

# Green Buildings Analysis for Energy Efficiency Enhancement– Jordanian Concept

Abdullah A. Alshorman, Ph.D.\* and Malek Alshorman M. Sc.\*\*

\*Al-Balqa' Applied University- Al-Huson University College, Mechanical Engineering Department,

P.O.Box 50 - Al-Huson 19117- Irbid – Jordan,

\*\*Research Associate-mshorman86@gmail.com

## Abstract

The concept of green building related to many parameters that is basically interrelated to the building design and structure style, energy efficiency and saving, water management and minimizing any CO<sub>2</sub> emission by working systems and occupants within the building. This building style reducing the environmental impact and improve the sustainability and lowering both initial and running costs of building. So it is real efficient, attractive and got international scientific and technical standardization and implantation in developed countries.

To get benefits of green building for Jordan and introduce a practical Jordanian green building model (JGBM), a series of simulation studies (3 stages) were conducted starting by parametric modeling analysis of JGBM, then building up applied simulation JGBM based on field data analysis and finally validating and evaluating the Jordanian model by the Leadership in Energy and Environmental Design (LEED) Standards (LEED Standards).

In this research an energy efficiency enhancement in the green buildings was investigated, different items were studied, these items were Photovoltaic systems, Insulation, Shading, Appliance, Lighting and People. In purpose of validate the model results a 50 buildings in Irbid area were studied, based in the model a wall insulation was the most effect method for energy saving by 63.11% of energy saving then using solar photovoltaic panels by 14.11%, using double glazed windows can save about 7.26% of energy, while using LED light bulbs, windows overhanging and light color stones take 6.89%, 5.14% and 3.46% of energy saving respectively. Different insulation layer thicknesses were investigated; based on the model the most efficient thickness when less than 5 cm and energy saving is very superior but if thickness more than 15 cm the energy saving can be ignored.

\*Dr. Abdullah A. Alshorman, Associate Professor, Mech. Eng. Dept., Al-Balqa Applied University (BAU) – Jordan, Mobile: 00962-775613175, Email: [alshormana@asme.org](mailto:alshormana@asme.org)

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## Introduction

Green building (GB) concept start to distribute around world, 60% of project in USA, Germany and UK will be green building by 2018. According to some estimates, there are approximately 81 million buildings in the United States [1-3]. Most of these buildings use energy inefficiently, generate large amounts of waste in their construction and operation, and emit large quantities of pollutants and greenhouse gases. To reduce environmental effect of buildings construction, operation, maintenance, renovation and deconstruction and to avoid all these pollutants green building concept was created.

The Environmental Protection Agency (EPA) defines green building 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 [4].

Based on the definition of the green building practice; it could be considered as an integrated process start from planning stage and end by demolishing stage [5].

One of the major part in green building practice is energy consumption and energy saving. Building heating and cooling are the most energy-intensive activities, followed by electricity use for lighting and appliances [6,7]. In this study practice and framework for estimating the energy saving from applied green building practice were studied.

### Major Parameters of Green Building for Thermal Characteristics

There are many parameters that form the major structure of thermal characteristics of green building, this includes thermal insulation, building structure color, location, shape and orientation, energy saving, lighting, windows overhang, shading, appliances, occupants and method of using. All of these parameters have a quantitative rate of contribution in cost and energy saving and efficiency of green building according to the building style, location environment and type of applications [8].

## Methodology

### Data collection procedures

Several studies and statistics on different buildings in Jordan had achieved to see the general pattern of the buildings, and to be closer in this research and design to the Jordanian culture and taste in the side of architecture.

### Sampling procedure

In aim of validate the model many parameters are considered in analyzing of Jordanian buildings for green building analysis, these parameters are as following:

1. Average of the internal areas for residential flats and houses
2. Interior design of buildings
3. Outside features
4. Urban locations

Fifty (50) buildings have been studied for a zone in the city of Irbid (north of Jordan), this study is aiming to knowledge the main architectural parameters which effect on the energy consumption and saving.

