Peer-reviewed version available at *Sustainability* **2020**, *12*, 719; doi:10.3390/su12020719

Article

Economic and Technical Considerations in Pursuing Green Building Certification: A Case Study from Iran

Ali Amiri*, Juudit Ottelin, Jaana Sorvari, and Seppo Junnila

Department of Built Environment/School of Engineering, Aalto University, Espoo 00076, Finland; juudit.ottelin@aalto.fi (J.O); jaana.sorvari@aalto.fi (J.S); seppo.junnila@aalto.fi (S.J)
* Correspondence: ali.amiri@aalto.fi; Tel.: +358-403211200

Abstract: Buildings use 30-40 % of all energy resources and are thus their main consumers in modern society. Moreover, buildings require a vast amount of different raw materials. During the last two decades, several green building certifications have been created in order to consider social, economic and environmental aspects of sustainability of buildings. One of the most famous and widely used of these certifications is Leadership in Energy and Environmental Design (LEED). So far, the use of LEED has concentrated in the US and other developed countries. One reason that restricts the use of this point-based system certification in developing countries is the limited data about its costs. In this study, the extra cost of the certification process will be evaluated besides the changes needed in the design of the building to reach the points required by LEED. At the first stage, the number of points the case study earns in its current format (Scenario 1) were assessed, then the cost difference of getting either the Certified (Scenario 2) or Silver (Scenario 3) level LEED certification for the building was studied. It was found that besides some technical considerations, filling the criteria of the Certified and Silver level increases the total costs of construction by 3.4% and 5.9%. Further improvement of the building's energy efficiency would enable the attainment of a higher-level certification. The results of the study could help to promote the use of green building certifications in Western Asia.

Keywords: Leadership in Energy and Environmental Design; LEED; sustainable construction; cost; Iran

1. Introduction

1.1. Background

The willingness to consider sustainability aspects in the construction of buildings has increased during the last decades [1-3]. As the latest Intergovernmental Panel on Climate Change (IPCC) report revealed, restricting climate change to 1.5 °C degrees is going to be challenging, since global greenhouse gas emissions show no downturn [4]. Similarly, global material consumption keeps increasing [5,6]. In addition, continuous rise in energy consumption makes it necessary to construct energy efficient and environmentally friendly buildings [7,8].

Construction sector causes almost half of the greenhouse gas emissions and uses nearly 40% of the natural resources worldwide [9]. It plays a significant role in countries´ economies and provides job opportunities [10]. The effect of construction on the environment becomes particularly important in developing countries that use a large amount of resources for their construction activities [11]. Buildings as one of the construction activities consume the main part of energy produced all over the world [12-14]. According to the building sector, in UK and US buildings use 45% and 42% of the entire produced energy respectively [15], while this amount is 30% in China [16]. Buildings' energy consumption in Iran as the second largest country in Middle East is 41.9% of the total energy use which is produced from sources of natural gas 66%, petroleum 20%, electricity 2.5% and other sources 1.5% [17]. Due to the high energy consumption and material use by buildings, plans and rules are needed to minimize their environmental impact and make them green [18-20].

 doi:10.20944/preprints202001.0022.v1

Peer-reviewed version available at *Sustainability* **2020**, *12*, 719; doi:10.3390/su12020719

Understanding on what green building means in practice varies in different parts of the world. In some countries, residents might consider their building as green if there is onsite energy production. Or in another location, using recycled material might be considered as green construction as it has lower impact on the environment. There are different definitions for green building. Yudelson [21] defines a green building as: "A high-performance property that considers and reduces its impact on the environment and human health". Alternatively, Kibert [22] defines green building as: "Healthy facilities designed and built in resource-efficient manner, using ecologically based principles". Hence, there is a need to have a clear, uniform definition for green building worldwide.

This has brought about the development of different green building certification systems [23-27]. The British Building Research Establishment Environmental Assessment Method (BREEAM) is the first one of these, while the most commonly used system is the Leadership in the Energy and Environmental Design (LEED) of the U.S. Green Building Council (USGBC), released in 1998. The LEED certification is based on points and includes four levels, namely Certified (40-49 points), Silver (50-59 points), Gold (60-79 points) and Platinum (80+ points).

LEED is currently the most famous building certification system and it is used all over the world [28-32]. The USGBC [33] describes LEED as follows:

> *"LEED, or Leadership in Energy and Environmental Design, is the most widely used green building rating system in the world. Available for virtually all building, community and home project types, LEED provides a framework to create healthy, highly efficient and cost-saving green buildings. LEED certification is a globally recognized symbol of sustainability achievement."*

Green certifications can bring economic benefits for the property owners and tenants. In the literature, the economic benefits of green certified buildings have been divided into four categories of 1. Lower operation costs because of saving in electricity 2. Lower maintenance costs as a result of functional testing of all energy systems before occupation 3. Increased value of building, which directly correlates with energy saving and 4. Tax benefits offered by the government or local authorities [34].

Furthermore, Burnett [35] stated higher quality places for working and living as social benefits of green buildings. Using maximum natural light in green buildings makes them more attractive than conventional ones [19]. Green buildings try to limit the use of fossil fuels and replace them with renewable sources of energy while improving the reuse and recycling of materials instead of using new materials [36]. Thus, green buildings reduce the negative environmental impacts of the building sector [37].

However, the LEED certification might result in additional expenses in building projects [36,38-42]. Different studies have concluded that construction of LEED-certified buildings will result in extra cost. On the other hand, some researchers believe that construction of LEED-certified buildings is possible without any extra cost [43,44]. Hence, it is difficult to draw definite conclusions on the cost effect, especially when comparing buildings in different locations of the world including developed or developing countries with different construction regulations. In addition, the version of LEED and level to be pursued (Certified, Silver, Gold and Platinum) play a significant role.

