Renewable and Sustainable Energy Reviews 81 (2018) 1476–1483

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

An examination of the LEED green building certification system in terms of construction costs

Latif Onur Uğur[a,*], Neşe Leblebici[b]

[a] Düzce Üniversity, Faculty of Civil Engineering, Düzce 81620, Turkey
[b] Energy Market Regulatory Authority, Ankara 06530, Turkey

ARTICLE INFO

Keywords:
Green building
LEED-certification system
Construction costs

ABSTRACT

This study was conducted to assess cost-benefit analysis and payback period of two green buildings located in Turkey. In this context, two buildings in gold and platinum categories according to the LEED certification system were studied to present the actual expenses caused by greening. For gold and platinum certified building respectively; the additional construction cost was found to be 7.43% and 9.43%, the share of soft cost in total construction cost was stated to be 0.84% and 1.31%, reduction in annual energy consumption cost was determined as 31% and 40%, also additional construction cost's payback period was calculated to be 0.41 and 2.56.

1. Introduction and background

Leadership in Energy and Environmental Design (LEED), which has played an important role in spreading the green building certificate system approach worldwide, aims to reduce negative environmental effects of buildings and ensure energy efficiency. To be successful, a green building project is expected to cost less than what it brings during the lifetime of the building. We will estimate the extra constructions costs required to have two buildings in Turkey LEED-certified.

Because of the definition of what constitutes a green building is constantly evolving, the green building definition varies and there are numerous definitions for the green building. While green building is also known as a sustainable or high performance building, the Environmental Protection Agency (EPA) defines green building as follows: the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort [1–6]. In the course of design and construction, green buildings use recycled materials, less water, less energy and resource efficient techniques, thereby minimising adverse impact on the environment. Accordingly, green building construction process implicates environmentally, socially and economically [4,7–11].

The members of the United States Green Building Council (USGBC) achieved a consensus on supporting green buildings and acknowledged that it was necessary to promote higher economic vitality and environmental health and lower costs. The LEED system, which was developed within the framework of efforts carried out to this end and expanded its application area since the year 2000, is constantly being updated in line with changing conditions and needs and as new versions emerge. LEED v3 is the next version of the LEED green building certification system. Launched in 2009, LEED v3 builds on the fundamental structure and familiarity of the existing rating system, but provides a new structure for making sure the rating system incorporates new technology and addresses the most urgent priorities like energy use and CO_2 emissions. LEED v4, which is the latest version released in 2013, seems to address new sectors unlike previous versions, has increased technical requisites, shows improvements in environmental issues such as climate change and supports optimization in energy and water consumption. LEED v4 is more clear, easier to understand and implement and more functional. In addition, it lays greater emphasis on material and product transparency and brings innovations that increase the role of technology. Thus, LEED lays a foundation for its future versions and seems to progressively continue its leadership throughout the world despite the efforts of various countries to develop national certification systems [12–16].

LEED is a point-based system, different green features of a building will earn different points. LEED projects earn points by adhering to prerequisites and credits across some measurements for building excellence from integrative process to indoor environmental quality. The number of points the project earns determines its level of LEED

* Corresponding author.
E-mail addresses: latifugur@duzce.edu.tr (L.O. Uğur), nleblebici@epdk.org.tr (N. Leblebici).

http://dx.doi.org/10.1016/j.rser.2017.05.210
Received 1 March 2016; Received in revised form 25 March 2017; Accepted 23 May 2017
Available online 07 June 2017
1364-0321/

certification. Based on the number of credits achieved, a project earns one of four LEED rating levels: Certified, Silver, Gold, and Platinum. A basic LEED certification is awarded if a building amasses between 40 and 49. LEED Silver and Gold certifications are 50–59 and 60–79 points respectively. The highest LEED certification is LEED Platinum, awarded to buildings that attain 80 or more points. Within each of the LEED credit categories, projects must satisfy prerequisites and earn points. The basic credit categories of LEED certification include the following: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation in Design and Regional Priority [12–16].

Considering the studies performed in order to reveal the cost of green buildings in comparison to conventional-standard buildings, early studies initiated in 2000 mentioned an additional cost of more than 25% based on inexperienced estimations, whereas it was revealed in the light of more realistic data in following years that the additional cost of certification was less than feared. As a result of studies conducted in the US using a large data set, LEED certification costs were determined to increase the total construction cost by 4–11% [17]. Some researches argue that green buildings cost is not greater than conventional buildings, they suggest that green features can be achieved with little or no added extra cost [18–22]. Kats et at [22] analyzed the cost of 33 LEED certified green buildings compared to conventional designs for those buildings and found that the average premium for these green buildings is slightly less than 2%, substantially lower than is commonly perceived. It was found that the financial benefits of green buildings are approximately ten times larger than the average initial investment required to design and construct a green building. In a later study, Kats [23] conducted a survey for 170 green buildings in the United States and some other countries and concluded that the average cost increase for building green was 1.40%. In addition, compared with non green buildings, it was found that a direct energy cost reduction of 34% [24]. In a study conducted in California with new buildings in four different categories, the additional cost was found to be 0–2.50% for Certified buildings, 0–3.30% for Silver buildings, 0.30–5% for Gold Buildings and 4.50–8.50% for platinum buildings [25]. 90 non-certified buildings and 50 certified buildings were examined in a report on the cost of green buildings in 2004 and the assessment of the data related to the construction cost for different LEED certificate levels revealed that there was no statistically significant difference between the cost of standard buildings and the cost of green buildings [18]. Studies performed in following years presented that there was no significant difference between the cost of standard buildings and the cost of green buildings [19].

