 Yuan/m^2); (2) low-incremental-cost technology (0–30 Yuan/m^2); (3) relatively high-incremental-cost technology (30–100 Yuan/m^2); and (4) high-incremental-cost technology (>100 Yuan/m^2; Tian et al. 2012).

Currently in China, each evaluation item of LEED-NC and GBES-RB can (need to) be realized using technologies with different extent of incremental costs (no/low/relatively high/high). According to data analysis, we proposed that the distribution of incremental cost for technologies is required for achieving different evaluation items of LEED and GBES. Face-to-face interviews conducted as described in step 3 given in Sect. 2.3 generated the final results (Table 3).

As shown in Table 3, most of the evaluation items of LEED and GBES need to be realized with relatively high- and high-incremental-cost technologies, which is the main reason of the high incremental cost of green certification project, such as the prerequisite item of "fundamental building systems commissioning" and the general item of "optimize energy performance" for EA in LEED-NC. The prerequisite item of "adjust room temperature and heat metering device", the general item of "select and use the high efficiency of energy-using equipment", and the preferred item of "energy consumption of heating & cooling equipment cost lower than the requirement data of standards by 80 %" for EU in GBES-RB.

4.2.2 Analysis of the incremental cost for different LEED and GBES certification levels

Through data analysis, the ranges of incremental cost for each LEED-NC and GBES-RB certification level in China are proposed. Face-to-face interviews were conducted as in step 3 given in Sect. 2.3 to obtain the results shown in Tables 4 and 5.

Overall, the incremental cost for LEED- and GBES-certified projects in China is high. Compared with LEED, GBES has more prerequisite items (Sect. 3.2), and most of them

Table 4 General items (points) (achieved with lowest incremental cost technology in priority order) selected to achieve various LEED-NC certification levels and range of incremental cost for projects certified at different levels

LEED-NC certification levels	Total points required for general items	NICT (27 points)	LICT (6 points)	RHICT (10 points)	HICT (26 points)	Range of incremental cost (%)
Certified	26–32	26	Sl	Sl	Sl	0.00–1.66
Silver	33–38	27	6	Sl	Sl	1.24–2.26
Gold	39–51	27	6	6 (Sl)	Sl	1.60–6.41
Platinum	52–69	27	6	10	9 (Sl)	6.50–7.00

Sl selectable

Table 5 General or preferred items (achieved with lowest incremental cost technology in priority order) selected to achieve various GBES-RB certification levels and range of incremental cost for projects certified at different levels

GBES-RB certification levels	Required general items		Total required preferred items	NICT ($16 = 6^{I} + 1^{II} + 0^{III} + 4^{IV} + 0^{V} + 5^{VI}$)	LICT ($3 = 0^{I} + 0^{II} + 0^{III} + 1^{IV} + 2^{V} + 0^{VI}$)	RHICT ($17 = 3^{I} + 3^{II} + 3^{III} + 1^{IV} + 3^{V} + 4^{VI}$)	HICT ($11 = 1^{I} + 4^{II} + 5^{III} + 1^{IV} + 0^{V} + 0^{VI}$)	Range of incremental cost (%)
	Total items	Breakdown items						
★	19	$4^{I} + 2^{II} + 3^{III} + 3^{IV} + 2^{V} + 5^{VI}$	0	13	2	4	0	2.15–5.96
★★	26	$6^{I} + 3^{II} + 4^{III} + 4^{IV} + 3^{V} + 6^{VI}$	2	16	2	8	2	5.10–7.49
★★★	33	$7^{I} + 4^{II} + 6^{III} + 5^{IV} + 4^{V} + 7^{VI}$	4	16	3	12	6	7.80–11.59

I, LO; II, WU; III, EU; IV, MU; V, IQ; VI, OM need to be realized with high-incremental-cost technologies, such as sub-metering technology for EU prerequisite items. Therefore, GBES leads to higher prerequisite incremental cost, and the incremental costs of GBES-certified projects are higher on average than those of LEED-certified projects by 1.64–3.74 %.

4.2.3 Methods and suggestions for overcoming high incremental cost

The results indicate that green technologies with high incremental cost are the main causes of high incremental cost of green certification project in China. Two methods are proposed to overcome high incremental cost.

(1) Method one

This method mainly proposes the possible ways for incremental cost reduction in different certification level by choosing the general or preferred items in different priority order (other than prerequisite items), as shown in Tables 4 and 5.