1.2. Literature review on costs of LEED

The first version of LEED, LEED v1, was originally developed as a building rating system just for New Construction (NC) [45]. In 2001, the second version, LEED NC v2, was published followed by an update LEED NC v2.2 in 2005. The most widely used version, LEED v3 published in 2009, included a collection of rating systems for construction, design and operation. It was suitable for different types of buildings. LEED v4 was released in late 2013 with an update as current version, LEED V4.1, in 2019. As the most widely used version is v3 or 2009, a large number of LEED-certified buildings are labelled with this version. Considering cost as one of the main issues of getting a LEED certification, several previous studies have compared the cost difference between LEED-certified and conventional buildings.

Peer-reviewed version available at Sustainability 2020, 12, 719; doi:10.3390/su12020719

She et al. [40] stated that in order to construct buildings sustainably in China and to get a LEED certification, a premium cost of 4.5% to 11% is needed. A study conducted in California showed the extra cost from different level of LEED certification as 0-2.5% for Certified, 0-3.3% for Silver, 0.3-5% for Gold and 4.5-8.5% for Platinum level LEED-certified buildings [46]. In this research, different case buildings including K-12 public schools, research laboratories, public libraries and multi-family affordable housing were studied.

Kats et al. [39] analyzed the cost of 33 LEED-certified buildings in California to find out the cost difference of certified and non-certified buildings. They found out that the extra cost of the studied LEED-certified buildings was 1.84% on average. While they considered the cost difference small, they concluded that the benefits of LEED-certified buildings exceed the additional costs and can be compensated in two or three years. The benefits include lower maintenance and operation costs, reduced energy, improved health of its occupants, and enhanced productivity.

According to Fuerst and Franz [41], additional expenses of 2 % to 10 % are expected when a buildings is certified with the LEED system. Their study was focused on cost difference besides sales and rental price premiums of eco-friendly buildings in US. They found no significant change in the average selling time of eco-certified buildings. In addition, no noticeable advantages of rent for certified buildings with lower levels of certification were seen.

In 2017, Uğur and Leblebici [47] analyzed the cost of two LEED-certified buildings in Turkey, one having a Gold and the other a Platinum level certification, and ended up with a 7.43 % and 9.43 % extra costs caused by certification compared to non-certified buildings. The reduction in annual energy consumption cost of studied buildings was determined as 31% and 40%, while the payback period for additional construction cost was calculated to be 0.41 and 2.56 years.

On the other hand, some researchers have ended up with different results and reported no cost difference between green construction and traditional construction. For example in a widely cited article, Matthiessen and Morris [43] compared the actual costs of 45 LEED-certified buildings with 93 non-certified similar buildings using a t-test in US. They concluded that there is no significant difference in terms of costs between these two groups of buildings.

An analysis of extra cost comparing two LEED-certified bank buildings with eight non-certified ones located in Colorado was done by Mapp et al. [48], which showed insignificant cost difference. The study evaluated total building costs, square footage costs, hard costs, and soft cost. In another study, Matthiessen and Morris [44] confirmed no cost difference in their study of 221 buildings, of which 83 were pursuing a LEED certification. Their study included different types of buildings in US such as office, libraries, hospitals, residential apartments, student houses, theaters, and sport facilities.

It should be noted that LEED certification has changed significantly from its initial version to LEED v4, which may explain some of the differences in the findings on the costs of LEED certification. Majority of the previous research, including the above-mentioned studies, has focused on the buildings' cost, which have earned a certification based on LEED v2, or v3. According to literature, studies conducted on v4 LEED-certified buildings are rare because this version was announced only in late 2013.

Previous studies have mainly evaluated the cost difference of the buildings that already have LEED, not those that do not have any certification in their current format and are willing to predict the extra cost of getting the certificate. Therefore, further studies on LEED-certified buildings, especially with v4, are necessary in order to evaluate the need for technical changes in addition to the costs of getting a building LEED certified.

Another important issue is that the majority of the existing LEED-certified buildings are located in US and Canada [49]. Also, the previous studies on the costs of LEED have focused on US and developed countries in general. In addition, several studies have been conducted in China, where the number of LEED certified buildings is increasing. However, it would be important to provide case studies for developing countries, where LEED is not yet popular. Currently, there are more than 94000 building projects participating in LEED globally [29]. None of these projects are located in Iran. One possible reason for this is the lack of knowledge on the costs of LEED. Relying on the case studies of developed

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 3 January 2020 doi:10.20944/preprints202001.0022.v1

Peer-reviewed version available at Sustainability 2020, 12, 719; doi:10.3390/su12020719

countries and China, and following their approaches might not be completely helpful for developing countries with different circumstances.

1.3. Aim of this study

As described above, there is a lack of case studies on the costs of LEED in other developing countries aside China. Furthermore, the majority of the existing literature is focused on the costs of the previous versions of LEED, instead of the latest version LEED v4. Therefore, the aim of this study is to provide a timely case study on the costs of LEED in a developing country, where the uncertainty of the costs may well be one of the main barriers for pursuing green certificates for buildings. The study evaluates the extra cost of the certification process taking into account the changes in design of the building to reach the points required by LEED v4 by using a real case building located in Karaj (Iran). Currently, this building has no green building certification of any kind. In addition to studying the cost difference, this study provides technical details for design and construction phases, which enable the attainment of a LEED certificate.

2. Materials and methods

2.1. Case building

Typical buildings in Iran are five to six floors (one ground floor plus four to five floors) in most cities. For these kind of buildings it is common to use reinforced concrete for structure as use of steel structure will result in at least 20% extra cost for structure [50]. The case building was selected so that it represents a customary building in Iran. Regarding the location, the city of Karaj, it is necessary to mention that construction costs in this city are very similar to other cities in Iran except the capital city (Tehran) where costs are higher because of different conditions e.g. higher salaries.

Considering the above mentioned facts, the selected case study comprises a six floor building (Table 1) located in the region two of Karaj city (Iran). The ground floor is used for parking and five other floors contain private residential units (three units in each floor). The construction of the building began in 2017 and it was finished in 2019. The structure including foundation, columns, beams, and slabs are made of reinforced concrete. Inner and outer walls are made of clay brick. Inner walls are covered by a mix of gypsum and clay while outer walls are covered by cement lining.