In a study on soft cost elements conducted in Malaysia, it was suggested that registry, approval and consultancy costs which were determined to be soft cost elements, could affect decisions of investors to develop green buildings [26]. It was shown in a study on operating expenses of 6 LEED certified buildings that certified buildings performed better compared to the reference building in terms of water and energy consumption [27]. Gabay et at. [28] estimated the optimum alternative, leading to maximum savings in resources use, and the economical alternative, which minimizes initial investment. The optimum alternative, involved an additional cost, ranging between 4% and 12%, whereas under the economical alternative the additional cost was only 0.12–1.33%. The relationship between energy costs and operating expenditures was tested in a study in the US conducted with a large data set containing office buildings and their rents. Contrary to expectations, it was found that eco-certification was correlated with higher energy expenses [29].

A methodology was suggested in a study to analyze the green value in the assessment of green buildings. In this methodology, the wasted/saved energy was accepted to be the difference in energy demand between a reference building and a green building [30]. A study in India aimed to review the literature on the green building construction movement and green building assessment systems. Benefits and costs, and green design strategies were reviewed and their effects on the future of sustainable development in India were discussed [31]. In a study on financial effects of green buildings, it was pointed out that the value of a piece of real estate was not only composed of its economic value but it was also possible to mention environmental, social, cultural and image values depending on the capacity of technical, economic, functional, environmental, social and aesthetic performances to contribute to said real estate's value [32]. Buildings in the same submarket were compared in a study on effects of certification on price of commercial real estates in the US and it was found that the rental premium was about 5% and the sales premium was about 25% in buildings evaluated with the LEED certification system [33]. With the aim of assessing the application of green elements to the building development process in terms of cost and difficulties encountered in China, three case studies in which additional costs were analyzed showed that high costs, considered to be the main obstacle, restricted comprehensive green technology applications [34]. Statistically significant differences were found in a study on effects of non-environmental quality related factors on user satisfaction in LEED certified and non-LEED certified buildings, however, it was also stated that effects of these differences were practically negligible [35]. In a study on effects of the plant cover on the energy saving performance in LEED certified buildings, although the plant cover was found to decrease negative heat transfer significantly, it was shown that it was not cost-effective in winter or regions with cold climates [36]. In a study on the effectiveness of LEED certification in energy consumption and greenhouse gas emission in large office buildings in New York, LEED gold certified buildings were found to perform 20% better [37].

Studies carried out by the World Green Building Council (WGBC) address the cost of green buildings with comprehensive reports based on global projects. In a report prepared in 2013, it was stated that the cost of design and construction was not higher for green buildings compared to standard buildings when cost strategies, program management and environmental strategies were integrated to the project development process from the very beginning. The reduction in long-term operating and maintenance costs with the efficient use of energy and water is considered to be the money-saving feature of green buildings. It is suggested that the cost of design and construction should pay off in a reasonable time with energy saving alone [38]. In 2015, another report prepared with the participation of councils from the US, China, England and Colombia and the contribution of a large number of relevant organizations, the issue of health, comfort and productivity was addressed and the results were in support of the results of the 2013 report [39].

There are several environmental methods for evaluating environmental performance of buildings. The available green building assessment systems worldwide are built upon various principles and different evaluation tools, data and criteria. It is stated that there are more than 30 green building assessment systems. Some of them which are members of WGBC and widely accepted as the following: Green Star (Australia), DGNB (Germany), IGBC (India), CASBEE (Japan), BREEAM (the UK), LEED (the USA) and also HQE (France) [40]. In Turkey, while international green building certification systems, such as LEED, BREAM and DGBN, are used generally, it is also trying to establish a national rating system. In the system being developed in Turkey, it is trying to develop a different evaluation system from other certification systems by taking notice of fire and earthquake safety, radiation impact properties of materials, electromagnetic pollution and analysis based on field measurements [41].

2. Research framework

Under the scope of the buildings examined, the objective of this study was determined as to present the realized construction costs and actual operating expenses caused by LEED system. In this context, this study has been conducted to assess cost-benefit analysis and payback period of two green buildings located in Turkey. Thus, subject buildings have been studied to present the sustainable features and additional costs caused by LEED.

The main material of the study consists of the data obtained from two green buildings selected based on the relevant literature data and the field study. Two buildings in gold and platinum categories according to the LEED certification system located in Ankara constitute the main material of the study.

The compilation of the relevant literature data showed that the increased project cost was an accepted fact for the LEED certification process. Accordingly, the total cost of the project included land acquisition, preparation of the construction area, permissions, design and construction costs, landscaping, furniture and fixtures. The construction cost refers to expenses for construction of the building by the contractor according to design features and excludes costs related to land, design, furniture and fixtures and other elements. More than half of the construction costs consist of green features such as alternative systems, applications and materials, which bring points under the LEED system. Costs other than the construction costs, referred to as soft costs, include certificate application and approval costs, consultancy and commissioning costs and additional design costs [17,19,42]. In addition, it is considered that additional costs which set green buildings apart from standard buildings should be evaluated together with benefits throughout their economic life. It is necessary to perform an economic analysis with the costing method called the total cost of ownership or the life-cycle cost, which includes future benefits [21,42–52].