Theoretically, a high level of certification means a high performing building. Meanwhile, other than mandatory prerequisite items, the more general items (points) or preferred items implemented, the higher certification level and the higher performing building will be achieved. The prerequisite items are mandatory conditions and can guarantee certain improvements in environment/resource sustainability; although most of the prerequisite items have high incremental cost, they must be included in any certification level for green certification buildings.

Based on the rating method of LEED and GBES, the selection of general or preferred items that can be realized with low (no)-incremental-cost technologies is an effective way to overcome the high incremental cost of certification projects (Tables 4 and 5). It is necessary to clarify that different evaluation items address the different environment issues. The general or preferred items that can be realized with low-incremental-cost technologies do not mean low environment performance. For example, the general items of "ozone protection" in LEED and "make good use of natural ventilation and natural lighting" in GBES also have significant impact on the improvement of environment performance. The technologies with low incremental costs in China have a high maturity level and are easy to apply. The method one in Tables 4 and 5 is explained as follows:

For LEED-certified projects, as shown in Table 4, the requirement for total score to achieve certified and silver certification level can be generally met by choosing general items that can be realized with low (no)-incremental-cost technologies, to overcome the high incremental cost for LEED certification level. However, the requirement for total score to achieve gold and platinum certification level should combine with the high (relatively high)-incremental-cost technologies to achieve higher certification level and corresponding environment performance.

As shown in Table 4, LEED-NC gold requires a score of 39–51 for general items, among which, 27 points can be generally obtained by preferably selecting NICT; 6 points can be obtained by selecting LICT to realize; and another 6 points can be received by choosing RHICT. This way of selection thus meets the requirement for a minimum score of 39 points for LEED gold certification. In addition, 4 more points can be obtained by realizing certain general items with relatively high-incremental-cost technologies. Furthermore, to meet the maximum 51 points for LEED gold certification, 4 more points can be obtained by preferably selecting RHICT, while 8 more points can be achieved by using high-incremental-cost technologies.

For GBES-certified projects, as shown in Table 5, the general or preferred items among the six categories that can be realized with low (no)-incremental-cost technologies should be chosen with priority to reduce the incremental cost for each GBES certification level.

Are shown in Table 5, for instance, a total of 26 general items are required for certification of GBES two stars, and the 26 items have been allocated into each category, i.e., 6, 3, 4, 4, 3, and 6 items in category 1–6, respectively; the total number of required preferred items is 2. Therefore, general items/preferred items that can be realized with low (no)-incremental-cost technologies should be simply chosen; however, to simultaneously meet the requirement for both allocated number of general items and total number for general and preferred items (i.e., 28 in total), at least 16 items should be completed with no-incremental-cost technologies; two items should be satisfied with low-incremental-cost technologies; relatively high-incremental-cost technologies are needed to complete eight items; and finally, two items need to be completed with high-incremental-cost technologies.

The method one provides a reasonable way for overcoming the high incremental cost. The method has significant impact for lower-certification-level project; however, for incremental cost reduction in higher-certification-level project, it has little impact, because higher certification level means that more general and preferred items need to be achieved, which inevitably cause high incremental cost if the high-incremental-cost green technologies for realizing each item cannot be developed into cost-efficient.

In addition, the method one cannot address the problem of higher prerequisite incremental cost. Meanwhile, different project has different demand for environment improvement, especially for economically developed regions, where more attention is paid to solve certain environmental issue. Therefore, certain items with high-incremental-cost technologies are inevitable and chosen in priority. Therefore, the increase in the incremental cost efficiency of green technologies for realizing each item is significant.

(2) Method two

Overall, the incremental cost efficiency of green technologies for realizing LEED and GBES evaluation item should be enhanced by promoting the maturity level and industrialization of applied technologies. The government should strengthen policy guidance and provide support through incentives to enhance the incremental cost efficiency. The incremental cost efficiency of green technology is represented by the ratio of the level of environmental/resource performance brought by the green technology over incremental cost of the green technology.

The method two mainly proposes two ways to enhance the incremental cost efficiency of green technology: (1) reduce the incremental cost of green technology and maintain the level of environmental/resource performance; (2) reduce the incremental cost of green technology and increase the level of environmental/resource performance.

The reduction in incremental cost of green technology for realizing one evaluation item does not mean to replace the high-cost technology with another low-cost technology. On the contrary, it is achieved by improving the same technology into low-incremental-cost technology with the same (or even more) environment performance by increasing the maturity level of this technology and its industrialization.