The main source of heating is natural gas while electricity is used for cooling purposes. In Iran, the energy used for heating, cooling and hot water production is 83% of the entire energy use while appliance and lighting account for 8% and 9% respectively [17]. In the case building, hot water used for both the heating of building and daily hot water is produced by water-mounted heater using natural gas as source of energy. Electric evaporator cooler is applied for cooling purposes. For façade, travertine stone has been used and double glazing windows with standard PVC have been installed. The building is equipped with automatic lighting control systems for outdoor and common areas, and it has normal switchable lighting for indoor spaces.

Table 1. Building's features and construction costs

Type of building	Residential
Type of ownership	Private
Status	New construction
Number of floors	5+1
Number of units	15
Construction start date	October 2017
Construction end date	March 2019
Land area	660 m2
Building coverage	451 m2
Gross area (Total construction)	2740 m2
Height	21 m

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 3 January 2020 doi:10.20944/preprints202001.0022.v1

Peer-reviewed version available at Sustainability 2020, 12, 719; doi:10.3390/su12020719

Total construction cost	$ 527 024

2.2. LEED certification

In LEED v4, 110 points are allocated to nine categories: Integrative Process (IP), Location and Transportation (LT), Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Material and Resources (MR), Indoor Environment quality (EQ), Innovation (IN), and Regional Priority (RP). Each category includes several credits and the potential maximum number of points have been defined for each credit (Table 2). Some of the categories have prerequisites, which need to be fulfilled - no points are allocated for prerequisites. Table 2 shows the number of credits in each category and the number of points allocated for each credit.

Table 2. Categories, credits, prerequisites, and available points in LEED v4

Categories	Prerequisites	Credits	Available points	Share %
Integrative Process (IP)	-	1	1	0.9
Location and Transportation (LT)	-	7	16	14.6
Sustainable Sites (SS)	1	6	10	9.1
Water Efficiency (WE)	3	4	11	10
Energy and Atmosphere (EA)	4	7	33	30
Materials and Resources (MR)	2	5	13	11.8
Indoor Environmental Quality (IQ)	2	9	16	14.5
Innovation (IN)	-	2	6	5.5
Regional Priority (RP)	-	4	4	3.6
Total	**12**	**45**	**110**	**100**

2.3. Allocation of points

Firstly, the LEED categories and credits had to be examined, and the points that are already earned by selected building defined (Table 3). The next stage was to find out the potential points that the building is eligible to earn (Table 3) in order to attain the points needed for the LEED level being pursued (41 points for LEED Certified and 51 for LEED Silver). The construction experts in Rah Rizan Fardis Co. (a construction company) were consulted at this point in order to find the most feasible credits.

As described above, there are categories in LEED, such as Location and Transportation which have several credits. Each credit might have one to maximum of 18 points. As an example, Sensitive Land Protection (LT1) credit has one point that the case building obtains in its current format and therefore in table 3, the already earned column includes number one while eligible to earn column is empty. Hash sign denotes situations where earning a point is not possible, e.g., in the case of the High Priority Site (LT2) credit.

Table 3. Allocation of points for the studied building (s fulfill = should fulfill)

Symbol	*Points*	*Credit*	*Already earned*	*Eligible to earn*
		Integrative Process		
IP	1	Integrative Process		1
		Location and Transportation		
LT1	1	Sensitive Land Protection	1	
LT2	2	High Priority Site	-	-
LT3	5	Surrounding Density and Diverse Uses	5	

Peer-reviewed version available at Sustainability 2020, 12, 719; doi:10.3390/su12020719

LT4	5	Access to Quality Transit	3	2
LT5	1	Bicycle Facilities	-	-
LT6	1	Reduced Parking Footprint		1
LT7	1	Green Vehicles	-	-
		Sustainable Sites		
SSp	Prerequisite	Construction Activity Pollution Prevention		S fulfill
SS1	1	Site Assessment		1
SS2	2	Site Development - Protect or Restore Habitat	-	1
SS3	1	Open Space		1
SS4	3	Rainwater Management	3	
SS5	2	Heat Island Reduction	2	
SS6	1	Light Pollution Reduction		1
		Materials and Resources		
MRp1	Prerequisite	Storage and Collection of Recyclables		S fulfill
MRp2	Prerequisite	Construction and Demolition Waste Management Planning		S fulfill
MR1	5	Building Life-Cycle Impact Reduction	-	-
MR2	2	Environmental Product Declarations	-	-
MR3	2	Sourcing of Raw Materials	-	-
MR4	2	Material Ingredients	-	-
MR5	2	Construction and Demolition Waste Management		2
		Energy and Atmosphere		
EAp1	Prerequisite	Fundamental Commissioning and Verification		S fulfill
EAp2	Prerequisite	Minimum Energy Performance		S fulfill
EAp3	Prerequisite	Building-Level Energy Metering	Fulfilled	
EAp4	Prerequisite	Fundamental Refrigerant Management	Fulfilled	
EA1	6	Enhanced Commissioning		6
EA2	18	Optimize Energy Performance	-	-
EA3	1	Advanced Energy Metering	1	
EA4	2	Demand Response	2	
EA5	3	Renewable Energy Production	-	-
EA6	1	Enhanced Refrigerant Management	1	
EA7	2	Green Power and Carbon Offsets	-	-
		Water Efficiency		
WEp1	Prerequisite	Outdoor Water Use Reduction	Fulfilled	
WEp2	Prerequisite	Indoor Water Use Reduction	Fulfilled	
WEp3	Prerequisite	Building-Level Water Metering	Fulfilled	
WE1	2	Outdoor Water Use Reduction	2	
WE2	6	Indoor Water Use Reduction	-	-
WE3	2	Cooling Tower Water Use	-	-
WE4	1	Water Metering		1
		Indoor Environmental Quality		
IQp1	Prerequisite	Minimum Indoor Air Quality Performance	Fulfilled	
IQp2	Prerequisite	Environmental Tobacco Smoke Control		S fulfill
IQ1	2	Enhanced Indoor Air Quality Strategies	-	-

