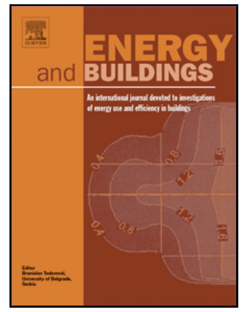

Title: Green Buildings Cost Premium: A Review of Empirical Evidence

Author: Luay N. Dwaikat Kherun N. Ali

PII: S0378-7788(15)30385-6
DOI: http://dx.doi.org/doi:10.1016/j.enbuild.2015.11.021
Reference: ENB 6266

To appear in: *ENB*

Received date: 18-4-2015
Revised date: 9-10-2015
Accepted date: 8-11-2015

Please cite this article as: L.N. Dwaikat, K.N. Ali, Green Buildings Cost Premium: A Review of Empirical Evidence, *Energy and Buildings* (2016),http://dx.doi.org/10.1016/j.enbuild.2015.11.021

Highlights:

- We analyzed the empirical studies which address the issue of green cost premium.
- There is not conclusive answer about the green buildings cost premium.
- There is no conclusive empirical evidence that the green building tends to cost more.
- Significant gap exists in the quantified cost premium range.
- The green cost premium that can be generalized ranges from -0.4 – 21%.

Green Buildings Cost Premium: A Review of Empirical Evidence

Luay N. Dwaikat[1,*] and Kherun N. Ali[2]

[1]Quantity Surveying Department, Faculty of Built Environment, Universiti Teknologi Malaysia (UTM), 81310 Skudai, Johor Bahru, Malaysia, Phone: +60-19-7292609, Email: luay.dwaikat@gmail.com

[2] Quantity Surveying Department, Faculty of Built Environment, Universiti Teknologi Malaysia (UTM), 81310 Skudai, Johor Bahru, Malaysia, Phone: +60-19-7750354, Email: b-kherun@utm.my

Abstract

Evidence indicates that green buildings can outperform conventional (non-green) buildings in many performance areas. Nevertheless, the perceived higher upfront cost by building owners and investors is frequently cited as a hurdle to a widespread adoption of green buildings. In this study, an extensive literature survey was conducted to aggregate the green cost premiums which were reported as results of published empirical studies that investigated the cost premium associated with the green building. Results and methodologies of 17 empirical studies were tabulated and comparatively analyzed to find a conclusive answer whether the green building costs more or less than its conventional counterpart. Yet, consensus is not reached, and a significant gap exists in the quantified cost premium range. More than 90% of the reported green cost premiums through empirical investigations fall within a range from -0.4 - 21%. Two studies found that green buildings cost less than their conventional counterparts. Surprisingly, among the 17 reviewed empirical studies, only six publications were classified as academic publications, of which four research articles published in peer-

[*] Corresponding author: Email address: luay.dwaikat@gmail.com, Tel No.: +06 019 729 2609 (L. Dwaikat)

reviewed journals, one conference paper, and one book. The size of the literature which addresses the issue of green buildings cost premium does not reflect the significance of the problem.

Keywords: Green buildings; Cost premium; Conventional buildings; Literature survey.

1. Introduction

Being the largest contributor to pollution and greenhouse gas emissions, the construction sector has gained momentum in sustainable development and plays a significant role in sustainability achievement [1–3]. The Construction sector occupies the first place as the largest contributor to pollution and greenhouse gas emissions [3]. According to the United Nations Environmental Program [3], one third of the total energy end use is consumed in buildings, it is also responsible for one third of the global resources consumption including 12% of all fresh water usage, as well as it produces around 40% of the total solid waste volume. Based on these estimates, in response to the concept of sustainable development triggered in the United Nations Global Assembly on March 20, 1987 through the report of Brundtland Commission [4], known as Our Common Future, in the early nineties, green buildings were introduced as a high potential solution to reduce gas emissions and to improve the economic, health, and environmental performance of the built environment [2,5].

While there is consensus about several benefits associated with the green building, its initial construction cost in comparison to a conventional counterpart is still debated. Several market surveys concluded that green building practitioners believe that the construction cost of the green building is significantly higher than that of its conventional counterpart [6,7]. However, still there is no much empirical evidence supports this general perception formed in the mindset of building owners and investors; the issue of green cost premium is still debated and three different opinions can be found in the literature. The first opinion suggests that there is no significant variation between the cost of green buildings and conventional buildings [8–10]. Advocates of this view empirically argue that green buildings cost premium is insignificant and even green buildings can be achieved with little or no added cost [11–13]. The second opinion says that the green building tends to cost more than its conventional (non-green) counterpart [14–16]. A third opinion suggests that the green building may cost less than a conventional building [17,18].

The purpose of this research is to survey the existing body of literature in order to aggregate the findings of the empirical investigations which address the controversial issue of green cost premium, and to comparatively analyze the evidences in order to find an answer whether the green building costs more or less than its conventional counterpart.

2. Background Information

2.1. The Concept of Green Buildings

The terms *green buildings, high performance buildings*, *sustainable buildings*, *sustainable construction*, *high performance construction*, or *green construction* are used interchangeably [2,12,19,20]. Intrinsically, sustainable construction should take into account the environmental aspects through the whole life cycle of a facility, including material acquisition, installation, operation, disposal, and recycling. However, the green building definition varies and there are numerous definitions for the green building [21,22]. Yudelson [23] defines the green building as: “A *high-*

performance property that considers and reduces its impact on the environment and human health". According to Yudelson [23], the green building is designed to use less energy and water as well as to reduce the life cycle environmental impact of the used material. Likewise, Kibert [2] suggests that the term *green building* describes the characteristics of the building which complies with the principles and practices of sustainable construction, he defines the green building as: "H*ealthy facilities designed and built in resource-efficient manner, using ecologically based principles*". Green buildings or sustainable buildings, according to the International Energy Agency [24], are characterized by increased energy and water efficiency, reduced material and natural resource consumption, in addition to improved health and environment.

