International Journal of Engineering & Technology, 7 (4) (2018) 3043-3047

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i4.15610
Research paper

Jordanian green building approach for energy efficiency improvement

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Abstract

Energy saving, getting higher energy efficiency and reducing the negative impact on human health and environment can be achieved by green building (GB) approach. This concept includes considering the overall process of GB from design and construction to maintenance, which contributes to increase the efficiency of energy and economic. In this research an energy efficiency enhancement in the green buildings was investigated and results optimized based on the current proposed Jordanian green building model (JGBM). The total cooling and heating loads and saving energy were calculated for JGBM before and after amendments to the windows, walls, PV system, thermal insulation, and light type. The insulation (polystyrene) for external building walls has been adopted, also the double glazing instead of the current single glass. The electricity for the lighting consumption by LED and the potential of utilizing it in the building were analyzed. It has been found that implanting the JGBM considerations enables for real energy saving. In this study about 115 apartments and 73 houses were investigated in 4 Jordanian cities (Amman, Irbid, Zarqa, and Aqaba). Based on the analysis and model validation; suggested Jordanian green building model will save about 68% of the energy needed for cooling and 65% of the energy used for heating. The total saving of energy of Polystyrene insulation, PV system, double glazing windows, LED light and windows overhangs were 63.11%, 14.11%, 7.26%, 6.89% and 3.46% respectively.

Keywords: *Jordanian Green Building Model; Energy Efficiency; Validation; Energy Saving; and LEED.*

1. Introduction

Jordan (The Hashemite Kingdom of Jordan) is a developing country located in the Middle East. The country has a total mainland of 89,341 km^2. This kingdom is relatively small, semi-dry, almost-landlocked country with a population numbering 9.99 million. Jordan is geographically divided into three regions: the North Region, Central Region, and the South Region. These regions enclose twelve governorates. Amman Jordan's capital locates in the middle region. Table 1 clarifies the area (Km^2), population, population density, and area percentage for each governorate [1-3]. The highest population in the central region is Amman, followed by Zarqa, in the northern region is Irbid, in the south region is Karak. The only coastal city in Jordan is Aqaba, which is the largest and most populous city in the Gulf of Aqaba.

Table 1: Population of Jordan, Area (Km^2) and Population Density by Governorate [2]

	Governorate	Population	Area(km²)	% of Area	Density (people/km²)
	North Region	2,809,600	28,951.8	32.7	97.04
1	Irbid	1,819,600	1,571.8	1.8	1,157.7
2	Ajloun	181,000	419.6	0.5	431.3
3	Jerash	243,700	409.8	0.5	594.7
4	Mafraq	565,300	26,550.6	29.9	21.3
	Central Region	6,222,400	14,400.6	16.3	432.1
5	Amman	4,119,500	7,579.2	8.5	543.5
6	Balqa	505,400	1,120.4	1.3	451.1
7	Zarqa	1,403,000	4,761.3	5.4	294.7
8	Madaba	194,500	939.7	1.1	207
	South Region	766,000	45,441.2	51.2	16.9
9	Karak	325,500	3,494.7	3.9	93.1
10	Tafilah	99,000	2,209.5	2.5	44.8
11	Ma'an	148,100	32,832.3	37	4.5
12	Aqaba	193,400	6,904.7	7.8	28
	Total	9,798,000	88,793.6	100	110.35

Jordan like other developing countries, economic growth has placed significant pressure on energy consumption, housing demand, and waste and pollution management. Future of energy is a significant concern for both developed and developing countries

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[4]. Both keeping available energy resources and efficient using of them are essential for the countries [5]. Efficient using of energy resources is essentially required for economic and environmental requirements.

Buildings affect humans and the environment in numerous ways [6]. As most people spend about 90% of their time indoor activities. Thus, buildings can positively and negatively impact on human life environment [U.S Environmental Protection Agency, 2004]. They protect people from natural extremes [6]; however, buildings exhaust volatile organic compounds which pose serious risks to health [7]. Buildings consume 50% of energy generated and 70% of all lumber as well as a considerable proportion of raw materials globally [8-10]. A significant quantity of wastes is also formed during their life cycle, from construction, operation and demolition processes [9-10]. Buildings contribute to waste pollution, air pollution, noise pollution, and water pollution [11].