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 3 January 2020 doi:10.20944/preprints202001.0022.v1

Peer-reviewed version available at *Sustainability* **2020**, *12*, 719; doi:10.3390/su12020719

IQ2	3	Low-Emitting Materials	2	-
IQ3	1	Construction Indoor Air Quality Management Plan		1
IQ4	2	Indoor Air Quality Assessment	-	-
IQ5	1	Thermal Comfort	1	
IQ6	2	Interior Lighting	1	1
IQ7	3	Daylight	-	2
IQ8	1	Quality Views	1	
IQ9	1	Acoustic Performance	1	
		Innovation		
IN1	5	Innovation	-	-
IN2	1	LEED Accredited Professional		1
		Regional Priority		
RP	4	Regional Priority: Specific Credit	3	-
	110	**Total**	**29**	**22**

At the following stage, the construction costs were estimated beside the technical considerations (Table 4) needed in order to get the points required for the specified certification level. As shown in Table 4, some of the required actions cause extra costs while some changes are reachable without any added cost and by just some technical modifications implemented in the design phase. Credits in the categories EAp2 and IQ7 are interrelated with IP. Finally, based on the requirements of the Certified and Silver level, the cheapest combination of required actions were identified (Table 4).

For instance, in order to get points for the Integrative Process (IP) credit, it is necessary to model the use of energy and water beides daylight simulation. Companies that provide such a service would charge $ 6850 for the case building. Technical consideration is needed for LT6; this incurs no extra cost. The case building has already prepared 18 parking spaces in the constructed area. Decreasing the number of needed parking spaces to 15 according to the number of apartments makes it possible to use the free space for other purposes, e.g., a lobby. Credits SS6 and MR5 are also free of charge. There is no difference in lighting fixtures prices in Iranian electrical market that have limited light pollution level into accepted level by appropriate design. In addition, limiting the amount of construction waste to less than 12.2 kg/m² needs careful and continuous waste management during the construction process. The case building has a waste management plan but without paying attention to the limitation of waste production required by LEED certification.

Table 4. Available points attainable by extra economic input or technical modifications

	Action required	Changes
IP	Conduct energy-related and water-related modeling including daylight simulation	$ 6 850,00
LT4	Access to Metro will launch in less than 18 months	Public action
LT6	Reduce prepared parking space to the minimum required	Technical consideration
SSp	Prepare plastic coverage of scaffolding during façade installation	$ 261,90
SS1	Conduct site survey including topography, hydrology, climate, vegetation, soils, human use, and human health effects	$ 1 309,52
SS2	Provide $ 4 per square meter as financial support for expanding green area of the city	$ 2 640,00
SS3	Use the space provided by removing extra parking as common space	Technical consideration

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 3 January 2020 doi:10.20944/preprints202001.0022.v1

Peer-reviewed version available at Sustainability 2020, 12, 719; doi:10.3390/su12020719

SS6	Reduce light pollution	Technical consideration
MRp1	Prepare storage and collection of recyclables including plastics, glass, mixed paper, corrugated cardboard, and metals	$ 1 428,57
MRp2	Prepare waste management plan for construction phase	$ 1 304,76
MR5	Limit construction waste to less than 12.2 kilograms per square meter	Technical consideration
EAp1	Hire commissioning authority (CxA)	$ 6 523,81
EAp2	Conduct energy modelling considering Applied Iranian National Building Code, Part 19 (Energy Conservation)	Fulfill IP
EA1	Manage and control activities related to energy, water, durability, and indoor environmental quality by CxA	Fulfill EAp1
WE4	Install water metering system for each unit	$ 1 785,71
IQp2	Prohibit smoking inside the building by installing adequate signs	$ 21,43
IQ3	Prepare Construction indoor air quality management plan by a safety and health expert	$ 978,57
IQ6	Use adjustable switches with at least three lighting levels (on, off, midlevel)	$ 952,38
IQ7	Conduct energy modelling including daylight simulation	Fulfill IP
IN2	Employ someone who is LEED Accredited Professional (AP) as advisor	$ 1 957,14

2.3.1 Scenario 1: current situation

Scenario 1 is equivalent to the current situation, i.e. building without any modifications. Majority of the points in scenario 1 were earned in the Location and Transportation (LT) category (30%). According to LEED, the building is constructed in a previously developed land located in a densely built area (more than 8035 m2 buildable land within a hectare with a radius of 400 m), which has a supermarket, hardware store, pharmacy, bank, gym, restaurant, and a K—12 school nearby. In addition, there is a governmental office serving public within 800 m from the entrance of the building. Furthermore, a bus connection is available with more than 150 connections during weekdays and 110 connections on weekends.

Among the points earned, 20% comes from the Indoor environmental Quality (IQ) category. Applied Iranian National Building Code (AINBC), Part 14 (Mechanical systems) has been adopted in the project. Other parts of AINBC that have been considered deal with electrical design, energy performance, and safety. In terms of mechanical design, installation of the heating system (water-mounted heater) in the balconies and cooling system (evaporative cooler) on the roof help improve the quality of the indoor environment. Enabling the use of adjustable radiators makes it possible to control the level of heat in separate spaces. Regarding electrical design, the specification of lighting fixtures has been taken into account by using light sources with a Color Rendering Index (CRI) of 80 or higher. Furthermore, the quality of views has been considered in the most regularly used areas (75%) by installing windows with colorless glass without frits, fibers, patterned glazing, or added tints that distort color balance.

The Sustainable Sites (SS) category corresponds to 17% of the total points earned by the studied building. Sedimentation and soil erosion are not relevant factors at the study location, and rainwater is infiltrated. High-reflectance material has been used in the roof.