### Assessment items

Different items were used to assess the energy consumption in the building; these factors are:

1. Photovoltaic systems.
2. Insulation of building
3. Shading
4. Appliance
5. Lighting
6. People (The occupants)

## Mathematical Modeling and Formulation

### Photovoltaic System:

To estimate the output power of photovoltaic solar panels, the following equation can be used:

$$E = 365 P_k r_p H_{hi} \quad (1)$$

In equation E is the yearly potential for electricity generation in kilowatt hours (kWh),  $P_k$  is the peak power of the equipment installed in kilowatts (kW),  $r_p$  is overall DC to AC derate (de-rate) factor (equals 0.769)[9],

(derating (or de-rating) is the operation of a device at less than its rated maximum capability in order to prolong its life) and  $H_{hi}$  is the yearly average of daily global radiation in kilowatt-hour per day.

Measured value of the yearly global solar radiation for the climate of Jordan is 2080 kWh/m<sup>2</sup> (5.7kWh/m<sup>2</sup> per day) [10].

### Insulation[11 - 13]

The overall heat transfer coefficient of walls, ceiling, floor, windows and doors were calculated, the overall thermal resistance for the heat transfer from 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<sup>2</sup>,  $U$  is Overall heat transfer coefficient, in W/m<sup>2</sup>.°C and  $\Delta T$  is Temperature difference in °C or K.

Infiltration is the leakage of outside air through cracks or clearances around the windows and doors and due to door opening and closing. The amount of this infiltrated air depends mainly on the tightness and type of the windows and doors and on the outside wind speed and its direction or the pressure difference between the outside and inside of the room.

The sensible heating load due to infiltration  $Q_{s,f}$ , is expressed as follows[6]:

$$Q_{s,f} = \rho V_f C_p (T_i - T_o) \quad (5)$$

Where  $Q_{s,f}$  is sensible heating load due to infiltration,  $C_p$  is specific heat at constant pressure,  $V_f$  is Volume flow rate of infiltrated outside air and  $\rho$  is density of infiltrated air at the outside design temperature.

### Shading[13,14]

The exterior sun controls are an ideal part of the "green" solution for their buildings. So this field is very important to be incorporated with the green building model. In addition to energy savings through reduced cooling loads, exterior solar shading can enhance a building's appearance, as well as provide controlled daylight and reduced glare.

The heat gain of the house from solar radiation can be given by the following equation [7]:

$$Q = A(SC)(SHGF)(CLF) \quad (6)$$

In this equation  $Q$  is cooling load in W,  $A$  is net glass area of the fenestration in m<sup>2</sup>,  $SC$  is shading coefficient,  $SHGF$  is maximum solar heat gain factor and  $CLF$  is cooling load factor.

**Appliances**[12- 14]

In a cooling load estimate, heat gain from all appliances electrical, gas or steam should be taken into account. The tremendous variety of appliances, applications, usage schedules, and installations, makes estimates very subjective.

Therefore, the maximum hourly heat gain for generic types of electric and steam appliances installed under a hood can be estimated from the following equation[7]:

$$Q_a = Q_i * FUA * FRA \quad (7)$$

Where  $Q_a$  is the hourly heat gain for general types of appliances,  $Q_i$  is total name plate or catalogue input, FUA is usage factor and it is taken 0.5 and FRA is conservative radiation factor and it is taken 0.32.

**Lighting**[12-14]

Lighting is often the major space load component; an accurate estimate of the space heat gain it imposes is needed. The rate of heat gain at any given moment can be quite different from the heat equivalent of power supplied instantaneously to those lights. The primary source of heat from lighting comes from the light emitting elements, or lamps, although significant additional heat may be generated from associated components in the light fixtures housing such lamps.

Generally, the instantaneous rate of heat gain from electric lighting may be calculated using equation (7):

$$HG_{el} = W * Ful * Fsa \quad (8)$$

In this formula W is total lamp watts, Ful is lighting use factor and Fsa lighting special allowance factor.