Aforementioned definitions imply similar characteristics of the green building; there is a consensus among the definitions that the green building is a healthy facility that has less negative impacts on the environment through using fewer natural resources. However, none of the definitions indicates life cycle thinking as a fundamental approach in assessing the performance of the green building. Life cycle thinking, which is also known as life cycle perspective [25], has recently gained considerable attention to account for the three pillars of sustainable development which are: environmental, economic, and social aspects [26–28]. In its principle, life cycle thinking means taking account of a product's impact on the three pillars of sustainability throughout its entire life cycle [25,29]. The term *product* is defined as any good or service [29,30].

In the light of discussed characteristics of the green building, and considering the life cycle approach, the green building can be defined as an eco-friendly economic facility that uses less natural resource to build and operate. It positively impacts productivity, health, and welfare of human being throughout its entire life cycle. This definition inherently adheres to the concept of sustainable development which balances the three pillars of sustainability [26,27,31]. The added keywords to the definition which are: economic and life cycle, are backed up by a growing body of evidence as discussed in the subsequent section 2.2.

The green building can reduce the carbon emissions up to zero levels through utilizing renewable energy systems to meet the requirements of its occupants [32]. Renewable energy systems in the green building can be either passive or active systems [3,33], while passive energy systems refer to improvements of building envelope elements to minimize the total energy demand [34], the active systems utilize newer technology and more efficient electrical devices and appliances to reduce energy demand, and to produce energy from renewable energy sources such as solar, wind, geothermal (Heat from the earth) [24,34]. Passive solar design has a potential to eliminate 50 – 75% of cooling and heating energy demand in buildings [35].

Energy efficiency and renewable energy sources utilization are key features of the green building [2,32,35,36]. Reducing energy demand through proper building orientation, more efficiently insulated and glazed building envelope, passive solar design approaches, in addition to more efficient electrical appliances and devices are major design strategies to meet the concept of the green building [5,24,35]. Reducing energy demand allows on-site energy production through renewable energy sources to cover a higher percentage of the total building energy demand [5], or completely cover the energy demand using renewable energy sources [32,35].

Typically, the environmental performance of green buildings is assessed and rated using building environmental assessment methods, in which a standard definition and performance for green buildings against sustainable development requirements are defined [2,23,37,38]. The main purpose of the green rating tools is to assess the sustainable design of a building in terms of compliance to sustainability requirements with various levels of assessment [38]. However, there is a plethora of green building standards and rating tools which vary from country to country based on need and climate requirements [39]. Internationally, almost 60 countries in the world [2] have developed their own rating systems to evaluate and promote the green building. Being the leading examples of green rating tools, the British Research Establishment Environmental Assessment Method (BREEAM) and the American Leadership in Energy and Environmental Buildings (LEED) are the first and most internationally recognized environmental assessment methods for green buildings [39,40].

Launched in 1990, the British Research Establishment Environmental Assessment Method (BREEAM) is an assessment and rating tool for sustainably designed buildings in which a standard definition and performance for the green building against sustainable development requirements are proposed [2]. In BREEAM, buildings are rated (or labeled) and certified based on a scale of Good, Very Good, Excellent, and Outstanding [41]. Later in 2002, the U.S Green Building council developed the Leadership in Energy and Environmental Buildings (LEED), it is also a rating system for green buildings with multilevel certification. Based on credit points achievement against sustainability requirements, buildings according to LEED are rated as: Certified, Silver, Gold, or Platinum, the sustainability requirements are increased for each level of certification [40]. Developed by the Green Building Council of Australia in 2003, Green Star is another internationally recognized sustainability rating system for buildings [42], in which buildings are assessed based on nine environmental categories, among others, indoor environment quality, energy efficiency, water efficiency, and emissions. Based on credit points achievement in the evaluation categories, buildings are rated as: 4 Star (best Practice), 5 Star (Australian excellence), or 6 Star (world leadership) [43]. The sustainability requirements in the discussed green rating systems are extensive and varied. It is not in the scope of this paper to review and analyze these requirements. However, as a general rule, sustainability requirements are increased to achieve higher levels of certification.

2.2. Green Buildings Benefits

From life cycle perspective, unprecedented consensus about a wide spectrum of green buildings merits and benefits can be found in the literature. A good example of these benefits to building owners and investors is the widely cited study which was conducted by Kats et al. [12], in which the authors concluded that green buildings cost less to run and save energy on an average of 30%. The authors further argue that by adding other benefits, such as reduced water consumption, maintenance cost, improved health and productivity, the financial benefits are 10 times as high as the average cost premium which equals 1.84%. Based on the Australian and international case studies and research, Madew [42] identified the following key economic benefits of green buildings: 60% reduction in water and energy consumption, 1-25% productivity increase, minimum 14% higher rate of return, 10% higher market value for asset, 5–10% higher rental rate, in addition to free promotion. Yudelson [23], listed 14 benefits of green buildings, among others, 30 – 50% typical energy and water saving, reduced maintenance cost, increased property value, a typical 3 – 5% improvement in productivity, 5% reduced absenteeism, in addition to other benefits related to health, risk, marketability, and competitiveness. In the health context, the author further argues that a green building can annually reduce the sick building syndrome of its occupants by 41.5%.

