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Energy audit, an approach to apply the concept of green building for a building in Jordan

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ABSTRACT

An energy audit for one department at the faculty of Engineering and Technology at the University of Jordan has been conducted as a way to apply the concept of green building to an existing structure. According to the Jordanian green building code, a classification for the green building has been carried out according to its saving in energy and water in addition to the other factors such as indoor quality and material.

The heating and cooling loads were calculated and the results were compared with the values for the same building after amendments to the windows and walls. The insulation for external walls of the building has been introduced in addition the double glazing instead of the current single glass windows for the building. The electricity for the lighting consumption of this building was obtained and analyzed and the potential of utilizing a lighting sensor for different halls and rooms was studied and analyzed. The boiler performance has been studied and an estimation of efficiency enhancement was proposed. It has been found that choosing a larger window area facing south, east and west can save more energy in winter and decreasing the heating costs using a certain types of double glazing, while decreasing the glazing area facing north can save money and energy. Also, it has been found that the payback period for the annual saving in fuel and electricity bills is less than 3 years. The needed investment for obtaining the energy saving is shown in the paper.

1. Introduction and methodology

Energy took an important place through the Human being history, starting from the prehistoric age. Before 1970, the supply and consumption of energy were relatively obscure matter to most people. Within less than a decade, however, “energy” has emerged as one of the most provocative words of the times.

Energy demand in Jordan is increasing largely during the last 20 years and it will continue increasing by the same rate. Energy consumption might be doubled between 2015 and 2020 referring to low production of energy and high growth of energy, (Al-Saeh, Al-Heeh, & Dolat, 2010).

The shortages and high prices that occurred with the oil embargo of 1973 and the rapid economical development, combined with the growing prices of energy, lead to an increasing recognition and understanding for the need of energy audit.

The running cost of green building is considered to be less than conventional buildings because the benefits of typical green buildings exceed the additional costs. Within the first two or three years and over a 15 year period provide financial benefits about ten times larger than the extra cost of building green.

Now homeowners and business owners are interested in upgrading their homes and facilities to be more energy efficient and to reduce the cost of their monthly energy bills, (Free Guide, 2010).

In the last few years, energy and electricity price in Jordan increased many times. The energy bill for Jordan represents 20% of the Jordanian GDP and it affects the most aspects of the Jordanian life. Therefore, the motivation in the country is moving quickly toward the energy saving buildings in order to reduce the operating cost of the building.

The main goal of this study is to use energy audit to reduce energy consumption rate of an existing building at the University of Jordan, by understanding how energy is being presently used and possibly being wasted and to recommend proper condition that

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ensure human comfort of users of the department. The novelty of this study is that it suggests some important points that should be taken into consideration to reduce energy bell in an important building in Jordan.

The methodology which was adopted for this audit was visual inspection and data collection, observations on the existing condition of the facility, equipments and quantification, identification/verification of energy consumption and other parameters by measurements and potential energy saving opportunities.

The calculation of the cooling and heating loads in each zone of the building is the most important step in determining the size of the cooling and heating equipment. Cooling and heating load calculations were conducted to size HVAC (heating, ventilating, and air-conditioning) systems and their components. In principle, the loads were calculated to maintain the indoor design conditions and reduce energy consumption, e.g. (Bhatia, 2012; Green Seal, 2011).

As infiltration in building has great effect on the fuel consumption, highly performance and very well sealed openings (doors and windows) were used in the building so the influence of infiltration was considered to be ignorable.

2. Study case

The case study, which was investigated, was a department at the faculty of engineering and technology at the University of Jordan in Amman. The total area of each floor in the department is about 400 m^2. The maximum temperature at the University of Jordan is taken as 35 °C, and the minimum is 2.4 °C. The inside designed temperature is considered as 24 °C, the maximum relative humidity is 75% and the minimum relative humidity is taken to be 45%. The Latitude of Amman is 32.1 N and the longitude is 35.52 E. The department has five floors; each floor has unequal sections: classrooms, halls, bathrooms, stairs and offices. One floor at the department was built under ground and the other four floors stand over it by 13 m.

