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A Simulated Case Study of Office Building in Pakistan to Improve the Energy Efficiency

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Abstract— Office buildings are one of the basic consumers of energy everywhere including Pakistan. As a case study, the present research effort focuses on estimation of energy consumption of a three-storey office building located in Islamabad Pakistan. Essential data was collected and simulated through eQuest Software. Important parameters like window size, double glazing, energy saving lighting, higher thermostat set point and efficient air-conditioning equipment, are then taken as decision variables and are simulated to study their impact on energy consumption. Cost factor in the prevailing market and the payback period including comparison with the baseline model is also presented in this research effort. Results showed that 37.7% of electrical energy used for cooling purposes can be saved by improving the above parameters.

Index Terms— EEM, Energy Efficient, HVAC, Area Lights

I. INTRODUCTION

Energy consumption is directly proportional to the industrial expansion and population growth. To be with the pace of growth not only new energy resources are discovered but focus is placed on efficient use of available ones. Residential and office buildings are the primary consumers of energy, around 25 – 40% in many countries, and major part of this is used to fulfill needs of HVAC (Heating ventilating and air conditioning) [1]. Tsinghua University China [2] reported that 15% of China's available energy is consumed for fulfilling heating and cooling needs of buildings. CO_2 is major byproduct of this energy consumption and causing threat to environment [1]. Therefore, energy efficiency is becoming more important around the globe. Equal attention should be paid to the aesthetic looks of the buildings and energy efficiency measures by coordinating with HVAC engineers and building physics professionals [3]. Due to various national and international issues the world resources are uncertain in terms of availability over building life [4]. Therefore, it is necessary to consider the energy efficiency in building designs. The concept of zero energy buildings [5] and initiatives, such as taken by European Union to reduce CO_2 emissions [6] can help us to achieve better energy efficiency and environment. The difference between the available energy resources and energy demand is increasing at a rapid pace in Pakistan [8, 9].

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II. BASELINE MODEL

Temperature profile of Pakistan divides the climate in five categories naming; hot, warm, mild, cool, and cold [10]. Weather data available on DOE2 website forms the basis of current research effort [11]. The National Energy Conservation Center (ENERCON) has suggested making the future buildings more energy efficient by minimizing the consumption by 30% [12]. Therefore, South facing office building of 734 m^2 was selected. The required design data of this baseline building was collected and simulated in energy simulation tool eQuest [11]. In depth analysis of building envelope were performed to calculate heat transfer coefficients. The coefficients were in range of 2.0±0.5W/ m^2/°C for exterior walls, partition walls, and roof. For Inner floors slab it was 3.27 W/ m^2/°C while for glass it was 5.96 W/ m^2/°C. Other features included absorptance of 0.7 for walls and 0.6 for roof slab, 15.2 cm in reinforced slab and 6 mm single glazed windows. Table 1 shows the windows-to-wall percentages and lighting power density, respectively.

Table 1. Windows to Wall Percentage of Office Building [13]

Walls	Gross area (Ground to Roof) m^2	Windows area
East Wall	93.64	19%
West Wall	93.64	13.00%
North Wall	314.383	19.00%
South Wall	314.38	28%

The lighting power density was calculated from the information of the building. The average lighting power density of Executive offices, General offices and Computer Rooms was 3.0±0.1 W/ m^2. An infiltration rate of 0.0035 CMM/m^2 based on crack length method and ventilation rate of 0.57CMM/person was used [4]. Based on the building data the occupancy, in terms of m^2/Person, was 8.0±1 for Executive offices and General offices while 3.7 for computer rooms.

III. RESULTS AND DISCUSSION

A. Office Baseline Model

The office building was simulated with the data presented above and the results were obtained. Building peak occupancy is from 8 am to 4 pm Monday to Friday. High energy consumption was found in the months of June, July and August due to peak summer conditions (Figure 1- Baseline Model).

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The total annual electrical energy consumption for space cooling is 35,890 Kilo Watt hour (KWH).

B. Office Baseline Model and Windows area Energy Efficient Model (EEM) Comparison

The windows-to-wall percentages were calculated for the actual office building followed by optimization. Both of the percentages are mentioned in the Table 2.

Table 2. Windows Area Details of Office Baseline and Energy Efficient Model [13]

Walls	Baseline Windows area	Windows Energy Efficient model
East Wall	19%	4%
West Wall	13%	4%
North Wall	19%	10.5%
South Wall	28%	15.8%

The reduced windows size from 3.34 m^2 to 1.85 m^2 yielded reduction is annual electrical energy consumption to 10.5%. The monthly analysis is shown in Figure 1 (Window Area Reduction EEM).

C. Office Baseline Model and Double Glazing EEM Comparison

If double glazed window is used, the Overall heat transfer co-efficient for glass reduces to 3.12 W/ m^2/°C from 5.96 W/ m^2/°C. The color of the window glass also reduces the shading coefficient (SC) and visible transmission (VT). Brown tinted double glazed window have SC of 0.7 and VT of 0.62 which is 20% less than that of the single glazed plain glass used in the building. The single glazing was changed to double glazed brown tinted without changing the window size and the building was resimulated. This change has reduced the annual energy concusmption by 5.0% as shown in Figure 1 (Window Glazing Type EEM). The cost analysis based on the prices [14] of local market was also carried out and the annual return in terms of electrical energy saving was calculated. The additional initial investment is the difference of the prices for double and single glazing, which comes out to be PKR 272500/- First year annual return achieved is PKR. 22044/. In this way the additional initial investment can be recovered in less than 12 years.