At any time, the space cooling load from lighting can be estimated as:

$$Q_{el} = HG_{el} * CLF_{el} \quad (9)$$

Where  $Q_{el}$  is cooling load from lighting in W,  $HG_{el}$  is heat gain from lighting in W and  $CLF_{el}$  is lighting cooling load factor

**People**[12-15]

The total sensible heat gain from people is not converted directly to cooling load. The radiant portion is first absorbed by the surroundings (floor, ceiling, partitions, furniture, etc.) then convected to the space at a later time, depending on the thermal characteristics of the room. The instantaneous sensible cooling load is thus

$$Q_s = N (SHG_p)(CLF_p) \quad (10)$$

Where  $Q_s$  is sensible cooling load due to people, N is number of people, SHG<sub>p</sub> is sensible heat gain per person and CLF<sub>p</sub> is cooling load factor for people.

The latent cooling load of people can be given by the following equation:

$$Q_l = N (LHG_p) \quad (11)$$

Where  $Q_l$  is latent cooling load due to people within the building (The occupants), N is number of people and LHG<sub>p</sub> is the latent heat gain per person

**Simulation computerized modeling Jordanian Green Building Model (JGBM)**

The above mathematical model in addition to green building considerations and Jordanian environmental data are joined together to build up a simulation computerized model using MATLAB<sup>®</sup> software to form the main characteristics structure of JGBM and. Successively this simulation model is operated to perform full subsequent investigations of each structural parameters of JGBM, such that the results of these investigations are presented in the following sections below.

## Results

The simulation model of green building is operated using the data collected in field survey and green building considerations to investigate the characteristics parameters and elucidate their percentage contributions in energy efficiency of this green building model. As a primary illustration of energy saving for part of these parameters the results of simulation investigation were presented through figures (1-5) as following:

### 1. Insulation:

Effect of installing extruded polystyrene insulation on reducing the heat gain through the construction is summarized in figure 1 below for different values of insulation thickness from 3 to 30 cm.

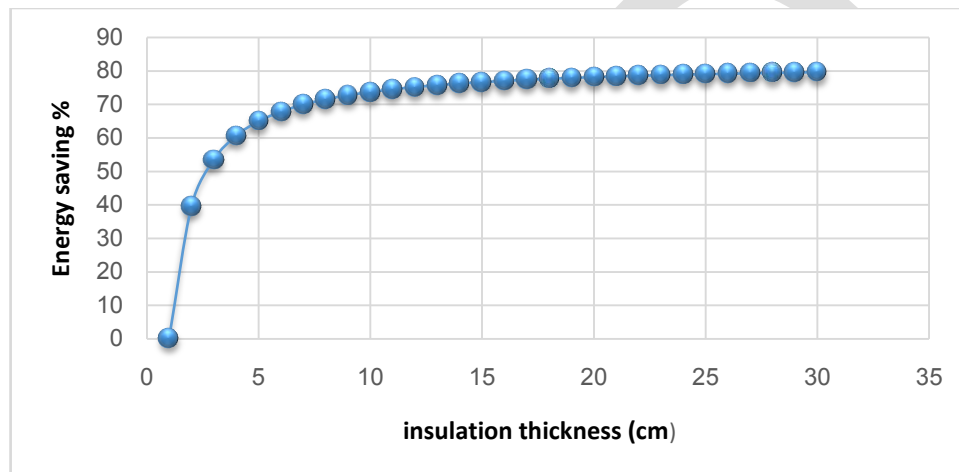


Figure 1: energy saving percent vs. insulation thickness.

It could be noted from figure 1 that a high rate of energy saving (i.e. 55% to 65%) occurs at slightly low insulation thickness range of 3-5 cm. However, the energy saving percent due to insulation reaches its maximum limit of 80% at insulation thickness of 15 cm then the relation starts to have asymptotic behavior at constant energy saving rate of 80% for any insulation thickness more than 15 cm. These findings suggest that the optimal insulation thickness for JGBM structure is 5 to 10 cm to achieve the concentrated range of energy saving of 65% to 80%. Certainly any insulation thickness more than 15 cm will not contribute any further energy saving more than 80% but it will raise the cost and complications of constructions in significant amount without any added benefits.

### 2. Windows Overhangs:

Using the windows overhangs in terms of reducing the heat gain through the windows glass have been studied to find out the optimized range of windows overhangs width on the basis of the energy saving, economic feasibility and the structural possibility. As shown in figure 2, percentage of energy saving increases with overhang width increase in nonlinear relation. Precisely the best recommended range of windows overhang width according to structural considerations is (0.5 to 0.7) m. However this range could be increased with extra structural arrangements and more economical cost, which is in contradiction of the green building necessities.