For both buildings in the study, the application manner and amount of the criteria required by the LEED certification system were examined on site and from documents, written and visual; documents related to technical and architectural features were obtained, individual interviews were conducted with authorized persons and relevant registry systems were used to compile total project costs, soft costs, construction costs and energy expenses. In this context, it was observed that there were difficulties in terms of accessing the data related to project development and construction and operating costs and the general attitude was reluctant and hesitant.

The basic method of the study is made up of data collection, field survey-analysis, individual interviews and case study based on observation. Also, static methods such as cost-benefit rate and payback period were used in the analysis of costs.

3. Research findings

This section covers the general information related to the buildings, their technical and architectural features and sustainability criteria and includes the evaluation of the data related to construction costs and operating expenses.

3.1. Examination in terms of general features and certification criteria

The scores of the two buildings in the study according to the LEED certification system assessment of the buildings' sustainability features were summarized in Table 3.1.

As can be seen on Table 3.1 that the platinum certified building stood out with a full score in the water efficiency category. In addition, the building managed to achieve platinum certificate level with points scored for both its indoor environmental quality and its innovative design. The score of the platinum building in the materials and resources category was significantly higher compared to the gold certified building as well. The gold certified building scored the highest points in the sustainable sites category. Being in an organized industrial zone was a great advantage for the building, helping it to obtain a higher score, since it is a fact that contributes to preservation of green spaces and agricultural lands. On the other hand, although the gold certified building stood out with points scored in the energy and atmosphere category, it scored lower compared to the platinum certified building.

Table 3.1
Comparison of quantitative values of sustainability criteria.

Certification Categories	Scoring	Score	
		New Construction LEEDv3-Gold	New Construction LEEDv3-Platinum
Sustainable Sites	26	22	22
Water Efficiency	10	6	10
Energy and Atmosphere	35	21	19
Materials and Resources	14	6	8
Indoor Environmental Quality	15	7	13
Innovation	6	4	5
Regional Priority	4	4	4
Total Score	110	70	81

According to the information given by the related persons; it was found that both gold and platinum certified buildings were showed parallels in terms of project development, planning, construction and certification periods and also had similar features in terms of the purpose of use and also were planned in full accordance with the wishes of their owners and developed as need-specific projects. In the other words, both buildings were planned for the use of their owners and the building was attempted in a way that they would respond to their needs as much as possible, reflect their corporate identity, support their vision and ensure prestige. Thus, subject buildings have been planned without much consideration to profitability and with ease of use, image, prestige, comfort, quality, durability and aesthetics in mind and built as energy efficient buildings to this end, aimed to obtain a LEED certificate. Gold and platinum certified buildings, both have been built with a comprehensive project management taking economic and environmental strategies into account from the planning stage and certified in May 2014 and the guidance, control and monitoring necessary for a LEED certificate were provided by LEED consultancy and commissioning services.

3.1.1. Gold certified building

The building was planned in order to be used as regional administration and service building of a private company and the project works started in October 2011, with the construction starting in July 2012 and ending in September 2013. The building has a total construction area of 4131 m^2 and a land area of 3764 m^2. The building has a total of 4 floors including an office area in the basement floor. The service area, also referred to as workshop, is built on 670 m^2 and used for sales and maintenance-repair services for heavy equipment. Applications aimed at comfort, aesthetics and quality are evident throughout the interior of the building, which is located in an industrial area and stands out with its general appearance and green features.

The features of the building that stand out and meet the LEED certification criteria are a trombe wall, rainwater harvesting system and green roof system.

A narrow greenhouse, also referred to as a trombe wall, is built up to the height and length of the wall on the Southern side of the building. The trombe wall, planned to provide energy saving through natural ventilation, relies on the principle of letting in the air heated between the greenhouse and the concrete wall, which constitutes the thermal mass, through holes on the upper part of the wall and letting out the cold air inside the building through holes on the lower part of the wall.

Within the context of rainwater management, perforated stones are used in the parking lot in order to allow rainwater to penetrate through soil and be absorbed by soil to preserve underground water resources and their quality. It is observed that water saving is achieved in the building with the storage and distribution system which makes it possible to reuse the rainwater stored on the roof of the building. The choice of plants appropriate to the environment and low water consumption in landscaping and the use of a drip irrigation system to reduce water consumption are other measures that allow for water saving.

The green roof built in order to increase the use of green space presents a design example that provides connection with the nature. In addition to visual aesthetics, acoustic and visual privacy, shading, additional insulation and improved air quality, the recreational area created with green roofs is known to have positive effects on human health and contribute to development of green consciousness. The green roof retains water during heavy rain falls and reduces the load on the draining system, and thus presents an innovative solution to problems caused by rainwater.

3.1.2. Platinum certified building

The building was developed as the office of an organization and the project works started in September 2011, with the construction starting in August 2012 and ending in October 2013. The building has a total construction area of 5397 m^2 and a land area of 1295 m^2. The building has a total of 7 floors including three basement floors. The building is surrounded with luxurious residential areas containing housings, offices, sport facilities, and shopping malls where real estate prices are relatively high.

The building has been granted various awards due to its original architecture and design approach. The features of the building that stand out and meet the LEED certification criteria are thermal labyrinth system, thermal concrete slab heating and cooling system, chilled beam system, metal mesh curtainwall and a ventilation system that improves interior air quality.