Moreover, identifying technologies that can reduce the incremental cost with the same (or even more) environment performance is of significance for better targeted enhancement of the incremental cost efficiency of green technology. Therefore, the next Section will be focused on this topic.

Table 6 Applied technologies related to the category of SS (LO)

CA	AICT (%)	Applied technologies	Type of technology	Incremental cost	Percentage of application (%)
SS (LO)	1.74	R/VG	Passive	Low	100.00
		ADUS	Passive	No	95.65
		OPS	Passive	Low	86.96
		SOWE	Passive	Low	83.33
		TO	Passive	No	36.23
		RAS	Active	High	23.19
		NDP	Passive	Low	14.49
		PSPS	Passive	No	13.04
		SAHI	Passive	Low	13.04
		ROB	Active	Relatively high	7.25

CA certification category of LEED (GBES), *AICT* average incremental cost of technologies, *R/VG* roof/vertical greening, *ADUS* appropriately develop underground space, *OPS* outdoor permeable surface, *SOWE* simulation of outdoor wind environment, *TO* transportation optimization, *RAS* recycling of abandoned site, *NDP* noise design and prediction, *PSPS* perfect supportive public services, *SAHI* simulation analysis of heat island, *ROB* reuse of old building

Table 7 Applied technologies related to the category of EA (EU)

CA	AICT (%)	Applied technologies	Type of technology	Incremental cost	Percentage of application (%)
EA (EU)	70.60	EI	Passive	Low	100.00
		EEW	Passive	Low	100.00
		S/RTC	Active	Relatively high	100.00
		SOE	Passive	Low	72.46
		ELS	Active	Relatively high	71.01
		RE	Active	High	64.49
		SWHE	Passive	Low	34.78
		AFAR	Active	High	29.71
		ILC	Active	Relatively high	28.26
		WHU	Active	Relatively high	2.90
		TS	Active	Relatively high	2.17
		CCHP	Active	High	0.72

EI envelope insulation, *EEW* energy-efficient exterior window, *S/RTC* sub-metering/room temperature control, *SOE* simulation-based optimization for energy consumption, *ELS* efficient light source, *RE* renewable Energy, *SWHE* solar water-heating equipment, *AFAR* adjustable fresh air ratio, *ILC* intelligent lighting control, *WHU* waste heat utilization, *TS* thermal storage, *CCHP* combined cooling heating and power

4.3 Overcoming the other major barrier

Based on the data analysis, the major applied technologies in each certification category of LEED and GBES as well as their average incremental cost and ratio of application are proposed. Face-to-face interviews were conducted as described by step 4 given in Sect. 2.3

Table 8 Applied technologies related to the category of WE (WU)

CA	AICT (%)	Applied technologies	Type of technology	Incremental cost	Percentage of application (%)
WE (WU)	5.95	WA	Passive	No	100.00
		WI	Active	Relatively high	81.88
		RCR	Passive	Low	76.09
		RIM	Active	Relatively high	49.28
		URW	Active	Relatively high	47.10
		CCR	Active	Relatively high	5.80

WA water-saving appliances, *WI* water-saving irrigation, *RCR* rainwater collection and reuse, *RIM* rainwater infiltration measures, *URW* use of reclaimed water, *CCR* condensate collection and reuse

Table 9 Applied technologies related to the category of MR (MU)

CA	AICT (%)	Applied technologies	Type of technology	Incremental cost	Percentage of application (%)
MR (MU)	1.38	RC	Passive	Low	100.00
		IDC	Passive	No	76.09
		URM	Passive	No	44.93
		HC/HS	Passive	Relatively high	34.78
		SOBS	Passive	High	22.46

RC ready-mix concrete, *IDC* integrated design and construction, *URM* utilization of recyclable materials, *HC/HS* high-performance concrete/high-strength steel, *SOBS* system optimization of building structure

Table 10 Applied technologies related to the category of EQ (EQ)

CA	AICT (%)	Applied technologies	Type of technology	Incremental cost	Percentage of application (%)
EQ (EQ)	16.21	NV	Passive	No	100.00
		SID/P/SIS	Active	Relatively high	100.00
		OLS	Passive	Low	100.00
		CACTCS	Active	Low	76.81
		CSO	Passive	Relatively high	57.97
		IAQMS	Active	Relatively high	50.72
		AES	Passive	Relatively high	40.58

NV natural ventilation, *SID/P/SIS* sound insulation design/prediction/sound insulation slab, *OLS* optimization of lighting simulation, *CACTCS* central air conditioning terminal control system, *CSO* CFD simulation optimization, *IAQMS* indoor air quality monitoring system, *AES* adjustable exterior shade

to derive the final results, as shown in Tables 6, 7, 8, 9, 10, and 11. Then, the strategies for enhancing incremental cost efficiency and targeted development of the level of applied green technologies for realizing the evaluation items in each certification category of LEED and GBES are proposed.

