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Validation of Jordanian Green Building Based on LEED Standard for Energy Efficiency Methodology

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Abstract

In this research, validation of Jordanian green building model (JGBM) based on Leadership in Energy and Environmental Design (LEED) standards was investigated. Different items were studied for energy efficiency analysis. Photovoltaic systems, thermal insulation, shading, appliance, lighting and residential people were the items included in this research study. The field work of JGBM covered about 115 apartments and 73 houses in 4 Jordanian cities (Amman, Irbid, Zarqa, and Aqaba). Based on the technical analysis calculations and model validation, it is suggested that Jordanian green building model can save about 68% of energy needed for cooling, reaching 69 points out of the total 110 points, this JGBM rated the gold class according to the LEED-nominal classification.

Saving energy was investigated in terms of different parameters of a proposed model of the architectural side, which were showed high efficiency of saving energy; 63.11% of polystyrene insulation, 14.12% of PV system, 7.26% of double glazed, 6.89% of LED light, 5.1% of overhangs and 3.46 % light color stone.

Keywords: *Validation, Jordanian green building model, energy saving, LEED, BD+C System*.

1. Introduction

The future of renewable energy supply is an essential concern for many developing countries [1,2], especially in the Middle East. Recently, the need for energy security has increased even more because of the political and economic conditions relating to the energy crisis in the region. Moreover, the environment issue requires considerable efforts by decision makers and researchers to reduce the side effects of fossil fuels [3]. In this context, countries and organizations are presenting various mechanisms across different sectors to improve energy efficiency, one of which is the building and construction sector [4]. Many studies on the building sector reveal an intense consumption of energy resources [5, 6]. In fact, buildings account for 40 % of global energy use [7]. Therefore, due to the fact that buildings are physical structures, the possibility of achieving savings in this sector is enormous [8].

Based on Environmental Protection Agency (EPA), green building is defined as "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. Green building is also known as a sustainable or 'high performance' building" [9].

For Jordan, the construction sector is under pressure to meet the increasing demands for energy. Jordan imports about 98% of energy from other countries, in addition to a rapidly growing need for housing and commercial space [10]. Those require many measures that comply together with sustainable energy technologies, which can be achieved by the construction and building management codes. According to UNEP, (2007) building sector consumption accounts for more than 33% of total energy consumption, it is also responsible for the high emission of CO_2. In fact, Jordan suffers from serious challenges and most of which are a scarcity of supply of natural resources and unsteady energy supply, that required encouraging and providing incentives for green building application. The Jordan Green Building Guide (JGBG) was developed in 2009 and was initiated in 2013, and after that it was launched on the 3rd of September 2015 [11], which includes comprehensive technical standards. It focuses on the requirement of energy efficiency, water efficiency, healthy indoor environment and Green Building (GB) management, to create a noticeable shift in construction practices, which lead to saving energy and the cost [12].

GB sector has a wide range implication on other sectors in addition to energy field, such as waste management, economic activities, and potable water. GB leads to an integrated systematic approach which explores ideal

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opportunities for the comfort of human and economic development. Moreover, improving the energy efficiency of building is among the most cost-effective ways of improving climate change, and decrease greenhouse gas rate [13]. Some studies reported that environmental design features should not be more expensive than those of traditional low-income housing [14]. Kats et al (2003) investigated the average cost premium for building, they concluded that can be saved of 20% of the construction energy cost by applying less than 2% of the code [15]. Kibert (2005) reported that to build GB, the building professionals should be qualified with skills and experiences needed, by taking into consideration important issues, such as: ventilation system, isolated system and construction items [16]. Till now, more than 31 GB certification programs and 55 schemes are used in over 30 countries around the world, and some programs LEED are used in most countries [17]

A rating system for Neighborhood Development Rating Systems is created in the United States, it is known as Leadership in Energy and Environmental Design (LEED). It primarily functions to evaluate the sustainable building through building scale assessment in terms of the developed area according to sustainability criteria which included environmental, social, economic, site/land activities, in addition to communication, transportation and the assessment of building forms for housing performance [18]. One of the most categories which required an assessment by IEEE, is the Indoor Air Quality (IAQ). Generally, IAQ is related to pollutants that can affect the human health, the indoor air of the space, and the sources contributing to the indoor air pollution [19].