The thermal labyrinth system, the first example of a system employing the passive heating and cooling technique in Turkey, makes it possible to maintain indoor thermal comfort. The most prominent sustainable feature of the building is this reinforced concrete labyrinth system. It is built as the third basement floor in order to minimize the energy spent for heating and cooling by making use of the temperature difference between day and night which is typical of the continental climate seen in Ankara. The air taken in from fresh air inlets in the basement floor is passed through the labyrinth, conditioned and conveyed to the air handling unit. Air ducts on each floor distribute the conditioned air through a central air corridor and convey it to the environment through pipes placed within the active thermal mass and active chilled beams. The chilled beam system spreads the air from the air handling unit to the building and performs final air conditioning checks to ensure thermal comfort.

Despite the building's transparent shell, the metal mesh facade feature covers the building with stainless steel mesh designed using energy modeling tests, and serves as a second layer. This mesh system provides great advantages in terms of air conditioning in LEED certification. The mesh system combines the architectural effect and environmental factors depending on the solar reflection and light status and regulates the indoor atmosphere by reducing the influence of the sun during the day. Solar heat gain is prevented through shading and solar control. This system is extremely resistant against external factors and long lasting, requires no maintenance or renewal, creates an innovative and different visual effect and contributes greatly in terms of security as well.

3.2. Examination in terms of costs and operating expenses

Documents such as project files, survey summaries and progress payments were obtained and energy modeling programs were examined and analyzed in order to assess additional cost increases and determine energy efficiency rates and operating costs for the green buildings in the study. The data collected as a result of individual interviews with the building owner, the project manager, the operating manager, the LEED consultant and the system commissioning and control specialist were compiled. When the data summarized in Table 3.2 is examined, it can be seen that measures and steps taken in order to effectively implement sustainable features stipulated by the LEED certification system increased the total project cost for both buildings, the project cost increasing according to the level of certificate and the total project cost of the platinum building being significantly higher.

Table 3.2
Construction features and construction costs of buildings.

Green Building Certification Score	LEEDv3-Gold	LEEDv3-Platinum
Type	Office and Service Building	Office Building
Status	New Construction	New Construction
Form Of Ownership	Owner	Owner
Project Start Date	October 2011	September 2011
Number of Users	35	30
Construction Start Date	July 2012	August 2012
Construction End Date	September 2013	October 2013
Land Area	3764 m^2	1295 m^2
Unit Land Trading Value	398.51 $/$m^2$	1158.30 $/$m^2$
Total Construction Area	4131 m^2	5397 m^2
Number of Floors	1+3=4	3+4=7
Building Coverage	1460 m^2	458 m^2
Total Height	12.20 m	22.70 m
Total Project Cost	$ 4,363,072	$ 11,971,768.27
Total Construction Cost	$ 2,877,423.23	$ 10,257,574

Considering that the data related to total project costs cannot be obtained in most studies and only the data related to construction costs are present, studies that use comprehensive data sets seem to evaluate results based on total construction costs only [6]. In this study, on the other hand, we were able to obtain the total investment costs and assessments were made using both total construction costs and total investment costs.

In addition, an attempt was made to separate costs related to green features of the buildings based on actual costs in order to determine additional green costs. At this point, attention was paid to correctly determine the investment items that earned the buildings the right to obtain green building certification; however, it was not easy to make the distinction.

In order to reveal the total cost of investment made for the buildings, an appraisal was made, which included the sum of land, design, construction, landscaping, furniture and fixtures costs. The construction cost was calculated considering expenses for the construction of the building by the contractor according to design features and excludes costs related to land, design, furniture and fixtures and other elements. In addition, the costs arising only from requirements of the certification process, referred to as soft costs, were also calculated. Considering that all investment items involved in the construction of a building are necessary expenses to build a modern building and make a profitable investment using today's construction technology and assuming that all investment items are within the scope of these necessary expenses even if a green building certificate is not to be obtained, the soft costs were determined to be application, certification, consultancy and additional design costs.

In order to determine actual annual operating expenses, the documents related to electricity, water and natural gas consumption were obtained and annual consumption volumes and total amounts were found. In addition, the energy modeling programs were examined and actual and projected energy savings rates of the buildings were compared to the reference building. Maintenance, repair, personnel and service savings rates were not included in the assessment.

Table 3.3
Green cost for the gold certified building.

Total Investment Cost ($)	4,477,609
Total Construction Cost ($)	2,877,423.23
Unit Construction Cost ($/m^2)	696.54
Unit Investment Cost ($/m^2)	1084
LEED Application, Certification, Consultancy and Commissioning Fee ($)	13,035
Additional Design Cost ($)	11,146
Additional Construction Cost ($)	189,647
Total Green Building Certification Cost ($)	213,828
Unit Green Building Certification Cost ($/m^2)	51.76
Percent of Total Investment Cost (%)	4.78
Percent of Total Construction Cost (%)	7.43

3.2.1. Gold certified building

The land with a surface area of 3764 m^2 was purchased for 398.51 $/m^2 in June 2012 and the construction was initiated with a total construction area of 4131 m^2 in July 2012. It was found that the actual investment cost was $ 4,477,609 at the construction completion date, September 2013. The unit investment cost was calculated to be 1084 $/m^2 and the unit construction cost was calculated to be 696.54 $/m^2 for the total construction area.

The cost of each additional green feature was identified for the green cost analysis considering the all items that separate the green building from a standard building, thus the green building certification cost was calculated. The share of the total green building certification cost in investment and construction costs is shown in Table 3.3. According to these values, when all investments identified to be aimed at constructing a sustainable building including the soft costs are taken into account, the green cost was found to be 4.78% in the total project cost. This figure increased to 7.43% in the total construction cost.