The construction sector is under high pressure to meet a rapidly growing need for housing and commercial space. However, so far the focus with regard to efficiency has been on raising the awareness of households regarding water and energy efficiency. Based on Ministry of Energy and Mineral Resources, Hashemite Kingdom of Jordan 41% of electricity consumed in Jordan at 2012 was from households [12].

In response to the development challenges and the green concern globally, at the side of Jordan imports about 98% of energy from several countries [13]. This directs to manage energy consumption by most efficient methods. One of the sustainable processes is the green building.

Based on Environmental Protection Agency (EPA) green building defines as "the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from sitting 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" [14]

The main objective of this study is to select the optimized green building design. This selection takes into account the criteria of the Leadership in Energy and Environmental Design (LEED) and Jordan conditions such as climate, traditions, economic, building style, lifestyle, …etc. This study passed on four governorates, three of them are the highest population governorates (Amman, Irbid, and Zarqa) and in Aqaba (the coastal city in Gulf) which has special topography.

2. Methodology

This research begins with collecting data of Jordanian residential areas in main Jordan locations. After that, mathematical model built to perform an intensive thermal analysis and to calculate the cooling and heating loads for green and non-green buildings for the selecting residential areas. Then the loads were compared with residential areas after adopting green building consideration. It also investigates the effect of different types of wall and windows insulation.

2.1. Major parameters of green building for thermal characteristics

Thermal characteristics of green building depend on many parameters. These parameters form the major structure of these characteristics such as thermal insulation and building structure (color, location, shape and orientation, energy saving, lighting, windows overhang, shading, appliances, occupants, and method of using). In addition, these parameters have quantitative rates of contribution in energy saving and efficiency of green building. This contribution relays on building style, location, environment, and utilization of the building.

2.2. Field work data collection

In order to achieve this optimized model of green building (JGBM), several studies and statistics on different areas in Jordan (Amman, Irbid, Zarqa, and Aqaba) had done. Consequently, the general pattern of the buildings is observed. Where this pattern is close to Jordanian design and culture, and taste the architecture side.

Sampling procedure

To validate the model, many parameters are considered in analyzing of Jordanian buildings for green building analysis, these parameters are:

- Average of the internal areas for residential flats and houses
- Interior design of buildings
- Outside features
- Urban locations

Random samples of apartments and houses had selected in different Jordan cities (Amman, Irbid, Zarqa, and Aqaba). More clarification about sample number and average area are shown in table 2, where 115 apartments with average areas 154 m^2 and 73 houses with average areas 415 m^2as summarized in the table.

Table 2: Summary of the Random Samples

Location	Residential Flats			
	n# samples	Average-area (m^2)	n# houses sample	Average-area (m^2)
Amman	42	170	27	455
Zarqa	29	156	16	444
Irbid	23	140	19	345
Aqaba	21	134	11	389
	Total: 115	Average:154	Total: 73	Average:415

Different factors are assessing the energy consumption in the building. These factors are photovoltaic systems, thermal insulation, shading, appliance, lighting, and residential people.

In this study, 42 buildings have been studied within the selected areas of Jordan. In terms of achieving the target of this study to obtain the optimized design of Jordanian green building model JGBM. Accordingly the characteristics of optimized green building model house are specified in table (3).

Table 3: Main Architecture Parameters of Buildings According to Green Building Considerations

Category	Result
Outside door	Off-white
Outside construction	Stone
Presence of garden house	Found
Windows area	$(2.0\times1.1)m^2$
Number of bedrooms	Three
Number of guest house	One
Number of living rooms	One
Number of bathrooms	Three
Number of kitchens	one
Average area of apartments	154 m^2
Average area of houses	415m^2

The target of this study is to find the optimized design of Jordanian green building model (JGBM). This design based on the field surveys, a theoretical house was proposed. The main characteristics of the proposed model are summarized in table (4). Based on the effective parameters of green buildings and simulated general characteristics of Jordanian buildings, the results were analyzed.