The Leadership in Energy and Environmental Design (LEED) specifications will be adopted on display of the design and construction characteristics where the more cost-effective measures will be shown, these measures can be considered to qualify for certification under LEED-NC for Retail 2009, so a better experience on the green building can be achieved.

To evaluate the performance of insulation of energy issues, there are two factors used to specify the best products that suit for the building; R-value and U-values. R-value related to resistance issues while a U - value is used to measure the rate of heat transfer. For efficient energy performance, and to reduce the energy consumption, a system with the highest R-efficiency is the best effective performance-based value for the insulation products being installed, especially because the overall energy performance of the building is clearly influenced by the issues associated with the selection and installation of the insulation system. In response to achieving lower energy consumption, the regulations of building that focus on reducing energy and heat transfer through higher insulation levels increase air tightness [20]. One of the most essential materials used as the insulation is the polystyrene, it is widely used for building envelopes, roofs and below-grade foundations. However, the efficiency of polystyrene as an insulator is based on its thickness [22].

This program is concerned with greening the retail sector, so a number of criteria and standards are based on it to ensure that any building has the LEED certified will be in the allowable range on achieving this standard. Operators of the project had selected a certain number of points for each category that LEED is interested in. These categories and points of distributions are summarized in Table 1.

Table 1: LEED for retail 2009 System

Category	Total points	Issues Evaluated by the LEED-NC 2009 System
Sustainable Sites	26	Avoiding sensitive sites; locating to facilitate use of public transportation, reducing site impacts of construction, creating open space; enhancing storm water management; lowering the urban heat island effect; controlling light pollution.
Water Efficiency	11	Encouraging water conservation in landscape irrigation and building fixtures; promoting waste water reuse onsite sewage treatment.
Energy Efficiency	33	Energy conservation; using renewable energy systems; Building commissioning; reduced use of ozone depleting chemicals in HVAC systems; energy monitoring; green power use.
Materials/Resources	13	Use of existing buildings; facilitating construction waste recycling; use of salvaged materials, recycled-content materials, regionally produced materials, agricultural-based materials and certified wood products.
Indoor Environment	16	Improved ventilation and indoor air quality, use of non-toxic finishes and furniture; greenhouse keeping; daylighting and views to the outdoors; thermal comfort; individual control of lighting and HVAC systems.
Innovation in design; Regionally Appropriate Measures.	10	Exemplary performance in exceeding LEED standards; use of innovative approaches to green design and operations; four points for addressing regionally significant issues.

From these classifications which are based on 110 available points to evaluate any building to have a LEED certified, the following table shows the nominal classification based on the number of points the building had achieved.

Table 2: Nominal classification for Green Building from LEED

Number	Classification	Points
1	Certified	40 to 49
2	Silver	50 to 59 points
3	Gold	60 to 79 points
4	Platinum	≥80 points

This research aims to contribute to a better understanding of the concept of green building rating system and its role in achieving sustainable development, and to improve the sustainable practices. In addition, it aims to validate the Jordanian green building based on LEED V4 Standard. Also, to verify cooling and heating load and critical factors to the success of sustainable development.

2. Methodology

To improve the consumed energy and increase renewable energy uses, energy measures were analyzed in four cities in Jordan. The categories performed in this study included: measures of energy efficiency based on available renewable energy in sites using the thermal numerical computerized model that is designed exclusively for this study as comprehensively explained in reference [21].

2.1. Location selection

In fact, Jordan is divided into three zones in the terms of climatic issues, as reported in Jordan Thermal Insulation Code, Appendix (B) [22]. As shown in Figure. 1, Zone- 1 the Rift Valley in the west, zone-2 the highland in the center and the zone-3 desert in the east where the chosen cities in this study within these regions, and these are the most densely populated regions where the average temperature is 8 - 27℃ in Amman, 15 – 45℃ in Aqaba, 7 – 33℃ in Irbid and 9 to 44℃ in Zarqa. Between day and night, the climate varies dramatically, as well as from summer to winter. This variation leads to different approaches for analysis of energy efficiency and insulation factor.