In this context, in addition to the soft costs, costs of all investment items that earn points in the LEED certification system such as a trombe wall, green roof system, photovoltaic panel system, solar chimneys, solar collectors, rainwater harvesting system, lighting and ventilation automation were included in the calculation. Accordingly, the unit green cost was calculated to be 51.76 $/m^2.

When only soft costs were calculated taking certification and consultancy fees and additional design costs such as energy modeling, erosion and sedimentation control plan and landscape planning into account, it was found that the share of soft costs was only 0.54% in total project cost. This figure increased to 0.84% in total construction costs. Accordingly, soft costs for the unit construction area was calculated to be 5.85 $/m^2.

Actual and projected energy and water efficiency rates were calculated within the scope of operating expenses. It was found that energy modeling was performed using the HAP v4.5 for the total air conditioning area of the building, which was 1875 m^2. According to this modeling, projected building values were determined by ASHRAE 90.1 2007 (US standard) and reference building values were determined by TS 825 (Turkish standard). Electricity, natural gas and water consumption amounts and costs for the actual and projected buildings and for the reference building were compared. The actual and projected energy efficiency rates are shown in Table 3.4. Accordingly, the savings rate between the reference building and the actual building was found to be 31%, which corresponds to $ 15,398/year.

As can be seen on Table 3.4 the natural gas consumption values for the reference building are lower than those determined for the projected building. This might be explained by the fact that the compared heating-cooling system depends more on electricity. In terms of water consumption, the values for the actual building were higher compared to the reference building. These deviations are attributed to the difference between capacity values accepted in the energy modeling and actual physical values. The deviation between the results of energy modeling programs and actual consumption is considered natural. However, a high deviation indicates either the energy modeling was not performed in accordance with the accepted assumption or capacity assumptions in the energy modeling were different from the actual physical values. Deviations may be fixed by checking systems such as lighting, heating and air conditioning automations.

3.2.2. Platinum certified building

The land with a surface area of 1295 m^2 was purchased for 1158.30 $/m^2 in May 2012 and the construction was initiated with a total construction area of 5397 m^2 in August 2012. It was found that the actual investment cost was $ 12,096,553.43 at the construction completion date, October 2013. The unit investment cost was calculated to be 2241.35 $/m^2 and the unit construction cost was calculated to be 1901 $/m^2 for the total construction area.

The thermal labyrinth system that earned points in the innovation category was a factor that increased the cost of the initial investment. However, it also led to a decrease in cost as well, since the system decreases the energy consumption necessary for heating and cooling the system, thus allowing for using mechanical devices with lower capacities to be used for heating and cooling.

The share of the total green building certification cost in investment and construction costs is shown in Table 3.5. According to these values, when all investments identified to be aimed at constructing a green building including the soft costs were taken into account, the green cost was found to be 8% in the total project cost and 9.43% in the construction cost. In this context, costs of all investment items such as thermal labyrinth system, chilled beam system, green roof system, photovoltaic panel system, graywater treatment system, solar collectors, rainwater harvesting system, lighting and ventilation automation were included in the calculation. Accordingly, additional costs for unit construction area was calculated to be 179.25 $/m^2.

When only soft costs were taken into account, it was found that the share of soft costs was found to be 1.11% in total project cost and 1.31% in total construction costs. Accordingly, soft costs for unit construction area was calculated to be 24.91 $/m^2.

Actual values for the energy and water consumption were analyzed with modeling data in order to find operating expenses. It was found that energy modeling was performed using the Design Builder for the total air conditioning area of the building, which was 3194 m^2. In this context, the standards used for determining the values are ASHRAE 90.1 2007 standards for the projected building and TS 825 standards for the reference building. Accordingly, the savings rate between the reference building and the projected building in terms of electricity, natural gas and water consumption was found to be 38%, whereas it

Table 3.4
Comparison of annual operating expenses of the gold certified building.

	Actual		Projected		Baseline	
	Consumption	Amount ($)	Consumption	Amount ($)	Consumption	Amount ($)
Electricity	161,346 kWh/year	18,969	177,000 kWh/year	20,809	300,000 kWh/year	35,271
Natural Gas	135,462 kWh/year	6212	131,000 kWh/year	6007.27	127,000 kWh/year	5559
Water	1943 m³/year	9186	1750 m³/year	8274	1890 m³/year	8935
Total		34,367		35,090.18		49,765

Table 3.5
Green cost for the platinum certified building.

Total Investment Cost ($)	12,096,553.43
Total Construction Cost ($)	10,257,574
Unit Construction Cost ($/m^2)	1901
Unit Investment Cost ($/m^2)	2241.35
LEED Application, Certification, Consultancy and Commissioning Fee ($)	68,188.47
Additional Design Cost ($)	66,221.82
Additional Construction Cost ($)	832,998
Total Green Building Certification Cost ($)	967,408.29
Unit Green Building Certification Cost ($/m^2)	179.25
Percent of Total Investment Cost (%)	8
Percent of Total Construction Cost (%)	9.43

was found to be 40% between the reference building and the actual building.