In a case study research, Ries et al. [44] argue that productivity increased about 25%, and energy decreased about 30% in a green precast concrete manufacturing facility certified by Leadership in Energy and Environmental Buildings (LEED) green rating system. In another case study research, Lau et al. [45], saying that a low energy office building with green features such as solar design and utility-interactive Photovoltaic (PV) system is saving 50.1% of energy cost compared to conventional buildings. In comparison to the US national buildings average performance, GSA

Public Buildings Service [46] summarized the following key findings of commercial green buildings benefits: 26% less energy use, 13% lower aggregate maintenance cost, 27% higher occupants satisfaction, and 33% fewer CO2 emissions.

2.3. Green Buildings Cost

Notwithstanding the numerous benefits associated with green buildings, the upfront cost issue is a frequently cited paramount obstacle which precludes a widespread adoption of green buildings [3,6,12,23,42,47–50]. Reviewing the literature shows some controversy related to the estimated cost premium associated with the green building. Among the literature, some views argue that green buildings cost is not greater than conventional (non-green) buildings [8,10,51,52]; they suggest that green features can be achieved with little or no added extra cost [8,10,12,13,53,54]. In the most widely cited investigation of green buildings costs and benefits, Kats et at. [12] compared the cost of 33 LEED certified green buildings with a conventional design for the same buildings and found that the cost of the investigated green buildings increased around 1.84% on average, which is equivalent to 4$ per square foot in California state. In a later study, Kats [13] investigated the design and construction cost of 30 green schools in different places in the United States and comparatively concluded that, on average, green schools tend to cost around 2% more than conventional schools. In a more recent study, the same author [53] conducted a survey for more than 100 architects, building owners, green building consultants to obtain information about the green cost premium of more than 170 green buildings in the United States and some other countries and concluded that most green buildings cost slightly higher than conventional buildings. The author found that the reported green cost premium for the whole sample ranging from 0 - 18%. But he argues that the cost premium of more than 75% of the analyzed green buildings falls within the range from 0 - 4%. The author also contends that investigating the incremental cost of green buildings using different approaches yields the same results.

In another widely cited study conducted by Matthiessen & Morris [10], the authors compared the actual construction cost of 45 buildings seeking green certification from Leadership in Energy and Environmental Design (LEED) against another 93 similar conventional buildings. In the study, the authors conducted a point by point evaluation of 69 elective points as sustainability measures grouped under six green rating categories which are: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation and design. Interestingly, they noted that the cost per square foot for LEED buildings was scattered throughout the cost range of the whole sample which consists of 138 buildings. As a result of using the t-test to analyze the sample variation, the authors statistically concluded that there is no significant difference between green and non-green buildings cost. In the same study, the authors also investigated the ability of 61 green buildings to meet certain LEED certification levels within the initially established budget and concluded that majority of the 61 green buildings were able to meet LEED certification without additional budget. The authors, however, contend that as there are low cost and high cost non-green buildings, there are also low cost and high cost green buildings.

In a later study, Matthiessen & Morris [8] confirmed the previous findings through analyzing the cost of a larger sample consists of 221 buildings, of which 83 buildings were seeking LEED certification and the other 138 buildings were designed following conventional standards. They contend again that the average cost of green buildings is not significantly different than the average cost of non-green buildings, and majority of projects were able to meet LEED certification levels without the need to extra budget. In New Zealand, Rehm & Ade [9] compared the actual cost of 17 green office buildings, certified as green by the New Zealand Green Building Council's rating tool (Green Star NZ Version 1.0), against cost models developed using cost manuals and handbooks for the same buildings. The authors used non-parametric Wilcoxon matched-pairs signed ranks test to determine whether the actual cost is significantly higher than the modeled cost. They found that green buildings cost were higher on average when compared to modeled cost estimates, but the difference is not statistically significant. Davis Langdon [11], an international cost consulting firm, indicated that the cost premium for constructing green office buildings under the National Green Rating System in Australia (Green Star) ranges from 3 - 5% for 5 Star certified buildings (buildings achieve 60 – 74 sustainability credit points according to Green Star rating scale), and this ratio goes beyond 5% for 6 Star non-iconic buildings (Buildings which are not designed as show-case and achieve more than 75 sustainability credit points according to Green Star rating scale). They argue that many cost drivers affect projects cost, and projects with similar nature have different cost rates which are not necessarily attributed to green features. However, as a trade publication, the consulting firm did not provide much information regarding the adopted methodology in their research. In conjunction with Davis Langdon, the U.S. Green Building Council [52] examined the construction cost of 107 luxury residential new construction projects and commercial interior projects to assess the green design impact on projects cost. They found that the cost per square foot between green and non-green buildings is not significantly different.

In contrast, there are views and findings in the literature contradict the former arguments that green buildings can be achieved at a very little cost premium or at no extra costs, and there is no significant difference between the cost of green buildings and their conventional counterparts. A good example of these counter views is a study by Shrestha & Pushpala [16], in which the authors analyzed the construction cost and time of completion of 30 green school buildings and another 30 non-green school buildings. As a result of statistical analysis, the authors comparatively concluded that the green school buildings cost is 46% higher than that of the conventional school buildings, and the mean construction cost per square foot of the green schools was significantly higher than that of the conventional schools. The green school buildings, which were used in the analysis, were new constructed energy efficient school buildings adopted sustainable construction methods or incorporated sustainable features include improved air quality and day lighting, and solar energy utilization for heating and cooling. However, the authors were silent regarding the level of compliance by the green school buildings to a specific sustainability rating tool, or design code.