The rest of the points are earned in the categories of Energy and Atmosphere (EA, 13%), Regional Priority (RP, 10%), Water Efficiency (WE, 7%), and Integrative Process (IP, 3%) whereas no points are attainable in the Material and Resources (MR) and Innovation (IN) categories. A water metering system covering the whole building has already been installed. Besides, each of the 15 units has a natural gas and electricity metering system. Price of electricity varies from high to medium and low according to the local electricity provider. Regarding the RP category, it is necessary to pay more attention to the

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 3 January 2020 doi:10.20944/preprints202001.0022.v1

Peer-reviewed version available at Sustainability 2020, 12, 719; doi:10.3390/su12020719

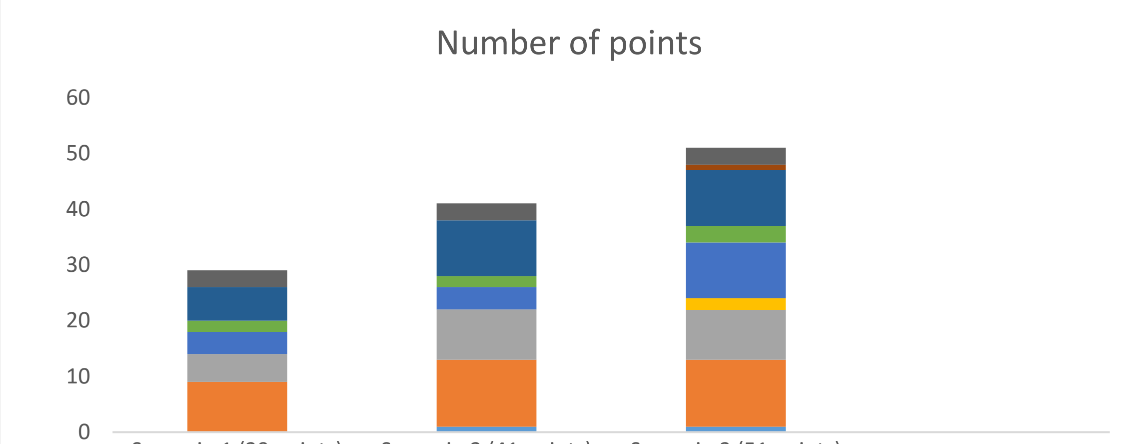
environmental issues. This means that at least one point should be earned for thermal comfort (EQ5), two points for heat island reduction (SS5), and two for water use reduction (WE1) outdoors in the location of the project according to USGBD website. Each of these three elements gives one LEED point.

2.3.2 Scenarios 2 and 3: building with technical modifications

In addition to the baseline scenario (i.e. current situation, Table 3) two scenarios were created. Scenarios 2 and 3 demonstrate how the building could attain a Certified or Silver level LEED certification by implementing some technical modifications and with extra cost. In addition to fulfilling the Scenario 1 conditions, Scenario 2 needs to apply credits IP, LT4, LT6, SS1, SS2, SS3, SS6, IQ3, IQ6, and IQ7 as well. These credits were selected to have lower cost compared to other remaining credits in table 4 and are feasible for getting the points required for the Certified level. Likewise, Scenario 3 should justify all the remaining credits while passing Scenario 2 conditions.

3. Results

In its current format (Scenario 1), the case building located in Karaj city (Iran) can earn 29 points obtained from the LEED credits of LT1, LT3, LT4, SS4, SS5, EA3, EA4, EA6, WE2, IQ2, IQ5, IQ6, IQ8, IQ9, and RP (Table 3 and Fig. 1). Additional 12 points are required in order to gain the Certified level of LEED certification. Scenario 2 illustrates how these points can be earned with the lowest possible cost (Table 4 and Fig. 1). The points were selected from credits IP, LT4, LT6, SS1, SS2, SS3, SS6, IQ3, IQ6, and IQ7 (Table 4). Some of these credits require technical modifications without any extra costs. Finally, it is necessary to fulfill all technical actions that incur extra costs (Table 4) to obtain the 22 extra points needed to get the Silver level of LEED certification (Fig. 1).



	Scenario 1 (29 points)	Scenario 2 (41 points)	Scenario 3 (51 points)
RP	3	3	3
IN	0	0	1
IQ	6	10	10
WE	2	2	3
EA	4	4	10
MR	0	0	2
SS	5	9	9
LT	9	12	12
IP	0	1	1

Figure 1. The number of points earned from each credit category (note: needed points for Certified level are 40-49 and for Silver level are 50-59).

The additional costs of gaining even the Certified level LEED certification are noteworthy (Table 5). The LEED cost itself is divided into two parts including registration ($ 1500) and certification review

Peer-reviewed version available at Sustainability 2020, 12, 719; doi:10.3390/su12020719

process ($ 3420). Extra design and construction cost added to the LEED certification cost will result in total additional costs of 3.4 %, at the minimum. For the Silver level LEED certification 22 points are needed, which will result in at least 5.9% higher total costs (Table 5).

Table 5. LEED certification of the case building: cost difference between the Certified and Silver level certification

LEED points and level	41 points (Certified)	51 points (Silver)
Total construction cost ($)	527 024	527 024
Unit construction cost ($/m)	192,4	192,4
LEED cost ($)	4 920	4 920
Extra design and construction cost ($)	13 014	26 014
Total LEED certification cost ($)	17 934	30 934
Unit LEED certification cost ($/m)	6,55	11,29
Percent of added cost (%)	3,4	5,9

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 3 January 2020 doi:10.20944/preprints202001.0022.v1

Peer-reviewed version available at Sustainability 2020, 12, 719; doi:10.3390/su12020719

4. Analysis and discussion

4.1. Interpretation of the results

This paper evaluated the possibility of getting a building LEED certified in Iran by implementing technical modifications. It was found out that besides technical considerations, a minimum extra cost of 3.4% and 5.9% is needed in order to gain a Certified or Silver level LEED certification, respectively. According to the literature, the results seem to be comparable. Fuerst and Franz [29] expected an additional cost of 2% to 10% and She et al. [27] estimated the cost difference to be 4.5% to 11%. Regarding the location, the study by Uğur and Leblebici [30] carried out in Turkey is the nearest corresponding to the studied case study as both Iran and Turkey have undeveloped green building market. In the Turkish study, the extra cost of two LEED-certified buildings with Gold and Platinum level was 7.43% and 9.43% from the total costs. It is necessary to mention that for the case study, it was targeted to get the lowest total points for earning a Certified level (41 points) or a Silver level (51 points) certification, while the same level of certification is awarded to a building with 49 or 59 points, which would incur higher costs.