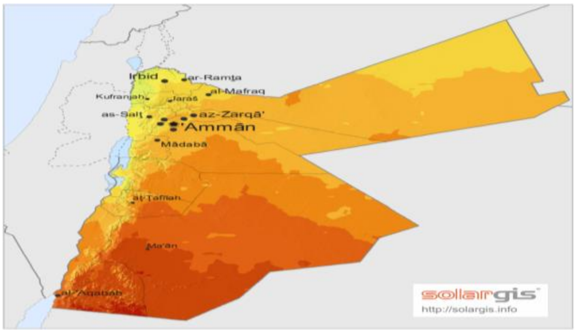

Figure 1: Jordan three climatic regions.

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Samples

Based on the design characteristics of green buildings that are available in LEED standard, and the results of the Jordanian building characteristics will be combined in the Jordanian green building model with Architectural design and Construction materials. Random samples were taken from apartments and houses in different cities in Jordan, including: Amman, Irbid, Zarqa and Aqaba. One hundred and fifteen apartments with average areas 154 m^2 and 73 houses with average areas 415 m^2.

Different items were used to assess the energy consumption in the building; these factors are Photovoltaic systems, Insulation, Shading, Appliance, Lighting and people. The results in terms of residential flats can be summarized by the following table:

Table 3: Mean area of residential flats:

Location	**Number of samples**	**Average area (m^2)**
Amman	42	170
Zarqa	29	156
Irbid	23	140
Aqaba	21	134
	Total: 115	Average:154

Table 4 shows the same procedure had applied to a sample of houses in various locations in Jordan to find out the average area for it, the results were as follows:

Table 4: Summary of data resources referenced in this study.

Location	Number of samples	Average area (m^2)
Amman	27	455
Zarqa	16	444
Irbid	19	345
Aqaba	11	389
	Total: 73	Average:415

To recognize the effectiveness of the green buildings installation in Jordan, the total saving of the proposed model of green building will be compared with a general house (non-green building) in terms of cooling and heating load requirements using thermal computerized model that is designed exclusively for this study as comprehensively explained in reference 21. This study sample was chosen from various grade construction, the results were analyzed.

Different suggested considerations related to energy consumption and energy saving were studied in an attempt to find both quality and quantities of energy saving methods. Based on the field survey and data collected the proposed model of green building for Jordanian climate succeed in reducing the cooling load requirements by 68% and the heating load requirements by 65%.

On the basis of LEED v4 for Building Design and Construction (BD+C) System (i.e., (B) for Building, (D) for design and (C) for construction); the suggested model of the Jordanian green building had achieved 69 points from the total 110 points, and from the LEED-nominal classification, this Jordanian green building model deserved the gold class.

The focus was on the field of energy, in terms of increasing the energy efficiency and reducing the requirements of heating-ventilating -air-conditioning (HVAC) systems. To improve the Jordanian green building model, several features (several green building standards, certifications, and rating systems were publicized in the last two decades) and should be studied and considered.

Measures for heat gains reduction, including radiant barrier, shading, heat dissipation contributed the highest energy use reduction in cooling dominated locations. The development in the chosen cities (Amman, Irbid, Zarqa, and Aqzba) shows that building measures that resulted in large heating energy savings increased the cooling energy use exceeded the heating energy use. A certain green practice and green products could improve indoor air quality, by focusing on ventilation control and openings control.

3. Results and discussion

3.1. Energy consumption factors of buildings

As mentioned before, there are different items shares to specify the quantity of energy consumption, such as insulation thickness, PV panels with different of installing area, overhang width, different types of windows, lighting, appliances and masonry stone color. To address the heat loss and improve energy efficiency, a model of the components of the architectural side was proposed as shown in Table 5.

Table. 5: Components of the architectural side of the proposed model

Element	Number	Orientation	Area of windows (m^2)
House entrances	2	South, North	-
Guestrooms	1	East, North	1.5 x 1
Bedrooms	1	South, West	2 x 1
Bathrooms	3	East, South, West	0.5 x 0.5
Kitchens	3	South, West	2 x 1

The effect of the thickness of polystyrene on the amount of heat loss is shown in Fig. 2. With the increase of thickness, the amount of heat loss decreases. This agrees with recent studies have demonstrated that polystyrene insulation is the most energy-effective way to reduce significantly heat losses [21, 22, 24].