Table 4: The Main Suggested Considerations of the Proposed Green Building

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

Shading	the living room and kitchen to the south. -GE energy smart LED is used as energy-saving lamps. 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).

2.3. Mathematical equations and calculation model

In order to calculate the energy required and energy saving due to apply green building model, the following equations are required:
Photovoltaic System:
To estimate the output power of photovoltaic (PV) solar panels, the following equation can be used:

$$E = 365\ Pk * rp * Hhi \quad (1)$$

Where E is the yearly potential for electricity generation (kWh), P_k is the peak power of the equipment installed (kW), r_p: Overall DC to AC derate factor (equals 0.769) [15] and H_{hi} is the yearly average of daily global radiation in kilowatt-hour per day.
The Measured value of the yearly global solar radiation for the climate of Jordan is 2080 kWh/m^2 (5.7kWh/m^2 per day).
Insulation:
The overall heat transfer coefficient of walls, ceiling, floor, windows, and doors was calculated, the overall thermal resistance for the heat transfer from the air on one side of the wall to air on the other side is given as follows:

$$R_{th} = R_0 + R_i + \sum_{i=1}^{n}(R_{Cond})i \quad (2)$$

In formula; R_{th} is overall thermal resistance, R_i is inside convection resistance and R_o is outside convection resistance.
Then, the overall heat transfer coefficient of the wall (U) is defined in terms of the overall thermal resistance as follows:

$$U = \frac{1}{R_{th}} \quad (3)$$

Heat losses from the walls, ceiling, floor, windows, and doors can be calculated by the following equation:

$$Q_{loss} = UA\Delta T \quad (4)$$

In this equation A is Area in m^2, U is Overall heat transfer coefficient, in W/m^2.C^o and ΔT is Temperature difference, C^o. Table 5 shows the rest of heat loads used to set mathematical model [more details are explained in reference 16]

Table 5: Governing Equation for Heat Loads [16-18]

Heat Load		Governing Equation	Components of Governing Equation
$Q_{s,f}$	sensible heating load due to infiltration	$Q_{s,f} = \rho Vf\, Cp(\, Ti - To\,)$	P: Density of infiltrated air at the outside design temperature C_p: specific heat at constant pressure. V_f: Volume flow rate of infiltrated outside air.
Q	heat gain of the house from solar radiation	$Q = A(SC)(SHGF)(CLF)$	A: Net glass area of the fenestration in m^2, SC: Shading coefficient. SHGF: Maximum solar heat gain factor CLF: Cooling load factor
Qa	hourly heat gain for general types of appliances	$Qa = Qi * FUA * FRA$	Qi: total nameplate or catalogue input. FUA: Usage factor =0.5. FRA: conservative radiation factor = 0.32
Qel	Cooling load from lighting in W	$Qel = HGel * CLFel$	CLF_{el}: lighting cooling load factor HG_{el}: Heat gain from lighting in W. $HGel = W * Ful *. Fsa$ W: total lamp watts. Ful: lighting use factor. Fsa: lighting special allowance factor.
Qs	Sensible cooling load due to people	$Qs = N * (SHGp) * (CLFp)$	N: number of people. SHGp: sensible heat gain per person. CLFp: cooling load factor for people.
Ql	Latent cooling load due to people	$Ql = N * (LHGp)$	N: number of people. LHGp: latent heat gain per person.

Computerized Model
MATLAB code was programmed to calculate the total power consumption for non-green and green building and to perform full thermal analysis of the JGBM to determine the percentage contribution of each parameter in energy saving for JGBM. In the first phase, the total power consumption for non-green building was calculated, where the non-green building is constructed without insulation, without PV-system, it has traditional lighting and normal type of glaze (single glass) which is associated with high power consumption rate.
In the second phase, the code was used to calculate the total power consumption for green building. Green building has insulation, PV-system, special types of glass window (double or triple glaze) and special types of lighting (such as LED).