In a recent study by Kim et al. [14], the authors reported an increase of 10.77% in the construction cost due to incorporating new green building code for residential projects development, as a result of comprehensive cost and time of completion comparative analysis of one residential building as a case study. According to the authors, the case study which was used in the analysis is a single-family residential building designed and constructed in compliance to the applied Green Building Code in Los Angeles (Article 9, Green Building Code of Los Angeles Municipal Code). It incorporates green features include a grid connected or utility-interactive Photovoltaic (PV) system as alternative power supply, electrical vehicle charging system, high-efficiency cooling and heating system, energy efficient water heater and electrical device, in addition to energy efficient lighting fixtures.

Using a five-story federal courthouse and a nine- story federal office building as case studies, Steven Winter Associates [17] investigated the cost implications associated with achieving different levels of sustainability credit points in Leadership in Energy and Environmental Design (LEED version 2.1) which are: Certified (achieving 28 credit points), Silver (achieving 35 credit points), and Gold ratings (achieving 41 credit points), they concluded that the green cost premium ranges from 1 - 8.1% depending on the sought level of certification.

In a single case study research conducted by the National Association of Home Builders (NAHB) Research Center [15], the authors evaluated the cost impact of incorporating the National Green Building Standard (ANSI ICC 700-2008) to a green home in USA. In the study, the authors argue that the case study meets the Silver level (minimun 406 points) of the National Green Building Standard in which buildings are rated as: Bronze (minimun 222 points), Silver (minimun 406 points), Gold (minimun 558 points), and Emerald (minimun 697 points) [15]. As a result of conducting itemized cost impact analysis for each green credit point achieved by the case study, the authors concluded that the required cost premium to achieve the Silver level (minimun 406 points) of the National Green Building Standard (ANSI ICC 700-2008) is around 17%. However, it is worth noting that with the exception of Shrestha & Pushpala [16] work, aforementioned empirical investigations are based on one or two case studies at most.

3. Research Methodology

Systematic literature search was conducted to collect data from empirical published research which includes scholarly articles published in peer-reviewed journals and conference proceedings, books, study reports, and trade publications. Based on contents, the following databases were searched to find potential literature sources: Web of Science, American Society of Civil Engineers, EBSCOHost, Emerald, Sage Journals, Science Direct, Scopus, Springer Link, Taylor and Francis, Wiley Online Library, and Google scholar.

A pilot literature search was performed to evaluate the size of the literature which addresses the economic issues of green buildings. It was observed that the literature which addresses the various economic implications of green buildings is bulky and extensive. Furthermore, considerable portion of the literature investigates the economic returns and benefits associated with green buildings from life cycle perspective. Since the main objective of the research is to aggregate and review the empirical arguments about the issue of green cost premium, the search was limited to the articles and publications which provide empirical evidence about the green cost premium associated with the green building. A challenge represented in finding the literature sources which meet this selection criterion was reduced by the assumption that the terms “green building”, or “sustainable building” and “cost” supposed to be used in the title of the publication or in the publication keywords. Therefore, these terms were used as keywords in the search fields which were limited to publication title and keywords. However, this option was possible in all of the searched databases except Google Scholar, EBSCOHost, and Springer Link in which the search field was limited to publication titles only due to unavailability of keywords search option.

A summary of the search results is shown in table (1). It is worth noting that summing up the results does not provide meaningful information due to the fact that many publications appear in more than one database search. The retrieved publications were evaluated and a literature source was considered in the analysis if it meets the following criteria: (i) the publication addresses the issue of green buildings cost premium as a main topic in the research, (ii) the publication draws a clear conclusion about the cost premium issue, (iii) the publication relies on empirical data to draw the conclusion. As a general rule, publications which address the economics of green building and do not provide empirical argument about the estimated cost premium were excluded. Based on these criteria, a total of 17 empirical studies were left for further review and analysis.

Table 1: Summary of the search results

No.	Database	Search Fields	Number of retrieved results for each search term	
			"green building*" and cost	"Sustainable building*" and cost
1	Web of Science	Title, keywords	24	3
2	American Society of Civil Engineers	Title, keywords	3	1
3	EBSCO	Title	57	7
4	Emerald	Title, keywords	0	0

6	Sage Journals	Title, keywords	1	0
7	science Direct	Title, keywords	8	4
8	Scopus	Title, keywords	85	35
9	Springer Link	Title	13	3
10	Taylor And Francis	Title, keywords	0	0
11	Wiley Online Library	Title, keywords	5	1
12	Google scholar	Title	157	42

Each publication was studied in term of reported green cost premium and how the premium was concluded, in addition to how many buildings were used in the analysis. Then, a descriptive analysis was conducted after tabulating the results and the adopted methodologies in each reviewed study. Besides summarizing the findings and methodologies, the purpose of the tabulation is to classify the studies in term of publication type. The classification was essential to investigate if significant variations in term of result and methodology can be observed between the different types of publication.

4. Results and Discussion

Being the frequently cited paramount obstacle hurdles a widespread adoption of green buildings, this literature survey shows that the published empirical studies which address the issue of green cost premium are very limited and do not reflect the significance of the problem. Notably, very few academic studies were published. Among a total of 17 reviewed empirical studies, only six publications were classified as academic research, of which four scholarly articles were published in peer-reviewed journals, one conference paper, and one book contains empirical study about the green cost premium. All of the academic publications are relatively recent and published from 2010 onwards. The remaining 11 studies are professional research conducted and published by industry professionals and green building consultants. In term of the geographical distribution of the studies, more than 80% of the studies (14 studies out of 17) were conducted in the United States of America, one study in the United Kingdom, one trade publication in Australia, and one academic research in New Zealand.