To evaluate the insulator effect on the heat efficiency, and to address the heat loss, an innovative polystyrene is used as a potential solution. Using polystyrene is important to increase the thermal performance in the building sector, in addition, to reduce the impact of urban noise. In this study, was highlighted on the effect of the thickness of polystyrene on the energy efficiency, the result was agreed with [25, 26]. Yu et al, (2009) was concluded that the optimum insulation thicknesses conjunction with higher saving energy, it varied in a wide range, and expanded polystyrene was the most effective insulation [26]. Referring to Fig.2 it is clear that the optimal insulation thickness range was (5-10) cm (i.e., 7-cm) to have functional heat saving and minimum heat losses through building walls.

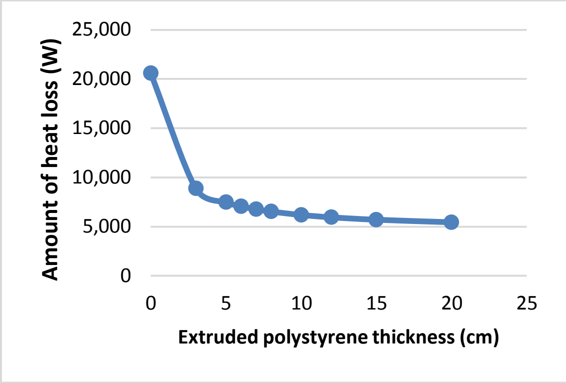

Figure.2: performance of polystyrene versus heat loss .

Also, as the increase insulation thickness, the energy performance increase as shown in Table 6, Installing more insulation in the building increases the R-value and the resistance to heat flow.

Table. 6: The effect of insulation thickness VS heat gain and energy saving

Insulation thickness (cm)	Heat Gain (KW)	Energy Saving (%)
0	25.5458	0 .0
1	14.2959	39.5971 %
2	10.3489	53.5190 %
3	8.3355	60.6268 %
4	7.1142	64.9401 %
5	6.2945	67.8362 %
6	5.7061	69.9151 %
7	5.2633	71.4800 %
8	4.9180	72.7004 %
9	4.6412	73.6789 %
10	4.4143	74.4809 %
11	4.2250	75.1502 %
12	4.0646	75.7172 %
13	3.9270	76.2037 %
14	3.8077	76.6258 %
15	3.7031	76.9953 %
16	3.6108	77.3217 %
17	3.5288	77.6119 %
18	3.4553	77.8717 %
19	3.3891	78.1057 %
20	3.3292	78.3175 %
21	3.2748	78.5101 %
22	3.2250	78.6860 %
23	3.1794	78.8473 %
24	3.1374	78.9957 %
25	3.0987	79.1328 %
26	3.0628	79.2598 %
27	3.0294	79.3777 %
28	2.9984	79.4875 %
29	2.9694	79.5900 %
30	2.9423	79.6859 %

Table 7 presents the electrical power production can be produced through PV system that based on the PV installing area. The energy consumption in the building was assessed according to different items: insulation thickness, PV panels with different of installing area, overhang width, overhang width, different types of windows Energy consumption was investigated with installing a PV system, which cover a part of required energy of the building. The results were consistent with Hwang et al. [27]. That they reported the PV systems can cover in the range of 1- 5% of electrical energy consumption of the office building.

Table. 7: The effect of area of insulation on the monthly acquired power from PV

Percentage-of ceiling area (%)	PV installing area (m^2)	Output power (kWh)
10 %	15.5	172.2
20 %	31.0	344.4
30 %	46.5	516.6
40 %	62.0	688.8
50%	77.5	861.1
60 %	93.0	1033.3
70 %	108.5	1205.5
80 %	124.0	1377.7
90 %	139.5	1549.9

A range of exposed overhang width was investigated to evaluate energy saving. As reported in Table 8, the heat gain decreasing with overhang width increasing. Actually, overhang width is an effective factor on energy performance and can be considered it as a passive cooling option on the building [21, 29]. Table 9, shows the effect of window width on the energy efficiency of buildings.