Table 11 Applied technologies related to the category of ID (OM)

CA	AICT (%)	Applied technologies	Type of technology	Incremental cost	Percentage of application (%)
ID (OM)	4.13	WC	Active	Relatively high	100.00
		SW/E/G	Active	Relatively high	100.00
		PIS	Active	Relatively high	93.48
		AMS	Active	Relatively high	44.93

WC waste classification, *SW/E/G* sub-metering for water, electricity, and gas, *PIS* perfected intelligent system, *AMS* automatic monitoring system

4.3.1 Analysis of applied technologies for each certification category of LEED and GBES

(1) Applied technologies for SS (LO) in China

As show in Table 6, the main applied technologies related to the category of SS (LO) are mostly low-incremental-cost technologies. However, the ratio of application of some low-incremental-cost technologies remains low in China; such as TO, NDP, PSPS, and SOWE. In addition, due to the current high incremental cost for treatment and development of contaminated lands, technologies for ROB have not been widely applied yet.

(2) Applied technologies for EA (EU) in China

Table 7 shows the major technologies related to the category of EA (EU), which mostly are relatively high (high)-incremental-cost technologies. The energy consumption per unit construction area in China is 2–3 times of that in developed countries under the same climatic condition (Sun 2006). Since China urgently needs to improve building energy efficiency, three technologies including EI, EEW, and SOE are in great demand and extensively applied. The prerequisites of China's GBES require mandatory use of sub-metering technology. Therefore, although the incremental cost of S/RTC technologies is relatively high, they remain widely used in China. In addition, currently, China has less experience in energy-saving technologies such as CCHP, WHU, and TS, etc.

(3) Applied technologies for WE (WU) in China

Table 8 lists the major applied technologies related to the category of WE (WU), most of which are relatively high (high)-incremental-cost technologies. Because more than 400 out the 669 China cities have insufficient water supply, the prerequisites of China's GBES require mandatory use of water-saving appliances. In addition, WI can greatly improve water utilization rate, effectively reduce the irrational use of water resources, and prevent the water environment from deterioration. WI is a very effective water-saving technology and widely applied in China, though its incremental cost is relative high.

(4) Applied technologies for MR (MU) in China

Table 9 has shown the major applied technologies related to the category of MR (MU), most of which are low-incremental-cost technologies. During the process of construction, demolition of old buildings, and site clearing up, large amounts of recyclable solid waste were produced in China; however, URM was not adequately emphasized. In addition, although SOBS technologies can improve the performance and durability of the building structure and reduce material consumption, a relatively high cost restricted their application range.

(5) Applied technologies for EQ (EQ) in China

Table 10 has shown the major applied technologies related to the category of EQ (*EQ*), most of which are relatively high (high)-incremental-cost technologies. GBES has mandatory requirement in the three aspects of lighting performance, sound insulation and noise reduction, and indoor air quality. Currently, China uses very effective SID/P/SIS technologies to insulate sound and to reduce noise. Although these technologies are with relatively high-incremental-cost, they are widely applied nowadays in China.

(6) Applied technologies for ID (OM) in China

Similarly, Table 11 has shown the major applied technologies related to the category of ID (OM), and most of them are relatively high (high)-incremental-cost technologies. Because GBES-certified projects in China are mandatorily required to use SW/E/G, and to enforce WC technology, these two technologies have been widely applied in China despite their relatively high incremental cost.

4.3.2 Strategies for increasing the application of green technologies

Tables 6, 7, 8, 9, 10, and 11 indicate that applied technologies in the category of EA (EU) show the highest average incremental cost, approaching 70.60 %, followed by the average incremental cost of applied technologies in the category of EQ (16.21 %); third comes the average incremental cost of applied technologies in the category of WE (WU) at 5.95 %. Applied technologies in the category of EA (EU) and EQ are the main factors that cause high incremental cost.