Although the concept of green buildings emerged in the early nineties [2,5], the publications which address the issue of green buildings cost are recent in general. The earliest publication found is a trade publication, a case study research report conducted by Xenergy and Sera Architects in 2000 to assess how three built buildings could have been built to meet LEED criteria which were not available when the original design of the three buildings were prepared, and to determine the cost and benefits that would have occurred as a result of meeting the LEED requirements [18]. Interestingly, the first academic publication was published in 2010, a book, authored by Greg Kats, contains empirical studies about the costs and benefits associated with green buildings [53]. It took almost 20 years until the first academic research was published.

Technically, there is no standardized definition for the green cost premium [54], as well as there is no clear methodology that describes its components and estimation methods. Kats [53] proposed a definition for the green premium as the differential cost between green and conventional (non-green) “version” of the same building. Houghton et al. [54] used a definition for the green cost premium as the additional design and construction cost associated with specific green components. Without standardized operational definition of the term “green cost premium” it would be difficult to answer the problematic question raised by Matthiessen and Morris [10]: if the green building costs more, more than what?

In terms of methodology, three approaches and methodologies were used in the studies to quantify the differential cost associated with the green design, and therefore, results must be interpreted with care. The first approach is comparing the design and construction cost of a green building with a similar conventional counterpart is the most predominant approach found in the literature. This approach was used in nine studies [8,10,11,13,14,16,51,52,55]. Rather than using modeled cost data, the rigor of this approach represented in the possibility of using actual cost records from both the green building and its conventional counterpart, and therefore, the obtained results can be more accurate since potential errors associated with cost modeling are eliminated.

The second approach is comparing the design and construction cost of the green building with the modeled cost of a proposed conventional design for the same building. This approach was used in seven studies [9,12,15,17,18,53,56]. In this approach, since the proposed conventional design does not exist in reality, the cost comparative analysis can be conducted using only one dataset of actual cost records; the other dataset relies on a modeled cost. The third approach is comparing the actual design and construction cost of the green building with its initially established budget. This was the least used approach and used in two studies only [10,54]. Table (2) provides more detailed information about the cost comparison methodologies used in the studies, in addition to a summary of the findings in each study.

Table 2: Summary of the empirical studies which address the issue of green cost premium

No.	***Author(s) (Year)***	***Publication Type***	***Country***	***Methodology***	***Findings***
1	Xenergy and Sera Architects (2000)	Trade publication	USA	Multiple-Case study research: Cost analysis of re-designing three constructed office buildings to meet certain LEED criteria.	The cost premium required to meet LEED requirements ranges from -0.3 - 1.3%.
2	Packard Foundation (2002)	Trade publication	USA	Single case study research: Comparative modeled cost analysis of different LEED certification levels against a market baseline typical office building.	The green cost premium ranges from 0.9 - 21% for various LEED levels.
3	(Kats et al. (2003)	Trade publication	USA	Cost comparative analysis of 33 LEED certified green buildings against conventional design for the same buildings.	The average green cost premium is 1.84%.
4	Matthiessen and Morris (2004)	Trade publication	USA	Statistical analysis of the actual cost of 45 LEED seeking buildings against 93 similar conventional buildings. Cost comparative analysis of 61 LEED seeking buildings against their initial budget.	There is no statistically significant difference between the cost of green buildings and the cost of conventional buildings. Majority of buildings were able to achieve LEED certification without additional budget.
5	Steven Winter Associates (2004)	Trade publication	USA	Cost comparative analysis of modeled cost of various green design scenarios for two buildings against modeled conventional design cost for the same buildings.	The cost premium ranges from around -0.4 - 8.1% depending on the level of LEED certification.
6	BRE and Cyril Sweett (2005)	Trade publication	UK	Multiple-case study: Cost comparative analysis of the actual cost of four case studies against modeled design cost based on standard building regulations.	The green cost premium ranges from 0 - 7%.
7	Kats (2006)	Trade publication	USA	Cost comparative analysis of the cost of 30 green schools against the average national conventional schools cost.	Green schools cost on average 1.7% more than conventional schools.
8	Matthiessen and Morris (2007)	Trade publication	USA	Cost per square foot comparative analysis of 83 LEED seeking buildings against another 138 conventional buildings.	There is no significant difference in average cost for green buildings as compared to non-green buildings.
9	Davis Langdon (2007)	Trade publication	Australia	Cost comparative analysis of green office buildings modeled cost against similar non-green buildings.	The impact on the construction cost ranges from 3 - 5% for 5 Star rating. And more than 5% for 6 Star

No.	Author(s) (Year)	Publication Type	Country	Methodology	Findings
					non-iconic design solutions.
10	Houghton et al (2009)	Scientific journal article – peer reviewed	USA	Multiple-case study: Cost comparative analysis of the impact of green design on the cost of 13 Healthcare LEED buildings	The green cost premium ranges from 0 - 5%.
11	NAHB Research Center (2009)	Trade publication	USA	Single case study research: Itemized cost impact analysis of incorporating the National Green Building Standard to a green home.	The cost premium required to meet a silver level is around 17%.
12	USGBC (2009)	Trade publication	USA	Statistical analysis of a sample of 15 LEED residential new construction projects and 22 non-LEED projects, and for a sample of 12 LEED commercial interior projects and 13 non-LEED projects.	The cost per square foot of green buildings is not significantly different than that of non-green buildings.
13	Kats (2010)	Book	USA	Estimating the green cost premium of 170 green buildings through information from green buildings developers and architects.	The green cost premium ranges from 0% - 18%, but majority of the cost premiums fall within a range from 0 - 4%.
14	Mapp et al. (2011)	Scientific journal article – peer reviewed	USA	Multiple-case study: Cost comparative analysis of the actual cost of two LEED certified bank buildings against the actual cost of similar eight non-green bank buildings.	The cost of green bank buildings is similar to and within the range of the cost of non-green bank buildings. LEED certification process adds less than 2% to the total project cost.
15	Shrestha and Pushpala (2012)	Conference paper	USA	Cost comparative analysis of 30 green school buildings against 30 conventional school buildings using statistical methods.	The green school buildings cost is 46% higher than conventional school buildings. The mean construction cost per square foot of green schools is significantly higher than that of conventional schools.
16	Rehm and Ade (2013)	Scientific journal article – peer reviewed	New Zealand	Cost comparative analysis of the actual cost of 17 green office buildings against modeled cost for the same buildings using statistical methods.	Green office buildings cost is higher on average than conventional buildings, but the difference is not statistically significant.
17	Kim et al (2014)	Scientific journal article – peer reviewed	USA	Single case study. Cost comparative analysis of one green residential building against similar conventional counterpart.	Construction cost increased by 10.77% as a result of incorporating green features.