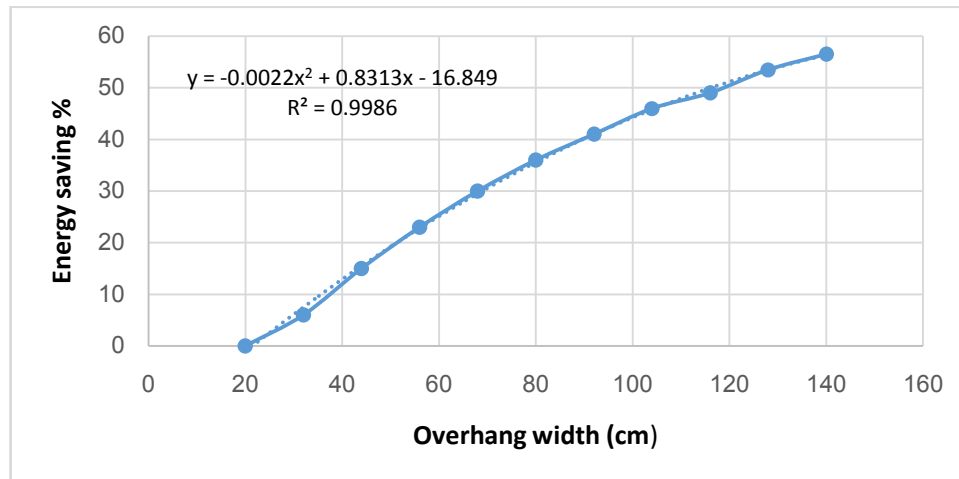
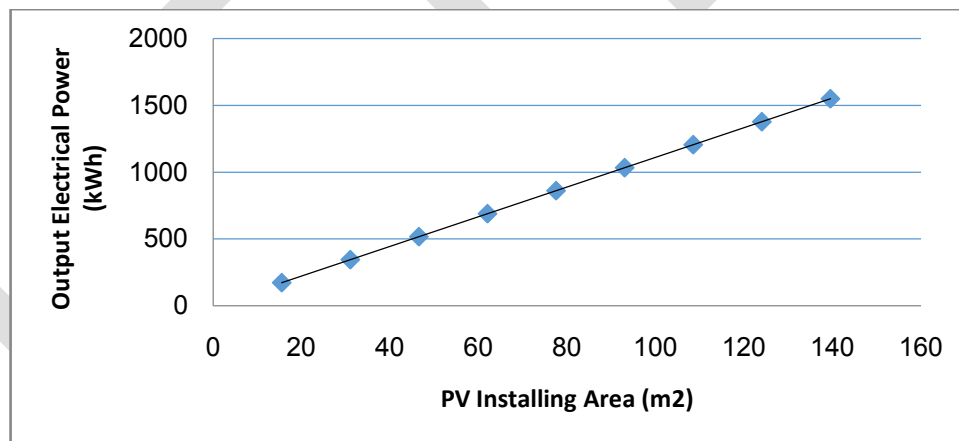


Figure 2: Energy saving according to overhang width.

### 3. Solar Photovoltaic Panels:

The acquired electrical power from the photovoltaic panels is directly proportional to the installing area on the ceiling. As stated from the specialized companies like Indian company of solar technologies “Solar Mango” that rooftop solar PV system typically requires 100-130 SF (about 12 m<sup>2</sup>) of shade-free roof area per kW of capacity [16,17]. The results of the monthly acquired power from the solar photovoltaic panels system of JGBM in proportion to the installing area on the ceiling is shown in figure 3.



Figur 3: The relation between PV installing area and the output electrical power

It could be noted that the range of PV installing area is between 15 to 140 m<sup>2</sup> with an output electrical power range of 200 to 1600 kWh. These ranges are covered the surface area of the proposed buildings of JGBM that are ranging from 150 to 450 m<sup>2</sup>. Also the low or medium range PV output electrical power (i.e., 300-800 kWh) will cover the different electrical needs of JGBM with zero monthly electrical bills, which will minimize the total running cost of JGBM.