3. Results and discussion

This case study of green building approach in Jordan highlights the innovation and methodology strategies which conjunction with high energy performance. Actually, This research is part of campaign of investigations to provide realistic Jordanian green building model (JGBM) as explained in previous published works [16].
The main objective of this study is to select the optimized green building design. Deciding the green building design depends on selecting the effective parameters, which effect on the energy consumption and saving energy percentage. This green building design takes into account the criteria of the Leadership in Energy and Environmental Design (LEED), the meteorological conditions in Jordan (Jordanian climate conditions), and the style of building at the major locations of Jordanian residential areas (i.e., North, middle and south of Jordan). In consequence, the following considerations are adopted JGBM of this study:

1) The extruded polystyrene thickness is 5cm.
2) The photovoltaic panel's area is 30% of the ceiling area.
3) The double glazed windows with air-filled are installed.
4) The used lighting type is LED lights.
5) The overhangs windows with a width are in the range of (50-65) cm.
6) The stone color is bone white with an absorbance of 0.34

Based on the collected data about the studied houses, the total cooling load is 42770.86 W; this load is excepting green building

considerations (Non-green building). It seems obvious that applying green building conditions will enable for substantial energy saving. The total saving energy after applying the above conditions of green building equals 71.3%, and the total cooling load of these green buildings is 12270.89 W. The final results of the cooling load requirements of the proposed JGBM can be obtained directly from the simulation model. These results are summarized in table 6.

Table 6: Cooling Load Requirements of Green and None Green Buildings

Category	Cooling load(W)	Cooling load(TR)	Saving (%)
Non green building	34786	9.89	None
Green building	11130	3.16	68.0%

As a result of comparison between green building and non-green building in terms of the cooling and heating loads requirements, applying green buildings items can save about 68% of the cooling load requirements, and about 65% of the heating load requirements. This means that the requirements of the HVAC (heating, ventilation and air conditioning) systems requirements in case of non-green building is three folds the requirements. Poddar et al. (2017) reported that to achieve 33% and 26% reduction in energy use intensity, and it was showed the extent to which GB could generate co-benefits. Poddar underlines the opportunities and barriers to push the agenda of GB forward [19].

Windows are essential in a building, to provide day lighting, visual contact with the outdoors, and a potential for natural cooling and ventilation. Although, windows positively impact a building's heating and cooling loads. This impact has traditionally known as 'energy losers" because of their low thermal resistance relative to the other building envelope elements. Thus, several insulation types of window were investigated for JGBM, by calculating its percentage of saving energy as summarized in table 7. The results of the investigation show a significant reduction in energy consumption of the building corresponding to the traditional one (single glazing), where the most effective category is the triple glazing (Krypton) with the higher energy saving value. While double glazing (Air) achieve lower saving energy value. The result which was achieved by glazing technique agrees with what reported by Hee et al. (2015) [20].

Table 7: Effect of Modified Windows on Energy Saving Percent

Window Type	U-Value	Energy Saving (%)
Single Glazing	5.6	0
double glazing (Air)	2.328	58.42
Double glazing(Argon)	1.817	67.55
double glazing(Krypton)	1.249	77.69
triple glazing(Air)	1.476	73.64
triple glazing(Argon)	1.079	80.73
triple glazing(Krypton)	0.681	87.83

Other extra parameters are investigated to elucidate the main characteristics features of JGBM building such as building stone color, windows glass insulation, heat gain of appliances and building occupants. Masood, et al.(2017) reported that the principle implementation of the and basics of green architecture and provides the building with its needs from PV system energy [21]. A typical Jordanian Green Building Model (JGBM) for energy efficiency enhancement was proposed based on LEED considerations. The characteristics of this JGBM are specified in table (8). The proposed model of green building for Jordanian climate will save about 6.73 Ton Refrigeration, which is a large value in terms of reducing the cooling load requirements and the exerted power consumption. A similar study, conducted by Ali. (2009), investigated a developed assessment tools for residential buildings in Jordan. Ali's study includes the and local context of Jordan and identifying the aspects which must be integrated with a local assessment system [22]