In term of results and findings, significant variations can be observed among the findings. As shown in table (3) below, 13 studies reported a green cost premium greater than 0%, and this, indeed, represents 100% of the studies since not all of the reviewed 17 studies aimed to quantify the extra cost associated with the green building. Only 13 studies have numerical results about the green cost premium. Out of the 13 studies, eight studies recorded a cost premium greater than 5%, and out of these eight studies, five studies recorded a premium greater than 10%, and out of the five studies, only two recorded a green cost premium greater than 20%. On the other hand, only two studies recorded a green cost premium less than 0% for some cases, which implies saving. However, none of these two studies have used actual cost record in the analysis, and both studies investigated a limited number of green buildings; not more than three green buildings at most.

Table 3: Number of studies that recorded a green cost premium higher than certain margins

No.	*Green Cost Premium*	*Number of Studies*	*Reference*
1	Less than 0%	2	[17,18]
2	Equals 0%	5	[17,18,53,54,56]
3	More than 0%	13	[11–18,51,53–56]
4	More than 5%	8	[11,14–17,53,55,56]
5	More than 10%	5	[14–16,53,55]
6	More than 20%	2	[16,55]

The lowest recorded green cost premium was -0.4% (saving) found by Steven Winter Associates [17] as a result of cost comparative analysis of modeled cost of various green design scenarios for two buildings against modeled conventional design cost for the same buildings, followed by -0.3% found by Xenergy and Sera Architects [18] as a result of cost analysis of re-designing three constructed office buildings to meet certain LEED criteria. Contrarily, the highest green premium is 46% found by Shrestha and Pushpala [16] as a result of comparing the Cost of 30 green school buildings against 30 conventional school buildings. The second highest finding is 21% reported by Packard Foundation [55]. By eliminating the finding of 46% as a potential outlier in the data, the green cost premium which can be generalized to include 92% of the studies (12 out of 13 studies) ranges from -0.4 - 21%. Only five out of 13 studies (38%) [11–13,18,54] found that the green cost premium ranges from 0 – 5%.

5. Conclusion

Reviewing the literature that addresses the benefits of the green building demonstrates conclusively that green buildings outperform conventional (non-green) buildings in all performance areas, and there is an extensive list of green building benefits. However, when it comes to the question whether or not the green building cost more than its conventional counterpart, there is no conclusive answer yet, and a significant gap exists in the quantified cost premium range. More than 90% of the results reported in the investigated empirical studies fall within the range from -0.4 - 21%. Very little evidence supports that the green building costs less than a conventional counterpart.

Remarkably, the literature which addresses the issue of green cost premium is limited and did not reach maturity yet. Moreover, the size of the literature does not reflect the significance of the problem. Only six publications were classified as academic research, while more than 70% of the empirical studies found in the literature are trade publications in some instances commissioned by governmental bodies. This provides clear evidence that the literature is dominated by professional studies executed by professional agencies rather than academic research. However, there is no remarkable variation between the academic and the trade publications in term of methodologies and findings. Both, in general, report the green cost premium as a percentage range.

All of the reviewed studies are devoid of generalization. A majority of the trade publications are unclear about the adopted methodology in the investigation and almost they are silent regarding the used data in the analysis. This, however, does not apply for the academic publications, but representativeness of the sample in the academic research, in addition to sampling criteria form a serious concern in term of generalizability. This can be deemed as a call for researchers to conduct more detailed research to evaluate the published research in term of scientific rigor. Further research is still required to provide measurable definitions for the green building and to define the green cost premium and its measurement methods.

Acknowledgment: The authors acknowledge the financial support provided by the Malaysian Ministry of Education, and the technical support provided by Universiti Teknologi Malaysia (UTM).

References:

[1] C. Choi, Removing market barriers to green development: principles and action projects to promote widespread adoption of green development practices, J. Sustain. Real Estate. 1 (2009) 107–138.

[2] C.J. Kibert, Sustainable Construction: Green Building Design and Delivery, 3rd ed., John Wiley & Sons Inc, Hoboken, New Jersey, USA, 2012.

[3] UNEP, Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication, United Nations Environment Programme (UNEP), 2011. http://www.unep.org/greeneconomy/Portals/88/documents/ger/9.0_Buildings.pdf (accessed April 7, 2014).

[4] G.H. Brundtland, Report of World Commission on Environment and Development (WCED): Our Common Future, A Report Prepared for the General Assembly of the United Nations, United Nations, 1987.

[5] J. Yudelson, Green Building A to Z: Understanding the Language of Green Building, New Society Publishers, Gabriola Islands, Canada, 2007.

[6] B.-G. Hwang, J.S. Tan, Green building project management: obstacles and solutions for sustainable development, Sustain. Dev. 20 (2012) 335–349. doi:10.1002/sd.492.