4.2. Importance of location

In the nine LEED categories, the case study got 12 points in the category LT (Location and Transportation). Generally, fulfilling the requirements of this category is the easiest but not cheapest way of getting the points needed for certification since 14 out of 16 points of this category can be achieved without extra cost and by just selecting a piece of land for construction located in a desirable place according to LEED. However, it is necessary to point out that preparing the land for construction might be more expensive in places that fulfill the requirements of different credits, such as access to quality transit, dense population with diverse uses or access to bicycle facilities. Selecting the location for a construction project will also affect other credits, such as EA7 (Green Power and Carbon Offsets) because it might be possible to buy green energy in some specific parts of the city. It is probable that clean energy is available in a specific part of a city, which will motivate investors to construct the buildings in such a location.

Regarding location in a wider scale (different countries), it is worth focusing on building standards and codes in different cities or locations of a country, and comparing developed, developing and non-developed countries. In some developed countries there are strict regulations and codes for construction, which might result in getting automatically more than 40 points and consequently, being eligible to the Certified level LEED certification. These codes and regulations include considerations of energy, water, indoor air quality, and material usage. Furthermore, there is access to construction materials with environmental product declarations, sourcing of raw materials, and material ingredients. This makes it possible to obtain six points from the MR2 (Environmental Product Declarations), MR3 (Sourcing of Raw Materials), and MR4 (Material Ingredients) credits.

Technology available in the location of a construction project plays a significant role in getting the necessary points needed for certification. There are materials and processes that need a higher level of technology and are considered as obstacles of improving green construction [29]. Unavailability of technology hindered the studied building to attain some points of the WE2 (Indoor Water Use Reduction) credit category. Six points of WE2 would be earned from the installation of water efficient fixtures. LEED gives one to six points in case of installed fixtures if they result in a reduction of 25% to 50% in water usage. The point here is that these new high-tech fixtures are not available for purchasing in the location of our study building. There is not even a specification from the manufacturers for how much water these fixtures use. This makes it impossible to earn all the available points.

The low price of energy in the location of the case building (Iran), including natural gas and electricity, has resulted in limited improvement in manufacturing equipment needed for the production of renewable onsite energy. Therefore, it is very difficult to earn the available three points in the EA5 (Renewable Energy Production) credit category. There is no company in the study location having the technology and providing installation for utilizing renewable energy resources, such as solar and wind. At the same time, the location is very favorable for producing solar energy. In addition, technology cannot improve green construction without being used by development institutes; research centers, such as universities; government; and non-governmental institutes [39].

4.3. Factual environmental performance of LEED-certified buildings

It is worth noting that it is possible to get a LEED certification, especially at lower levels, without gaining points in all categories. Excluding the IN (Innovation) category, it is clear that the studied building earned no points in the MR (Material and Resources) category for Certified level (see Fig. 1). Points in the categories LT (Location and Transportation) and SS (Sustainable sites) total 26 and if an investor focuses on the points in the IQ (Indoor environmental Quality) category, the Certified level of LEED certification is achievable. In this case, the efficiency of the building in energy and water consumption besides environmentally friendly materials usage is doubtful. A literature review paper by Amiri et al. [49] on the energy-efficiency of LEED-certified buildings revealed that the energy efficiency of LEED-certified buildings especially at the lower (Certified) level is questionable.

4.4. Suggestions for LEED and other policy implications

While LEED is a good tool for the evaluation of the sustainability of buildings, it has some shortcomings. These shortcomings appear particularly when looking at the construction in different parts of the world. LEED tries to take the location of the buildings into account by allocating four extra points to the category RP (Regional Priority) but this does not solve the problem. Therefore, it is recommended to modify LEED for the purposes of different countries while simultaneously keeping in mind the international, uniform definition (to be developed) for green building.

In order to meet the sustainability goals of LEED, it is necessary that the U.S. Green Building Council (USGBC) makes it mandatory for projects seeking LEED certification to earn some minimum number of points in all LEED categories except in the categories Integrative Process (IP), Innovation (IN), and Regional Priority (RP). This would guarantee that LEED-certified buildings even in lower levels indeed have less environmental and social impacts than other new buildings on average.

For some investors, especially the private ones, the possibility of charging added cost of changes needed for green certifications requirements is considered as a motivator. Because of low prices of energy and water in Iran, the willingness to pay extra money to buy buildings with lower water and energy consumption is very low. The only category that can be motivating is the indoor quality. This means that external environment (political) factors play more important role than economic and technical factors. To resolve this issue, governments or local organizations in Iran could grant awards or discounts in the permit process of construction to projects that aim at a green certification such as LEED. Giving the permission of an extra floor for a project seeking green building certification is an example of motivating award. It is also necessary to consider the awareness of people and constructors' access to technology besides environmental, social and economic concerns in the location.

5. Conclusions and recommendations for further research

Limited natural resources and continuous rise of energy use by buildings makes it necessary to construct them sustainably. Leadership in Environmental and Energy Design (LEED) is one of the most famous building certifications that tries to consider sustainability aspects in the construction of buildings. This certification might result in extra cost and so, the purpose of this study was to find out the magnitude of such extra costs added to the technical modifications needed for getting a building LEED certified in Iran.