According to the findings, the annual electricity, natural gas and water costs of the platinum certified building was 40% lower compared to the reference building. Accordingly, a total savings amount in this building from electricity, natural gas and water consumption was $ 27,715/year. As can be seen on Table 3.6 the actual natural gas consumption values were higher compared to the projected natural gas consumption values. However, considering that the deviation is low and the actual values are lower compared to the reference building, the difference may be attributed to operation management. A saving of 50% was achieved in terms of water consumption volume and amount compared to the reference building. Thus, it was observed that the building employed the features that made it possible to have a full score in the water efficiency category of the LEED certification system and significant improvements were achieved in terms of energy savings thanks to features such as labyrinth and chilled beam systems.

3.3. Cost and benefit analysis

In order to reflect the resulting benefits on costs, additional costs identified for each building were compared to savings amounts throughout the economic life. To this end, the present value formula was used for the capitalization of energy savings, similar to [44].

$$PV = A \times [(1+f)^n - 1)]/[(1+f)^n \times f)]$$

Where;

PV: Present Value ($)
A: Annual Cost Savings ($/Year)
f: Annual Discount Rate (%)
n: Economic Life (Years)

When determining capitalized savings value, the increase in unit price of natural gas, electricity and water was ignored, the discount ratio was taken 8% according to Eurobond interest rates, and inflation data, real estate risk premium and the economic life was assumed to be 20 years.

The present value of the annual energy savings for the gold certified building, which was found to be $ 15,398 in Section 3.2.1, was calculated to be:

$$PV = 15{,}398 \times [(1.08)^{20} - 1)]/[(1.08)^{20} \times 0.08]$$
$$= 15{,}398 \times 9.818 = \$151{,}177.56$$

For the gold certified building, the value of the annual energy savings amount per unit construction area was 3.73 $/m^2 and its present value of 20 years was calculated to be 36.60 $/m^2. It was found as a result of the comparison between the present value of energy savings and the unit value containing all additional investments (51.76 $/m^2), the payback period was determined to be 1.24 years. In other words, it was shown that the additional cost for sustainable features of the gold certified building was recovered in 1.24 years with savings from energy and water only. It was determined that the unit net present value of the initial investment for additional expenses decreased to 15.16 $ /m^2 when the benefit from energy savings is taken into account.

The present value of the annual energy savings for the platinum certified building, which was found to be $ 27,715 in Section 3.2.2, was calculated to be:

$$PV = 27{,}715 \times [(1.08)^{20} - 1)]/[(1.08)^{20} \times 0.08]$$
$$= 27{,}715 \times 9.818 = \$\ 272{,}105.87$$

For the platinum certified building, the value of the annual energy savings amount per unit construction area was 5.14 $/m^2 and its present value of 20 years was calculated to be 50.42 $/m^2. It was found as a result of the comparison between the present value of energy savings and the unit value containing all additional investments (179.25 $/m^2), that the payback period was determined to be 3.08 years. In other words, it was shown that the additional cost for sustainable features of the platinum certified building was recovered in 3.08 years with savings from energy only. It was determined that the unit net present value of the initial investment for additional expenses decreased to 128.83 $/m^2 when the benefit from energy savings was taken into account.

When Table 3.7 is examined, based on the results of the two case buildings, it can be found that the annual operating costs savings amount per unit construction area of the platinum certified building seems to be 1.38 times higher than that of the gold certified building. Considering that only energy and water savings are taken into account in this calculation, it is believed that the calculated payback period will be shorter and cost-benefit ratio will be higher when inestimable benefits from productivity and health in addition to benefits from operating and maintenance services are added to the equation.

4. Discussions

The paper has discussed two green buildings' construction costs caused by LEED. Accordingly, it is concluded that the gold certified building requires a lower additional cost compared to the platinum certified building, additional costs are recovered in a shorter period of time considering the present value of savings amounts for the gold certified building, therefore, it is a more profitable investment to construct a gold certified building. It is believed that the higher number of gold certified buildings in the world and in Turkey supports this conclusion. Compared to rates determined in previous studies on the

Table 3.6
Comparison of annual operating expenses of the platinum certified building.

	Actual		Projected		Baseline	
	Consumption	Amount ($)	Consumption	Amount ($)	Consumption	Amount ($)
Electricity	185,237 kWh/year	28,351	214,000 kWh/year	32,753	310,000 kWh/year	47,446
Natural Gas	244,199 kWh/year	10,722	145,000 kWh/year	6367	373,000 kWh/year	16,378
Water	636 m³/year	3007	842 m³/year	3981	1263 m³/year	5971
Total		42,080		43,101		69,795

Table 3.7
Cost-benefit analysis for example buildings.

	Gold Certified Building		Platinum Certified Building	
	$	$/m^2	$	$/m^2
Additional Cost Amount	213,828	51.76	967,408.29	179.25
Annual Savings Amount	15,398	3.73	27,715	5.14
Present Value Of Annual Savings	151,177.56	36.60	272,105.87	50.42
Present Value of Additional Costs	62,650.44	15.16	695,302.42	128.83
Payback Period (Years)	0.41		2.56	
Cost-Benefit Ratio	2.41		0.39	

subject and considering the undeveloped green building market in Turkey, the findings obtained in this study are considered to be reasonable.

Although there are efforts to follow in the footsteps of current developments in the world and accelerating the development of the green building sector in Turkey, it seems that the awareness regarding sustainability and energy efficiency has not yet been created in the real estate market, the ability of green features of buildings to adapt to the market has not yet developed and the market is not transparent and sustainability-oriented.