### 4. Energy Efficient Lighting

The fourth parameter of the green building considerations is the energy saving lights, so when the LED lights had been chosen instead of the incandescent lighting the amount of energy saving will

be noted easily as shown in figure 4. The LED light will minimize the heat gain from its light by 80% in comparison to incandescent lighting for the better service, longer life and low cost, which enhance the energy saving approach of green building.

Different types of energy efficient lamps had studied and observed that the GE energy smart LED consumes 13 watts with a life of 22.8 years (GE stands for General Electric Company), which is the best energy saving lamp in the present time. Also the LEED-NC for retail 2009 has recommended using this type of lamps, so the GE energy smart LED will be adopted for the proposed JGBM.

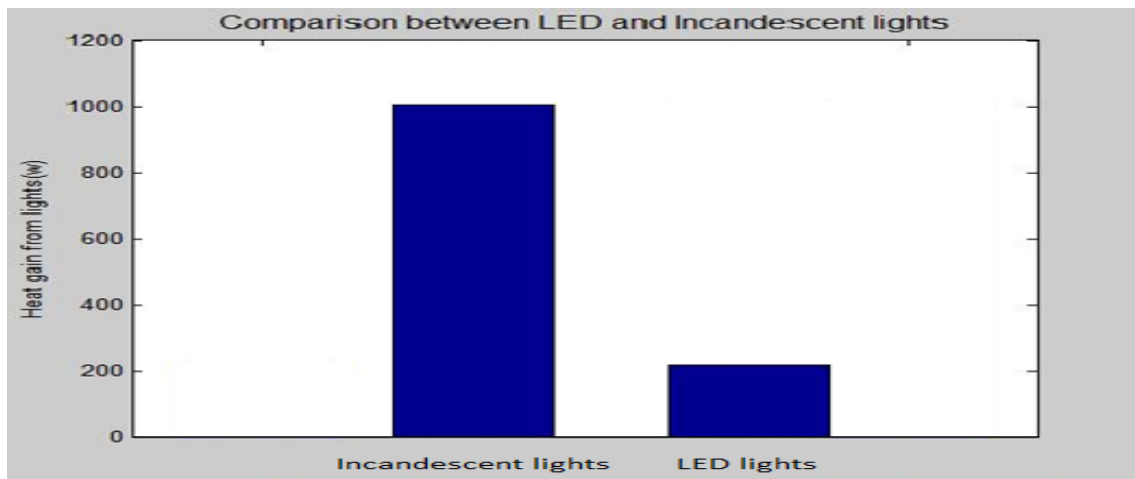


Figure 4: The heat gain from both incandescent and LED lights

Figure 5 shows a summarizing for the above parameters of JGBM and presented the percentage of each parameters in energy saving of green building. The most contribution come from construction insulation by 63.11% then photo voltaic panels by 14.11%, while windows insulation 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%.