The studied building earned 29 points out of 110 in its current format, most of these points come from the LT (Location and Transportation) credit category. Other categories including IQ (Indoor environmental Quality) and SS (Sustainable Sites) ranked second and third in the number of points

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 3 January 2020 doi:10.20944/preprints202001.0022.v1

Peer-reviewed version available at *Sustainability* **2020**, *12*, 719; doi:10.3390/su12020719

earned. In order to have 12 additional points and obtain the Certified level certification, an extra cost of 3.4% would be needed. Eligibility for the Silver level with 51 points (29+22) would require an additional investment of 5.9% of the total costs.

In general, location of the project, available technology, level of public awareness, and green regulations play a significant role in earning the points needed for LEED certification. Among these factors, location of the project is the easiest but not necessarily the cheapest way of getting 16 points if it is possible to select a location that is desirable from the certification perspective. Some credits of the WE or MR categories are impossible to obtain in Iran because of lack of access to LEED-specified fixtures in WE category or the shortage of regulations in MR category.

Considering the nine categories of LEED, when pursuing a higher level (Gold) LEED certification, it is recommended to research on the EA2 (Optimize Energy Performance) credit category, which covers 18 points. It is advisable to change the thickness or material of exterior walls, size of windows, and insulation since these serve as a way to decrease of energy consumption and earn the needed LEED points, which essentials the computer energy simulation of building case study. It should be noted that this study is based on one case building so the results cannot be generalized, although the building represents a typical residential building in Iran. Therefore, more case studies on the technical and economic feasibility and environmental impacts of the most recent LEED v4 are needed, particularly in the context of developing countries, in order to increase the use and impact of green building certifications.

Author Contributions: conceptualization, A.A., J.O. and J.S.; methodology, A.A.; validation, A.A., J.O. and J.S.; formal analysis, A.A.; investigation, A.A.; resources, A.A.; writing—original draft preparation, A.A.; writing—review and editing, A.A., J.O., J.S. and S.J; supervision, S.J.; project administration, J.S.

Funding: This research received no external funding

Acknowledgments: The authors thank Rah Rizan Fardis Co. for their advice and data preparation of case study building.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Robichaud, L.B.; Anantatmula, V.S. Greening project management practices for sustainable construction. *J Manage Eng* **2010**, *27*, 48-57.

2. Hwang, B.; Leong, L.P.; Huh, Y. Sustainable green construction management: Schedule performance and improvement. *Technological and Economic Development of Economy* **2013**, *19*, S43-S57.

3. Junnila, S.; Horvath, A. Life-cycle environmental effects of an office building. *J Infrastruct Syst* **2003**, *9*, 157-166.

4. IPCC. Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Eds. Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-

Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield. World Meteorological Organization, Geneva, Switzerland, 32 pp.

5. Schandl, H.; Fischer-Kowalski, M.; West, J.; Giljum, S.; Dittrich, M.; Eisenmenger, N.; Geschke, A.; Lieber, M.; Wieland, H.; Schaffartzik, A. Global material flows and resource productivity: forty years of evidence. *J Ind Ecol* **2018**, *22*, 827-838.

6. Junnila, S.I. Empirical comparison of process and economic input-output life cycle assessment in service industries. *Environ Sci Technol* **2006**, *40*, 7070-7076.

7. Junnila, S. *The environmental impact of an office building throughout its life cycle,* Helsinki University of Technology: 2004;.

8. Hong, H.; Wang, S.; Wu, Z.Z. Implementing sustainable management in construction industry, Advanced Materials Research, Trans Tech Publ: 2011; , pp. 85-88.

9. Williams, K.; Dair, C. What is stopping sustainable building in England? Barriers experienced by stakeholders in delivering sustainable developments. *Sustainable Dev* **2007**, *15*, 135-147.

10. Du Plessis, C. A strategic framework for sustainable construction in developing countries. *Constr Manage Econ* **2007**, *25*, 67-76.

11. Shen, L.; Tam, V.W.; Tam, L.; Ji, Y. Project feasibility study: the key to successful implementation of sustainable and socially responsible construction management practice. *J Clean Prod* **2010**, *18*, 254-259.

12. Nilforooshan Razieh , Adamo-Villani Nicoletta , Dib Hazar A study of the effects of computer animation on college students' learning of Leadership in Energy and Environmental Design - LEED. **2013**, *01*, 1-9.

13. Gurgun, A.P.; Arditi, D. Assessment of Energy Credits in LEED-Certified Buildings Based on Certification Levels and Project Ownerships. *Buildings* **2018**, *8*, 29.

14. Ferreira, J.; Pinheiro, M.D.; de Brito, J. Portuguese sustainable construction assessment tools benchmarked with BREEAM and LEED: an energy analysis. *Energy Build* **2014**, *69*, 451-463.

15. Ryu, H.; Park, K. A study on the LEED energy simulation process using BIM. *Sustainability* **2016**, *8*, 138.

16. Zhong, Z.Y.; Chen, Y.G. Principles of sustainable construction project management based on lean construction, Advanced Materials Research, Trans Tech Publ: 2011; , pp. 766-770.

17. Riazi, M.; Hosseyni, S.M. Overview of current energy policy and standards in the building sector in Iran. *Sustainable Development and Planning V* **2011**, *150*, 189-200.

18. Pitt, M.; Tucker, M.; Riley, M.; Longden, J. Towards sustainable construction: promotion and best practices. *Construction innovation* **2009**, *9*, 201-224.

19. Tam, V.W.; Hao, J.L.; Zeng, S.X. What affects implementation of green buildings? An empirical study in Hong Kong. *International Journal of Strategic Property Management* **2012**, *16*, 115-125.

20. Schwartz, Y.; Raslan, R. Variations in results of building energy simulation tools, and their impact on BREEAM and LEED ratings: A case study. *Energy Build* **2013**, *62*, 350-359.

21. Yudelson, J. *The green building revolution*, Island Press: 2010;.

22. Kibert, C.J. *Sustainable construction: green building design and delivery*, John Wiley & Sons: 2016;.

23. Al-Ghamdi, S.G.; Bilec, M.M. Life-cycle thinking and the LEED rating system: global perspective on building energy use and environmental impacts. *Environ Sci Technol* **2015**, *49*, 4048-4056.