Furthermore, it can be estimated that the developments in the field of green buildings, picking up speed both in the world and in Turkey, will progress even further with the economic, environmental and social sustainability approach. Also, it is believed that steps such as establishing new-generation living spaces on a neighborhood and city scale, promoting sustainable construction and installing systems that will facilitate the use of renewable energy in buildings must be accelerated. Within the context of developments that will increase the priority of green buildings in terms of preference, goals related to cost reduction must be accomplished. In addition, it is estimated that the change in perception initiated with increasing social awareness will be effective in developing the green building sector. Trainings, projects and models are believed to be efforts that will contribute to the progress of the sector and spread of green buildings.

5. Conclusions

This paper presented a review of LEED's impacts on construction costs by examining two buildings in Turkey LEED-certified. The study concluded that:

- An additional construction cost was found 7.43% for the gold certified building and 9.43% for the platinum certified building. In other words, the unit cost of green elements was 3.46 times higher for the platinum certified building compared to the gold certified building.
- In spite of this, a cost decrease of 31% was evident in the gold certified building and a cost decrease of 40% was evident in the platinum certified building thanks to energy and water savings.
- Even without adding difficult-to-quantify benefits such as productivity, health, increase in indoor air quality and preservation of the nature, the payback period calculated by taking the present value of energy and water savings during the operating period and additional green costs into account was 0.41 for the gold certified building and 2.56 for the platinum certified building.
- In addition, the share of soft costs in total construction cost was found to be 0.84% for the gold certified building and 1.31% for the platinum certified building.
- Thus, it was determined that the increase in the level of certificate resulted in an increase in cost and a high level of certificate led to more savings from operating costs.
- When only the benefits from water and energy savings are taken into account, it was calculated that additional costs were recovered in a shorter period of time in the gold certified building in comparison to the platinum certified building and it was predicted that this period would be even shorter when other functional, environmental, social and aesthetic performances were added.
- In addition, it was found to be important to separate cost items related to a green building certificate when assessing the cost of sustainability. There were uncertainties about which construction costs were to be added due to the LEED certification process, however it was determined that all soft costs had to be included in the calculation.

References

[1] ⟨https://archive.epa.gov/greenbuilding/web/html/⟩.
[2] Dania AA, Larsen GD, Yao R.. Mainstreaming sustainable construction: case studies of an indigenous and multinational firm in Nigeria. Engineering Project Organization Conference. Colorado, USA; 2013.
[3] Circo CJ. Using mandates and incentives to promote sustainable construction and green building projects in the private sector: a call For more state land use policy initiatives. Penn State Law Rev 2007;112(3):732–82.
[4] Olubunmi OA, Xia PB, Skitmore M. Green building incentives: a review. Renew Sustain Energy Rev 2016;59:1611–21.
[5] Yudelson J. The green building revolution. Washington DC. USA: Island Press; 2008.
[6] Kibert CJ. The next generation of sustainable construction. Build Res Inf 2007;35:595–601.
[7] Wolff G. Beyond payback: a comparison of financial methods for investments in green building. J Green Build 2006;1:80–91.
[8] Hussin JM, Rahman IA, Memon AH. The way forward in sustainable construction: issues and challenges. Int J Adv Appl Sci 2013;2(1):15–24.
[9] Weeks JA. Understanding the issues of project cost and time in sustainable construction from a general contractor's perspective: case study [Master Thesis]. Atlanta. USA: Georgia Institute of Technology; 2010.
[10] Kubba S. Handbook of green building design and construction: LEEDS, breeam, and green globes. Virginia. USA: Butterworth-Heinemann; 2012.
[11] Zhao DX, He BJ, Johnson C, Mou B. Social problems of green buildings: from the humanistic needs to social acceptance. Renew Sustain Energy Rev 2015;51:1594–609.
[12] ⟨http://www.usgbc.org/leed⟩.
[13] ⟨http://www.buildinggreen.com/article/leed-2012-postponed-2013-renamed-leed-v4-0⟩.
[14] USGBC . Green building and LEED core concepts. Washington DC. USA: U.S. Green Building Council; 2009.
[15] USGBC . LEED V4 user guide. Washington DC. USA: U.S. Green Building Council; 2013.
[16] LEED{C} 2009 for New Construction and Major Renovations Rating System. ⟨http://www.usgbc.org/Docs/Archive/General/Docs5546.pdf⟩; 2009.
[17] Analyzing the Cost of Obtaining LEED Certification. Westford, USA: Northbridge Environmental Management Consultants; 2003.
[18] {C}Matthiessen {C}LF, {C}Morris P.{C} Costing green: a comprehensive cost databaseand budgeting methodology. Davis Langdon Management Consulting. ⟨http://kma.com.tr/fr/Cost_of_Green_LEED.pdf⟩; 2004.
[19] Matthiessen LF, Morris P. Cost of green revisited: reexamining the feasibility and cost impact of sustainable design in the light of increased market adoption. Davis Langdon Management Consulting. ⟨http://www.usgbc.org/resources/cost-green-revisited⟩; 2007.
[20] Mapp C, Nobe M, Dunbar B. The cost of LEED-an analysis of the construction costs of LEED and non-LEED banks. J Sustain Real Estate 2011;3:254–73.
[21] Luay ND, Kherun NA. Green buildings cost premium: a review of empirical evidence. Energy Build 2016;110:396–403.
[22] Kats {C}G, {C}Alevantis L, {C}Berman A, Mills {C}E, Perlman J. The costs and financial benefits of green buildings. A report to California's sustainable building taskforce. ⟨http://www.usgbc.org/Docs/News/News477.pdf⟩; 2003.
[23] Kats G. Greening our greenWorld: cost, benefits and strategies. Washington DC. USA: Island Press; 2010.
[24] {C}{C}Kaplow{C} {C}SD.{C}{C} Green Building Costs Less Than Conventional Building. ⟨http://www.stuartkaplow.com/library3.cfm.article_id=173⟩; 2010.
[25] {C}{C}Syphers{C} {C}G{C}{C}, {C}{C}Baum{C} {C}M{C}{C}, {C}{C}Bouton{C} {C}{C}D, {C}{C}Sullens{C} {C}W.{C}{C} Managing the Cost of Green Buildings. ⟨http://www.calrecycle.ca.gov/greenbuilding/Design/ManagingCost.pdf⟩; 2003.
[26] Nurul Zahirah MA, Nazirah Zainul A, Azlan R. Identification of soft cost elements in green projects: exploring experts' experience. Proc. Soc. Behav Sci 2015;170:18–26.
[27] Dobias J, Macek D. Leadersip in energy and environmental and it's impact on building operational expenditures. Proc. Eng 2014;85:132–9.
[28] Gabay H, Meir IA, Schwartz M, Werzberger E. Cost-benefit analysis of green