[7] M.H. Issa, J.H. Rankin, a. J. Christian, Canadian practitioners' perception of research work investigating the cost premiums, long-term costs and health and productivity benefits of green buildings, Build. Environ. 45 (2010) 1698–1711. doi:10.1016/j.buildenv.2010.01.020.

[8] L.F. Matthiessen, P. Morris, Cost of Green Revisited: Reexamining the Feasibility and Cost Impact of Sustainable Design in the Light of Increased Market Adoption, Davis Langdon Management Consulting, 2007. http://www.usgbc.org/resources/cost-green-revisited (accessed April 3, 2014).

[9] M. Rehm, R. Ade, Construction costs comparison between "green" and conventional office buildings, Build. Res. Inf. 41 (2013) 198–208. doi:10.1080/09613218.2013.769145.

[10] L.F. Matthiessen, P. Morris, Costing Green: A Comprehensive Cost Database and Budgeting Methodology, Davis Langdon Management Consulting, 2004. http://www.usgbc.org/Docs/Resources/Cost_of_Green_Full.pdf (accessed February 25, 2014).

[11] Davis Langdon, The cost & benefit of achieving Green buildings, Info Data Report, Davis Langdon Management Consulting, 2007. http://www.aecom.com/deployedfiles/Internet/Geographies/Australia-New Zealand/PCC General content/InfoData_Green_Buildings.pdf (accessed March 24, 2014).

[12] G. Kats, L. Alevantis, A. Berman, E. Mills, J. Perlman, The Costs and Financial Benefits of Green Buildings. A Report to California's Sustainable Building Task Force, 2003. http://www.usgbc.org/Docs/News/News477.pdf (accessed April 4, 2014).

[13] G. Kats, Greening America's Schools: costs and benefits, A Capital E Report, 2006. http://www.usgbc.org/Docs/Archive/General/Docs2908.pdf (accessed April 4, 2014).

[14] J. Kim, M. Greene, S. Kim, Cost Comparative Analysis of a New Green Building Code for Residential Project Development, J. Constr. Eng. Manag. 140 (2014) 1–10. doi:10.1061/(ASCE)CO.1943-7862.0000833.

[15] NAHB Research Center, The Added Cost of Greening a New Home, 2009. http://www.toolbase.org/PDF/CaseStudies/LCCTC_Added_Cost_Greening_New_Home.pdf (accessed February 15, 2015).

[16] P.P. Shrestha, N. Pushpala, Green and Non-Green School Buildings: An Empirical Comparison of Construction Cost and Schedule, Constr. Res. Congr. 2012, ASCE 2012. (2012) 1820–1829. doi:10.1061/9780784412329.183.

[17] Steven Winter Associates, LEED Cost Study: A Report Submitted to the U.S General Service Administration (GSA), 2004. http://www.ecy.wa.gov/programs/swfa/greenbuilding/pdf/gsaleed.pdf (accessed March 21, 2014).

[18] Xenergy and Sera Architects, Green City Buildings: Applying the LEED Rating System, A report prepared for Portland Energy Office, Portland, Oregon, 2000. http://neea.org/docs/reports/casestudyongreencitybuildingsmarketresearchreport.pdf (accessed February 15, 2015).

[19] USGBC Research Committee, A National Green Building Research Agenda, U.S. Green Building Council, 2008. http://www.usgbc.org/Docs/Archive/General/Docs3402.pdf (accessed March 15, 2014).

[20] T. Woolley, S. Kimmins, P. Hattison, R. Harrison, Green Building Handbook: Volume 1: A Guide to Building Products and Their Impact on the Environment, Taylor & Francis, 2005.

[21] M. Comstock, C. Garrigan, S. Pouffary, Building Design and Construction: Forging Resource Efficiency and Sustainable Development, a report produced under the coordination and supervision UNEP-DTIE, 2012. http://www.unep.org/sbci/pdfs/UNEP_SBCI_PositionPaperJune2012.pdf (accessed February 25, 2014).

[22] C.J. Kibert, The next generation of sustainable construction, Build. Res. Inf. 35 (2007) 595–601. doi:10.1080/09613210701467040.

[23] J. Yudelson, The Green Building Revolution, Island Press, Washington, D.C, 2008.

[24] J. Laustsen, Energy Efficiency Requirements in Building Codes, Energy Efficiency Policies for New Buildings, International Energy Agency (IEA), Paris, 2008. http://www.iea.org/publications/freepublications/publication/Building_Codes.pdf (accessed April 7, 2014).

[25] UNEP, Towards a Life Cycle Sustainability Assessment: Making informed choices on products, United Nations Environment Programme (UNEP), 2011. http://www.unep.org/pdf/UNEP_LifecycleInit_Dec_FINAL.pdf (accessed April 20, 2014).

[26] W. Klöpffer, Life-Cycle Based Methods for Sustainable Product Development, Int. J. Life Cycle Assess. 8 (2003) 157–159. doi:10.1007/BF02978462.

[27] W.M. Adams, The future of sustainability Re-thinking Environment and Development in the Twenty-first Century, Report of the IUCN Renowned Thinkers Meeting, prepared for The World Conservation Union, University of Cambridge, UK, 2006.

[28] UNEP, Greening the Economy Through Life Cycle Thinking, United Nations Environment Programme, 2012. http://www.unep.org/greeneconomy/Portals/88/documents/partnerships/UNEP BCGE A4.pdf (accessed May 25, 2014).

[29] UNEP/SETAC, Guidelines for Social Life Cycle Assessment of Products, UNEP/Earthprint, Paris, 2009. http://www.unep.fr/shared/publications/pdf/DTIx1164xPA-guidelines_sLCA.pdf (accessed April 23, 2014).