Green technologies in China are still in its initial development stage. On one hand, China has less experience in implementation of some (active) green technologies and has less optimization measures, thus most of the applied technologies are with relatively high incremental cost. On the other hand, attention to some low-incremental-cost and passive green technologies remains insufficient. Moreover, the lack of replicable, promotable, and highly operationally efficient green technologies (Ma et al. 2010) has resulted in a relatively high total incremental cost for green buildings and hinder its development in China.

(1) The first strategy

Most of the applied technologies for achieving items in each certification category of LEED and GBES, especially in energy and atmosphere EA (EU) as well as indoor environmental quality EQ, need to have the incremental costs reduced to realize the same or higher level of environmental/resource performance (enhanced incremental cost efficiency) by promoting the maturity level and industrialization of the applied technologies.

Most of the technologies with relatively high cost are active, such as WHU, TS, CCHP, WI, SID/P/SIS, WC, SW/E/G technologies. It is necessary to apply optimized active technologies. Take certain measures to introduce relevant foreign technologies and experiences, and increase the incremental cost efficiency of these active technologies.

(2) The second strategy

There is a vast space for the development of low-incremental technologies to reduce incremental cost of certified buildings. The adoption of some low-incremental-cost (passive) green technologies should be enhanced to make a full use of passive technologies.

For SS (LO), PSPS technologies should be further promoted; and TO technologies should be promoted by optimizing the site selection and the access to public transportations. The promotion of SAHI technologies needs to be strengthened. For EA (EU), more attention is needed for SWHE. For MR (MU), URM should be popularized. Technologies for the recycle of waste can be adopted almost at no extra cost and should be further promoted in China.

(3) The third strategy

Because the regional economic development in China is unbalanced, the government should provide support through incentives to enhance the adoption of green technologies. The integration idea needs to be strengthen (Yin 2012), which includes two steps: (1) use passive technologies with priority, and make a full use of passive technologies; (2) Apply optimized (highly cost-efficient) active technologies reasonably.

In most of the northern regions with low economic development level, the project developer should first concentrate on the development and application of these low-incremental-cost (passive) technologies, and then reasonably apply active technologies in demand, in order to boost the development of green buildings.

Whereas in most of the southern economically developed regions and part of the northern economically developed regions, the developer should not only focus on the development of low-incremental-cost technologies, but also develop active technologies, accumulate experience in implementation of active technologies and invent optimization measures, in order to reduce the incremental cost of the active technologies with the same or higher level of environmental/resource performance.

It is an effective way to spread the experience and optimization measures of active technologies from economically developed regions to economically developing regions, and to enhance the incremental cost efficiency of green technologies and promote green certification buildings in China.

5 Conclusions

The emergence, adoption, barriers, and solutions for LEED and GBES in China are presented in this study. Some conclusions are drawn as follows:

(1) China is currently in a period of rapid urbanization and industrialization, and there is a wide space for green building development. However, we found that the high incremental cost and the development level of applied green technologies are the two major barriers to the comprehensive development of green buildings.
(2) Solutions are proposed for overcoming high incremental cost, such as choosing the general or preferred items in different priority order (other than prerequisite items); and reducing the incremental cost of green technology while maintaining (or increasing) the level of environmental/resource performance.
(3) Strategies are proposed to increase the incremental cost efficiency. Most of the applied technologies, especially in EA (EU) as well as EQ, need to reduce incremental costs for the same or higher level of environmental/resource performance; the attention to some low-incremental-cost (passive) green technologies should be enhanced, and a full use of passive technologies is recommended. All these strategies aimed to target the development of green technologies with high incremental cost efficiency, and to vigorously develop green certification buildings.

Further improvement of applied green technologies and control of incremental cost of green building certification projects should be performed based on the purpose of conservation of land, water, energy, material, and indoor environment, which will ensure the rapid development of green buildings in China.

References

About LEED. (2014). http://www.usgbc.org/articles/about-leed.

Geng, Y., Dong, H., Xue, B., & Fu, J. (2012). An overview of Chinese green building standards. *Sustainable Development, 20*, 211–221.

Green Building Council. (2013). Analysis of the incremental cost of LEED-certified projects 2013. http://www.civilcn.com/jieneng/kejian/1331971312235118.html (in Chinese).