Table. 8: Heat gain and energy saving vs. Overhang width.

Overhang width (cm)	Solar Heat gain (KW)	Saving (%)
20	6.8269	0.0 %
32	6.4173	6.0 %
44	5.8029	15.0 %
56	5.2567	23.0 %
68	4.7788	30.0 %
80	4.3692	36.0 %
92	4.0279	41.0 %
104	3.6865	46.0 %
116	3.4135	49.0 %
128	3.1745	53.5 %
140	2.9697	56.5 %

Recently, triple glazing is increasingly being presented as the best solution for energy saving, and as the results shown in Table 9, it was better than doubled glazing. Switching to triple requires higher cost and material production has an impact on the environment. The optimum insulation material for filling gaps between the glass is the Krypton in both cases of double and triple glazing. The quantity of producing electrical power from photovoltaic (PV), for each sample, was based on the installed area, inclination and direction of the PV panels. As shown in Table 10, the quantity of saving energy is 14.2%, considering the seasons, Longitude and latitude of all sites for samples the percentage of saving energy it

is agreed with A. Alshorman and M. Alshorman (2017)[21]. Also, Using LED light system achieved

about 6.9, which is characterized with long cycle life respect to traditional type, in addition to it is considered as Eco-friendly

Table. 9: windows type and insulation material for filling gaps impact on energy saving..

Number	Windows type	U-value	Saving (%)
1	Single glazing	5.6000	0.0
2	Double glazing (Air)	2.3280	58.4286 %
3	Double glazing (Argon)	1.8170	67.5536 %
4	Double glazing (Krypton)	1.2490	77.6964 %
5	Triple glazing (Air)	1.4760	73.6429 %
6	Triple glazing (Argon)	1.0790	80.7321 %
7	Triple glazing (Krypton)	0.6810	87.8393 %

Table. 10: Proportion of each parameter saving.

No.	Parameter of energy saving	Proportion of saving (%)
1	Extruded Polystyrene insulation	63.11 %
2	Solar Photovoltaic panels	14.12 %
3	Double glazed windows	7.26 %
4	LED light bulbs	6.89 %
5	Windows Overhangs	5.15 %
6	Light color stone	3.46 %

One of the most important files that need to be discussed is the water efficiency, where the water resources of Jordan are very scarce. In addition, the water efficiency field is an important category in the green building considerations. Different ways can improve water efficiency such as greywater installation and reuse treated water in irrigation in gardens or flushes in bathrooms. Also, the innovation side needs more search and development to achieve more feasibility and ability to meet the various residential needs.

3.2. Scaling of Jordanian Green Building Model according to LEED Standard

According to the technical details of LEED-NC for retail 2009 [29], it is possible to introduce the main architectural features of the Jordanian green building model. This side of model can be described as detailed in Table 11 below according the structural design Methodology.

To avoid solar gain in the summer which requires increasing the cooling load and increasing heating load in winter, the openings require improved glass surfaces and shading matter. Considering passive and active heating, to reduce energy load all single pane windows should be replaced with double pane 2 × 1.1 m^2 (U 2.kW/m^2, air space 12mm), also, requires Venetian blinds and overhangs along it.

Table 11: Main Architectural parameters of buildings according to green building considerations

Category	Result
Outside door	Off-white
Outside construction	Stone
Presence of garden house	Found
Windows area	(2.0x1.1) m^2
Number of bedrooms	Three
Number of guest house	One
Number of living rooms	One
Number of bathroom	Three
Number of kitchen	One
Average area of apartments	154 m^2
Average area of houses	415m^2

One of the major architectural is orientation; as known of the sun path diagram that the southern facing side receives the most amount of solar radiations. For Jordan the wind direction is northwest, based on these facts and to achieve maximum energy saving the following considerations were taken:

Table 12: The achieved considerations in terms of best orientation.