Table 8: Main Parameters of JGBM Buildings According to Green Building Considerations

Category	Result
Outside door	Off-white
Outside construction	Stone
Presence of garden house	Found
Windows area	(2.0×1.1) m^2
Number of bedrooms	Three
Number of guest house	One
Number of living rooms	One
Number of bathrooms	Three
Number of kitchens	One
Average area of apartments	154 m^2
Average area of houses	415m^2

The efficiency of energy design with the focus on reduction strategies of energy that increase the overall save energy. The main applicable strategy is the introduce of polystyrene insulator (see Fig.1) in external wall of the building. Actually, the parameters of JGBM affect the energy saving percentage of green building. The percentage of each parameter is presented in Fig.1. The most contribution comes from construction insulation by 63.11% then photovoltaic panels by 14.11%, while window insulations and LED lights offered nearly the same rate of saving of about 7%. Windows overhangs provided 5.14% of energy saving and light color stone gave the lowest part at 3.46%. Based on this figure the most effective parameter is insulation layer, and then installed the PV panels which may save about 77% of energy. These results matched with a study performed by El-Din, (2012), the author developed new module of rating system which was applied in Egypt. His study carried out with a comparative analysis study for different global rating systems including LEED Rating system [23]. Albadry et al. (2017) presented an implementation of guideline to Net Zero-energy buildings through installing PV panel system [24].

Analytically, the results of this research were scaled and validated according to Leadership in Energy and Environmental Design (LEED) standared as clearly explained by Alshorman et.al.[25]

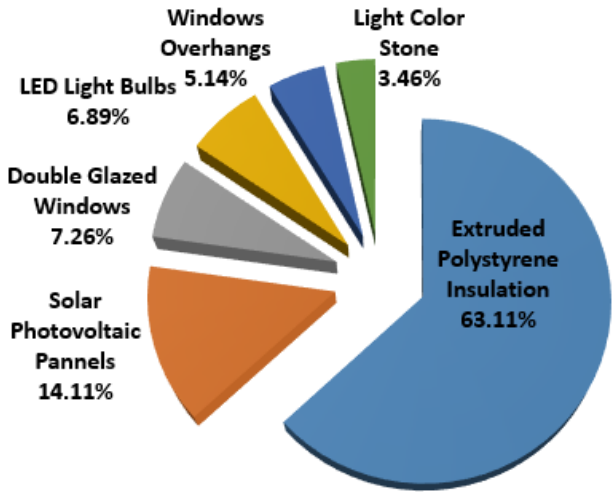


Fig. 1: Energy Saving Percent for Typical House.

However, upon increase energy demand, we recommended to apply green roof with the previously proposed categories in order to reduce building energy consumption, It can be reduced the temperature of the external surface of building and increase the efficiency of energy. Kolokotroni et al. (2016) reported that positive benefits for cool and green roofs can be achieved compared to base model with most savings achieved by green roof with solar reflectance (SR) of 0.90 [26].

4. Conclusions

It is well recognized that the standardization field of constructions sustainability is critically controlled by the differently known ap-

proaches of green building. These approaches are effective in quality of energy and promoting sustainability. Accordingly and based on the current analysis and results; using green building approach in Jordan as proposed in JGBM can help in energy saving for both heating and cooling and improve environmental impact. This saving depends on the considered applied items of green building. Predominantly, about 65% of energy used for heating will be saved while 68% of energy used for cooling will be saved.

The most effective item in energy saving for JGBM is thermal insulation of walls. Furthermore, using photovoltaic panels and double glazed windows will be respectively the second and third items that can save energy at high sensible scale. These three items can save more than 85% of energy in the JGBM houses.

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