24. Moore, S.; Rydin, Y. Promoting sustainable construction: European and British networks at the knowledge–policy interface. *J Environ Policy Plann* **2008**, *10*, 233-254.

25. Musa, M.F.; Mohammad, M.F.; Mahbub, R.; Yusof, M.R. Enhancing the quality of life by adopting sustainable modular industrialised building system (IBS) in the Malaysian construction industry. *Procedia-Social and Behavioral Sciences* **2014**, *153*, 79-89.

26. Komurlu, R.; Arditi, D.; Gurgun, A.P. Applicability of LEED's energy and atmosphere category in three developing countries. *Energy Build* **2014**, *84*, 690-697.

27. Lee, W.L.; Burnett, J. Benchmarking energy use assessment of HK-BEAM, BREEAM and LEED. *Build Environ* **2008**, *43*, 1882-1891.

28. Nilson, M.L. Quantifying the cost impacts of LEED-NC gold construction in New York city. *Senior Honor thesis, Dept.of Civil and Environmental Engineering, Lafayette College, Easton, PA* **2005**.

29. Pearce, D. Is the construction sector sustainable?: definitions and reflections. *Build Res Inf* **2006**, *34*, 201-207.

30. Jeong, J.; Hong, T.; Ji, C.; Kim, J.; Lee, M.; Jeong, K. Development of an evaluation process for green and non-green buildings focused on energy performance of G-SEED and LEED. *Build Environ* **2016**, *105*, 172-184.

31. Donghwan, G.; Yong, K.H.; Hyoungsub, K. LEED, its efficacy in regional context: Finding a relationship between regional measurements and urban temperature. *Energy Build* **2015**, *86*, 687-691.

32. Zhao, J.; Lam, K.P.; Biswas, T.; Wang, H. An online platform to automate LEED energy performance evaluation and submission process. *Construction Innovation* **2015**, *15*, 313-332.

33. USGBC. Available online: https://new.usgbc.org/ (Accessed on 15 March 2019).

34. Vyas, G.S.; Jha, K.N. What does it cost to convert a non-rated building into a green building? *Sustainable Cities and Society* **2018**, *36*, 107-115.

35. Burnett, J. Sustainability and sustainable buildings. *HKIE Transactions* **2007**, *14*, 1-9.

36. Shen, L.; Li Hao, J.; Tam, V.W.; Yao, H. A checklist for assessing sustainability performance of construction projects. *Journal of civil engineering and management* **2007**, *13*, 273-281.

37. Poveda, C.A.; Young, R. Potential benefits of developing and implementing environmental and sustainability rating systems: Making the case for the need of diversification. *International Journal of Sustainable Built Environment* **2015**, *4*, 1-11.

38. Green building cost and financial benefits. Available online: http://www.greenspacebuildings.com/wp-content/uploads/2011/05/Kats-Green-Buildings-Cost.pdf (Accessed on 22 November 2018).

39. Kats, G.; Alevantis, L.; Berman, A.; Mills, E.; Perlman, J. The costs and financial benefits of green buildings. *A report to California's sustainable building task force* **2003**, *134*.

40. She, Y.J.; Zhu, Y.H.; Huang, Q. System of sustainable construction based on project whole life cycle management, Advanced Materials Research, Trans Tech Publ: 2012; , pp. 2093-2097.

41. Fuerst, F. Building momentum: An analysis of investment trends in LEED and Energy Star-certified properties. *Journal of Retail & Leisure Property* **2009**, *8*, 285-297.

42. Fuerst, F.; McAllister, P. Eco-labeling in commercial office markets: Do LEED and Energy Star offices obtain multiple premiums? *Ecol Econ* **2011**, *70*, 1220-1230.

43. Matthiessen, L.F.; Morris, P. *Cost of green revisited: Reexamining the feasibility and cost impact of sustainable design in the light of increased market adoption*, Continental Automated Buildings Association: 2007;.

44. Matthiessen, L.F.; Morris, P.; Georges, D. *Costing Green: A Comprehensive Cost Database and Budgeting Methodology by Lisa Fay Matthiessen and Peter Morris*, Davis Landon Adamson: 2004;.

45. Sabapathy, A.; Ragavan, S.K.; Vijendra, M.; Nataraja, A.G. Energy efficiency benchmarks and the performance of LEED rated buildings for Information Technology facilities in Bangalore, India. *Energy Build* **2010**, *42*, 2206-2212.

46. Managing the Cost of Green Building. Available online: https://www.google.fi/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=2ahUKEwjU-5aO96rmAhXHwsQBHUy3BOEQFjAAegQIAxAC&url=https%3A%2F%2Fwww.calrecycle.ca.gov%2Fdocs%2Fcr%2Fgreenbuilding%2Fdesign%2Fmanagingcost.pdf&usg=AOvVaw0FuAY4O4kQ9fJ46qlHljFW (Accessed on 5.12. 2019).

47. Uğur, L.O.; Leblebici, N. An examination of the LEED green building certification system in terms of construction costs. *Renewable and Sustainable Energy Reviews* **2017**.

48. Mapp, C.; Nobe, M.; Dunbar, B. The cost of LEED—An analysis of the construction costs of LEED and non-LEED banks. *Journal of Sustainable Real Estate* **2011**, *3*, 254-273.

49. Amiri, A.; Ottelin, J.; Sorvari, J. Are LEED-Certified Buildings Energy-Efficient in Practice? *Sustainability* **2019**, *11*, 1672.

50. Building steel structure. Available online: http://www.abadsazeh-moradi.blogfa.com/ (Accessed on 10.12. 2019).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 3 January 2020 doi:10.20944/preprints202001.0022.v1

Peer-reviewed version available at *Sustainability* **2020**, *12*, 719; doi:10.3390/su12020719