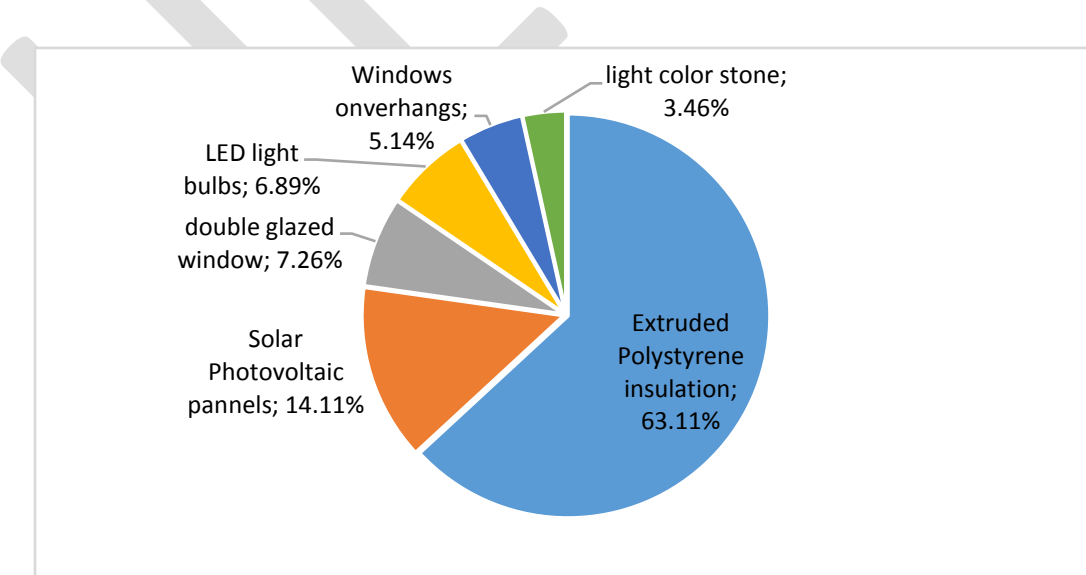


Figure 5: Energy saving percent for typical house



## Discussion and conclusion

The main objective of this study is to select the effective parameters which effect on the energy consumption and saving in green building design that take into account the criteria of the Leadership in Energy and Environmental Design (LEED).

Cooling load due to conduction and convection through the constructions had computed when the extruded polystyrene insulation is given with athickness range of (1cm - 30cm) fig.(1) shows the energy saving percent vs. the thickness of insulation extruded Polystyrene layer.

The curve shows three phases, first phase with thickness (1-5) cm; in this phase the energy saving is significant. The slope of curve is steep which means that the amount of energy saving for this range is very superior

Second phase is ranged when insulation layer thickness (5-10) cm. in this phase the slope of curve decrease comparing with first phase but the saving still considered.

Phase three start after layer thickness 10 cm. in this phase the energy saving will be disappeared, and the energy saving can be ignored after insulation thickness of 15 cm.

It can be observed that the output power from the photovoltaic panels is directly proportional to the installing area on the ceiling, so whenever the area of PV panels increases the energy efficiency will be better.

The PV panels installation are forced by some of restrictions like some local regulations, available area and roof using. For example, in apartment the available area for PV is limited and depends on the number of apartments in the building and normally the roof used for other uses like water storage tanks of air conditions compressors.

Figure 2 shows the percent of energy savingat different overhang width. Based on this figure the energy saving increase with overhang width, the saving start after overhang width 20cm. the energy saving increase based on the following equation:

$$y = -0.0022x^2 + 0.8313x - 16.849$$

Where (y) is energy saving percent (%), and (x) overhang width in (cm).

Also it is important to consider that the high values of overhangs width (more than 70cm) means that overhangs trusses must be installed in order to prove these high width overhangs, so additional cost will be affixed to the primary cost.

The optimized width of windows overhangs on the basis of energy efficiency and economic feasibility can be given by the range of (45cm to 65cm), in other words an energy saving of (23% - 30%) can be achieved.

Lighting systems had studied to choose the best lighting system for the proposed model of the green building in terms of reducing the heat gain from lights.

When the LED lights are used, this can offer an electrical energy saving of 78.2% of the heat gain when it is compared with the incandescent lights, in addition to the reduction on the heat gain from lights with the same percentage of the thermal energy saving (the reduction on the heat gain from lights decreases the cooling load requirements).

The achieved energy saving by using the LED lights is 6.9% of the total saving, so it is an economic value to be taken into account, where it is the third best parameter between the studied effective parameters.

The high efficient windows insulation will make a valuable reduction on the total cooling load requirements. Using high efficiency insulated windows can make high energy saving in comparison with the single glass window.

Using the Argon or Krypton as an inert gas will offer high thermal insulation in compared with air, but in the same time it will create extra cost, which can be obstacle to install these high-price windows types.



When the double glazing windows with air filled installed a proportion saving of 6.26% of the total green building saving will be achieved. So it is a good reduction on the cooling load requirements.

Figure 5 shows the percent of each parameter effect on energy saving, based on this figure the most effective parameter is insulation layer then installation the PV panels which may save about 63.11% of total energy saving.

Finally a comparison between green building and non-green building in terms of the cooling and heating loads requirements apply green buildings items can save about 68% of the cooling load requirements, and about 65% of the heating load requirements.

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