[30] ISO 14044, Environmental Management - Life Cycle Assessment- Requirements and guidelines (ISO EN 14044:2006), 1st ed., International Organization of Standardization (ISO), 2006.

[31] J. Burnett, Sustainability and Sustainable Buildings, HKIE Trans. 14 (2007) 1–9. doi:10.1080/1023697X.2007.10668079.

[32] UNEP SBCI, Buildings and Climate Change: Summary for Decision-Makers, United Nations Environmental Programme, Sustainable Buildings and Climate Initiative, Paris, 2009. http://www.unep.org/sbci/pdfs/SBCI-BCCSummary.pdf (accessed August 4, 2014).

[33] I. Sartori, a. G. Hestnes, Energy use in the life cycle of conventional and low-energy buildings: A review article, Energy Build. 39 (2007) 249–257. doi:10.1016/j.enbuild.2006.07.001.

[34] S.B. Sadineni, S. Madala, R.F. Boehm, Passive building energy savings: A review of building envelope components, Renew. Sustain. Energy Rev. 15 (2011) 3617–3631. doi:10.1016/j.rser.2011.07.014.

[35] M. Levine, D. Ürge-Vorsatz, K. Blok, L. Geng, D. Harvey, S. Lang, et al., Residential and commercial buildings, in: Clim. Chang. 2007 Mitigation. Contrib. Work. Gr. III to Fourth Assess. Rep. Intergov. Panel Clim. Chang. [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., 2007.

[36] J. Yudelson, Marketing Green Building Services: Strategies for Success, 1st ed., Elsevier Ltd, China, 2008.

[37] R.J. Cole, Rating Systems for Sustainability, in: Sustain. Built Environ., Springer, New York, 2013: pp. 464–477. doi:10.1007/978-1-4614-5828-9.

[38] J. Burnett, C. Chau, W. Lee, Green Buildings: How Green the Label?, HKIE Trans. 12 (2005) 1–8. doi:10.1080/1023697X.2005.10668014.

[39] R. Reed, A. Bilos, S. Wilkinson, K.-W. Schulte, International Comparison of Sustainable Rating Tools, J. Sustain. Real Estate. 1 (2009) 1–22.

[40] U.S. Green Building Council, U.S. Green Building Council, Leadersh. Energy Environ. Des. (2014). http://www.usgbc.org/leed (accessed April 15, 2014).

[41] BREEAM, Building Research Establishment Environmental Assessment Methodology, (2014). www.breeam.org (accessed September 24, 2014).

[42] R. Madew, The Dollars and Sense of Green Buildings, A report for the Green Building Council of Australia, 2006. http://www.gbca.org.au/resources/dollars-and-sense-of-green-buildings-2006-building-the-business-case-for-green-c/1002.htm (accessed March 25, 2014).

[43] The Green Building Council of Australia (GBCA), Green Star Overview, (2015). https://www.gbca.org.au/green-star/green-star-overview/ (accessed February 14, 2015).

[44] R. Ries, M.M. Bilec, K.L. Needy, N.M. Gokhan, The Economic Benefits of Green Buildings : A Comprehensive Case Study, Eng. Econ. 51 (2006) 259–295. doi:10.1080/00137910600865469.

[45] L.C. Lau, K.T. Tan, K.T. Lee, A.R. Mohamed, A comparative study on the energy policies in Japan and Malaysia in fulfilling their nations' obligations towards the Kyoto Protocol, Energy Policy. 37 (2009) 4771–4778. doi:10.1016/j.enpol.2009.06.034.

[46] GSA Public Buildings Service, Assessing building performance: A Post Occupancy Evaluation of 12 GSA Buildings Research, 2008. http://www.gsa.gov/graphics/pbs/GSA_AssessGreen_white_paper.pdf (accessed March 29, 2014).

[47] R. Bowman, J. Wills, Valuing green: How Green Buildings Affect Property Values and Getting Valuation Method Right, Green Building Council of Australia, Sydney, 2008. https://www.gbca.org.au/docs/NSC0009_ValuingGreen.pdf (accessed March 25, 2014).

[48] P. Morris, What does green really cost?, PREA Q. (2007). http://www.davislangdon.co.nz/USA/Research/ResearchFinder/What-Does-Green-Really-Cost/ (accessed May 15, 2014).

[49] T. Häkkinen, K. Belloni, Barriers and drivers for sustainable building, Build. Res. Inf. 39 (2011) 239–255. doi:10.1080/09613218.2011.561948.

[50] J. Yudelson, Costs of Green Buildings, in: Green Build. Through Integr. Des. (GreenSource Books), Access Engineering, McGraw-Hill Professional, 2009.

[51] C. Mapp, M. Nobe, B. Dunbar, THe Cost of LEED - An Analysis of the Construction Costs of LEED and Non-LEED Banks, J. Sustain. Real Estate. 3 (2011) 254–273.

[52] USGBC, Cost of Green in NYC, U.S. Green Building Council, 2009. http://urbangreencouncil.org/content/cost-green-nyc (accessed February 14, 2015).

[53] G. Kats, Greening Our Built World: Costs, Benefits, and Strategies, Island Press, Washington, D.C, USA, 2010.

[54] A. Houghton, G. Vittori, R. Guenther, Demystifying first-cost green building premiums in healthcare, Heal. Environ. Res. Des. J. 2 (2009) 10–45. doi:10.1177/193758670900200402.

[55] Packard Foundation, Building for Sustainability Report: Six Scenarios for the David and Lucile Packard Foundation Los Altos Project, 2002. https://folio.iupui.edu/handle/10244/28 (accessed February 15, 2014).

[56] BRE and Cyril Sweett, Putting a price on sustainability, Building Research Establishment (BRE), London, U.K., 2005.

Page 16 of 16