3. Heating and cooling load calculation

The calculation of heating and cooling loads on a building or zone is the most important step in determining the size of the cooling and heating equipment which means savings in initial and operating cost of mechanical equipment and increased comfort to occupants. Heat loss is divided into two groups:

- The heat transmission losses through walls, floor, ceiling, glass, or other surfaces.
- The infiltration losses through cracks and openings, or heat required to warm outdoor air used for ventilation.

The following equations are mainly used to calculate the heating load,

$$Q = A * U * (Ti - To) \tag{1}$$

$$Q_{\text{sensible}} = V_f * \rho_{\text{air}} * C_p * (Ti - To) \tag{2}$$

where U is the overall heat transfer coefficient and its values for wall is 1.7 W/m^2 °C, for doors is 2.8 W/m^2 °C, and for window single glass is 6.7 W/m^2 °C (AL-Saad and Hammad, 2009).

$$V_f = \text{No. of } ACH/h * \text{Room Volume} \tag{3}$$

$$\rho_{\text{air}} = 1/\nu_o,$$

Using psychometric chart, it was found that the value of ν_o = 0.89 m^3/kg (AL-Saad and Hammad, 2009).

Cooling loads fall into the following categories, based on their sources:

- Heat transfer (gain) through the building skin by conduction, as a result of the outdoor–indoor temperature difference.
- Solar heat gains (radiation) through glass or other transparent materials.
- Heat gains from ventilation air and/or infiltration of outside air.
- Internal heat gains generated by occupants, lights, appliances, and machinery.

Because of the inherent differences in these types of heat flows, they are calculated using the following equations

- Heat transfer through floor, doors and ceiling

$$Q = U * A * (T\text{adj} - Ti) \tag{4}$$

- Heat gain due to solar effects

$$Q_s = U * A * (CLTD)_{\text{corr.}} \tag{5}$$

- Heat gain through the glass window

$$Q_g = A * (SHG) * (CLF) * (SC) \tag{6}$$

- Heat gain due to occupancy

$$Q_{oc} = (\text{No. of person} * SG/1000) * (CLF)_{oc.} \tag{7}$$

- The heat gain due to lights

$$Q_{Lt} = (\text{Insulated lamp} * A/1000) * (CLF)_{Lt.} \tag{8}$$

- Heat transmitted due to infiltration

$$Qf = (Vf/vo) * (ho - hi) \tag{9}$$

where U for floor is 2.1 W/m^2 °C, for doors is 2.8 W/m^2 °C, for ceiling is 1.8 W/m^2 °C and for window single glass is 6.7 W/m^2 °C (AL-Saad and Hammad, 2009). The above values of U were obtained from Amman Chamber of Industry 2007.

$$T_{adj} = 29\,°C. \tag{10}$$

$$(CLTD)_{corr.} = (CLTD + LM)k + (25.5 - T_i) + (T_{o,m} - 29.4)f$$

where k = 1.0 and f = 1.0 for no roof fan and 0.75 if there is roof fan.

To find the saving, cost and payback period the following equations were used

$$S = (Q1 - Q2) * N * H * Ce, f \tag{11}$$

$$\text{Cost} = A_{w,g} * (\text{Cost of new unit} + \text{Installation process}) \tag{12}$$

$$\text{Payback period} = \text{Cost/Saving} \tag{13}$$

Heating and cooling load can be reduced by changing the type of window glass and insulating walls (NLPIP, 1990). Using double glass instead of single glass reduces solar heat gain in windows as shown in the Fig. 1.

The more heat flow resistance insulation provides, the lower the heating and cooling cost. Properly insulating the building not only reduces heating and cooling costs but also improves comfort, (Touqan, Yaseen, Zakarneh, & AL-zamer, 2012).

In this work, the glass was changed from single glaze to double glaze so that the U-value has been changed from 6.7 W/m^2 °C to 3.5 W/m^2 °C. Also the walls were insulated so that the U-value has been changed from 1.7 W/m^2 °C to 1.2 W/m^2 °C.

4. Lighting audit

The energy which is used for lighting inside the building is large and replacing the conventional lighting fixtures and lambs with more efficient fixtures and lambs can help in reducing the operating costs and the overall effects of electricity generation on the environment. To conduct lighting audit, basic lighting information was