buildings: an israeli office buildings case study. Energy Build 2014;76:558–64.
[29] Szumilo N, Fuerst F. The operating expense puzzle of U.S. green office buildings. J Sustain Real Estate 2013;5(1):86–110.
[30] Popescu D, Mladin EC, Boazu R, Bienert S. Methodology for real estate appraisal of green value. Environ Eng Manag J 2009;3(8):601–6.
[31] Mehta HS, Porwal V. Green building construction for sustainable future. Civil Environ Res 2013;3(6):7–13.
[32] Lorenz D, Lützkendorf T. Next generation decision support instruments for the property industry-understanding the financial implications of sustainable building. In: World Sustainable Building Conference, Melbourne. Australia; 2008.
[33] Fuerst F, McAllister P. Green noise or green value? Measuring the effects environmental certification on office values. Real Estate Econ 2011;1(39):45–69.
[34] Zhang X, Platten A, Shen L. Green property development practice in China: costs and barriers. Build Environ 2011;46:2153–60.
[35] Schiavon S, Altomonte S. Influence of factors unrelated to environmental quality on occupant satisfaction in LEED and non-LEED certified buildings. Build Environ 2014;77:148–59.
[36] Feng H, Hewage K. Energy saving performance of green vegetation on LEED certified buildings. Energy Build 2014;75:281–9.
[37] Scofield JH. Efficacy of LEED-certification in reducing energy consumption and greenhouse gas emission for large New York City office buildings. Energy Build 2013;67:517–24.
[38] The Business Case for Green Building. ⟨http://www.worldgbc.org/files/1513/6608/0674/Business_Case_For_Green_Building_Report_WEB_2013-04-11.pdf⟩; 2013.
[39] Health, Wellbeing and Productivity in Offices ⟨http://www.worldgbc.org/activities/health-wellbeing-productivity-offices/⟩; 2015.
[40] Fowler KM, Rauch EM. Sustainable building rating systems summary. USA Dep Energy 2006 ⟨http://www.usgbc.org/Docs/Archive/General/Docs1915.pdf⟩.
[41] ⟨https://www.tse.org.tr/en/⟩.
[42] Nurul Zahirah MA, Zainul Abidin N. Main elements of soft cost in green buildings. World Acad Sci Eng Technol 2012;72:992–7.
[43] Muldavin SR. Value beyond cost savings: how to underwrite sustainable properties. Expanded Chapter V, Green Building Finance Consortium. ⟨http://www.gbcsa.org.za/wp-content/uploads/2013/06/Scott-Muldavin-Report-Value-Beyond-Cost-Savings_How-to-Underwrite-Sustainable-Properties-2010.pdf⟩; 2010.
[44] Bienert S, Schützenhofer C, Leopoldsberger G, Bobsin K, Leutgöb K, Hüttler W, et al. Integration of Energy Performance and Life-Cycle Costing into Property Valuation Practice. ⟨http://immovalue.e-sieben.at/pdf/immvalue_result_oriented_report.pdf⟩.; 2010.
[45] Dobson DW, Sourani A, Sertyesilisik B, Tunstall A. Sustainable construction: analysis of its costs and benefits. Am J Civil Eng Archit 2013;1(2):32–8.
[46] Bartlett E, Howard N. Informing the decision makers on the cost and value of green building. Build Res Inf 2000;28(5):315–24.
[47] Kneifel J. Life-cycle carbon and cost analysis of energy efficiency measures in new commercial buildings. Energy Build 2010;42(3):333–40.
[48] Katz G. Greening America's Schools: Costs and Benefits. ⟨http://www.usgbc.org/Docs/Archive/General/Docs2908.pdf⟩; 2006.
[49] Liu H. Evaluating construction cost of green building based on lifecycle cost analysis: an empirical analysis from Nanjing, China. Int J Smart Home 2015;9(12):299–306.
[50] Liu Y, Guo X. Cost-benefit analysis on green building energy efficiency technology application: a case in China. Energy Build 2014;82:37–46.
[51] Tatari O, Kucukvar M. Cost premium prediction of certified green buildings: a neural network approach. Build Environ 2011;46(5):1081–6.
[52] Means R. Green building: project planning and cost estimating. RSMeans Series. New York City. USA: John Wiley and Sons; 2010.