Baylon, D., Storm, P. (2008). Comparison of commercial LEED buildings and non-LEED buildings within the 2002–2004 Pacific Northwest commercial building stock. In ACEEE Summer Study on Energy Efficiency of Buildings, American Council for an Energy-Efficient Economy (Washington DC, USA), pp. 4.1–4.2.

Binh, K., Nguyen, H. A., & Altan, H. (2011). Comparative review of five sustainable rating systems. *Procedia Engineering, 21*, 376–386.

Peng, B. (2012). Case study on life cycle energy consumption and CO2 emissions of green buildings. Tsinghua University., Master Thesis.

China Green Real Estate Network. (2013). http://www.lvdichan.com/ (in Chinese).

Chinese Green Building Evaluation Label. (2013). http://www.cngb.org.cn/listzx.aspx?cid=105 (in Chinese).

China Academy of Building Research. (2013). Survey and statistics of green building incremental cost. http://www.docin.com/p-188006718.html; 2012 (in Chinese).

D'Antonio PC. (2013). Costs and benefits of commissioning LEED-NC™ buildings. http://www.bcxa.org/ncbc/2007/proceedings/DAntonio_NCBC2007.pdf; 2007.

Du, N. (2006). Study of the assessment of green building and green construction. Huazhong University of Science and Technology (in Chinese).

Issa, M. H., Rankin, J. H., & Christian, A. J. (2010). Canadian practitioners perception of research work investigating the cost premiums, long-term costs and health and productivity benefits of green buildings. *Building and Environment, 45*, 1698–1711.

Jin, Z., Wu, Y., Li, B., & Gao, Y. (2009). Energy efficiency supervision strategy selection of Chinese large-scale public buildings. *Energy Policy*, *37*, 2066–2072.

Kats, G., Alevantis, L., Berman, A., Mills, E., Perlman, J. (2003). The costs and financial benefits of green buildings: A report to California's sustainable building task force. For full text and summary slides see http://www.cap-e.com. (1 October 2003).

LEED project directory. (2013). http://www.gbci.org/main-nav/building-certification/registered-project-list.aspx; 2009.

Li, J., Sun, D. (2013). Statistical analysis of the incremental cost of green buildings in China. http://wenku.baidu.com/view/84a475ebe009581b6bd9ebe1.html (in Chinese).

Liu, J. N., Low, S. P., & He, X. (2012). Green practices in the Chinese building industry: Drivers and impediments. *Journal of Technology Management in China., 7*(1), 50–63.

Ma, W., Mei, H., & Yu, T. (2010). The status and development strategy of green building technologies in China. *Architecture. Technology, 7*, 641–644. (in Chinese).

Ministry of Housing and Urban-Rural Development of the People's Republic of China. (2013). http://www.mohurd.gov.cn/ (in Chinese).

Miranda, H. (2005). Achieving low-cost LEED projects. *Heating/Piping/Air Conditioning. Engineering, 77*(4), 32.

Newshan, G. R., Mancini, S., & Birt, B. J. (2009). Do LEED-certified buildings save energy? Yes, but…. *Energy and Buildings, 41*, 897–905.

Sun, R. (2006). The energy consumption in China is 2–3 times of that in developed countries. *China's Reform Newspaper, 2*, 1. (in Chinese).

Tatari, O., & Kucukvar, M. (2011). Cost premium prediction of certified green buildings: A neural network approach. *Building and Environment, 46*, 1081–1086.

Tian, H., Zhang, H., Sun, D., Liang, Y., & Wang, Y. (2012). The status and prospect of green building development in mainland China. *Building. Science, 4*, 1–7. (in Chinese).

USGBC, LEED-NC v2.2. (2005). http://cn.usgbc.org/resources/leed-new-construction-v22-rating-system.
Wang, J. Q., Gao, X. F., Song, L., Li, H. L., & Li, L. (2012). Statistical report of certification logo of China's green buildings in 2011. *Construction Science and Technology, 6*, 15–18. (in Chinese).
Wu, S. (2011). Technological essential and proposed measures for promotion of green building. *Architectural Journal, 9*, 1–3. (in Chinese).
Xu, Z., & Zhao, Y. (2012). Current development and prospect of green building. *Architecture Technology, 4*, 300–304. (in Chinese).
Yin, B. (2012). Overview of the development of China's green building technologies in 2012. http://www.docin.com/p-438059078.html; 2012 (in Chinese).
Zhang, X., Platten, A., & Shen, L. (2011). Green property development practice in China: Costs and barriers. *Building and Environment, 46*, 2153–2160.