Category	Considerations
Living room windows facing side	In the proposed model, living room windows are oriented to south, so those large amounts of solar radiation and good passive lighting have been achieved.
Kitchen windows facing side	The kitchen windows should not be in the face of the prevailing wind direction because gases and odors that release of kitchen will spread to other spaces in the house, and this is achieved in the proposed model, where kitchen windows are oriented to south and east.
Bedrooms windows facing side	It is preferable with bedrooms windows to be oriented toward western or southern side.
House entrance orientation	Where the main entrance of the house is preferred to orient toward the public street, and this is applied in the suggested model where the street is proposed to locate in the northern facing side.

Different types of construction material were used in Jordan for walls and ceiling structure. The common building construction in Jordan will be adopted for this model, but one layer will be added which is: polystyrene insulation with 5 cm thickness (which is available in Jordanian market). The main characteristics of the proposed model are summarized in the Table 13.

Table 13: The main suggested considerations of the proposed Jordanian green building model (JGBM)

Category	The suggested considerations
Construction insulation	Using Extruded Polystyrene as an inside insulation material of walls and ceiling.
Glass insulation	A double glazing glass with 100% air filled is used.
Energy efficiency	Solar Photovoltaic panels are used as a renewable source of energy.
Lighting	-Natural lighting is successfully achieved by orientation the living room and kitchen to the south. -GE energy smart LED is used as energy saving lamps.
Shading	Windows overhangs to be installed in terms of reducing the solar heat gain through the windows glazing. These overhangs can oppose the summer solar noon radiations.
Stone color	The preferred color of the stone is the white degrees (which is given with low absorbance values).

Based on the analysis and data collection from field work different items for energy efficiency were studied, validation of the Jordanian green building model against to the LEED v4 green buildings criteria can be summarized in Table 14.

Table 14: Evaluation of the JGB on the basis of LEEDv4 for BD+C System.

Category	The stated Points from	The achieved points for the
	LEED – NC	JGB model
Location and Transportation	16	13
sustainable Sites	10	6
Water efficiency	11	1
Energy and Atmosphere	33	24
Materials and Resources	13	9
Indoor Environmental Quality	16	13
Innovation	6	0
Regional Priority	4	2
Total	110 points	69 points

To recognize the effectiveness of the green buildings installation in Jordan, the total saving of the proposed model of green building was compared with a general house (non-green building) in terms of cooling and heating loads requirements. This study sample was chosen from various grade construction, the results were analyzed.

Different suggested considerations related to energy consumption and energy saving were studied in aim to find the both quality and quantities of energy saving methods. Based on the field survey and data collected the proposed model of green building for Jordanian climate succeed in reducing the cooling load requirements with the proportion of 68% and the heating load requirements with the proportion of 65%.

The Evaluation of the JGB on the basis of LEEDv4 for BD+C System; the suggested model of the Jordanian green building had achieved 69 points from the total 110 points, and from the LEED-nominal classification, this Jordanian green building model deserved the gold class. Where the number of earned points according to LEED certification refers that it achieved a gold class (60-79 point) to be consistent in Table 1.

The Focus was on the field of energy, in terms of increase the energy efficiency and reduces the requirements of HVAC systems. But in order to improve the Jordanian green building model several files should be studied and taken into account.

4. Conclusion

Jordan has their own established GB assessment systems to assess for sustainability which are driven from LEED assessment. However, every aspect of the sustainability factors must be assessed to ensure a more conservation of the energy and health issues. The assessment tools of LEED are used as guidelines during the evaluation process of proposed Jordanian Green Building Model (JGBM).

The collected data through field survey in four Jordanian cities, in addition to the results of JGBM thermal investigations showed that Jordanian climate plays a role in reducing the cooling load requirements with the proportion of 68% and the heating load requirements with the proportion of 65%. The suggested model of the Jordanian green building had achieved 69 points from the total 110 points, and from the LEED-nominal classification, this Jordanian green building model deserved the gold class.

Proposed model of the components of the architectural side was investigated to address the energy consumption. The percentage of saving energy through proposed parameters are: 63.11% of polystyrene insulation, 14.12% of PV system, 7.26% of double glazed, 6.89% of LD light, 5.1% of overhangs and 3.46% light color stone.

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