D. Comparison of Office Baseline Model and Area Lighting EEM Model

To reduce the light power density, lights were replaced with 23 W energy saver bulbs. In way the overall lighting power density was reduced to 1.38±0.1 W/ m^2 from 3.0±0.1 W/ m^2. Changing of light source in energy saver bulbs showed 3.4% saving in the context of space cooling (Figure 1 – Area Lighting EEM). The market servey was conducted and both the savings and costs [14] were studied. The acumlative cost and the the saving analysis showed that the additional investment can be achieved back in the first year.

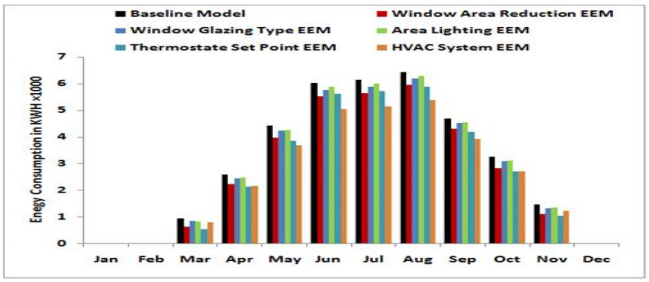

Figure 1. The Year Round Energy Consumption of the Baseline Model and Models with Different EEM

E. Comparison of Office Baseline Model and Thermostat Management EEM Model

Thermostat set points should be optimized for reducing the space cooling energy consumption. In the Thermostat Management EEM model thermostat set point temperature was set at 26^{0}C against the common practice of 24^{o}C. This has led to 12.0% savings (Figure 1- Thermostate Set Point EEM).

F. Comparison of Office Baseline Model and HVAC System EEM Model

Selection of efficient HVAC system is one of the important measures to get energy efficiency. Two different air-conditioning systems were considered with Energy Efficiency Ratio (EER) of 9.00 and 10.54 respectively. The simulation result shows 16.4% saving by selecting the high EER value equipment (Figure 1-HVAC System EEM). The market servey showed that higher EER value increase the capital costs[14]. Cooling load estimation revealed requirement of 22 units of 1.5 Tons capacity. Simulation results showed that this additional cost can be recovered within 5 years.

G. Comparison of Office Baseline Model and Energy Efficient Model

Based on the energy efficiency measures discussed above the building model was termed as energy efficient model. Energy saving was observed by incorporating the above mentioned EEM. It is evident from the results that 37.7 % saving can be achieved as shown in Figure 2.

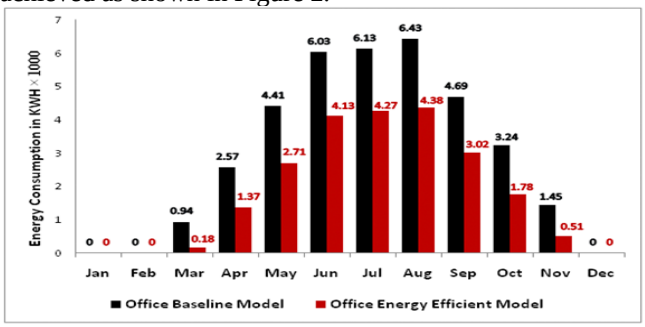

Figure 2. Comparison of Office Baseline and Energy Efficient Models

Based on the costs [14] and annual saving return as a result of electrical energy saving, the cost-benefit was also analyzed. Figure 3 show that saving pays back the investment in the first four years of operation. The windows area reduction and the turning the thermostat set point to the efficiency mode are bonus for energy saving, i.e. saving return without additional investment.

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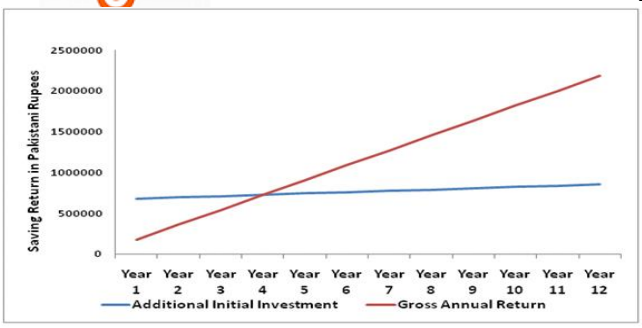

Figure 3. Cost Analysis of Energy Efficient Office Building Model

IV. CONCLUSIONS

Energy efficiency measures are important in the almost all type of buildings. To improve the energy resource management, five measures were applied to the baseline model of an office building and annual energy savings were visualized. It was found that additional investment of 678475/- PKR will be required to modify the existing building into an energy efficient one with the same size as that of the baseline model. Results show that energy efficient model requires 37.7% less energy than the baseline model under the similar operating requirements. It was estimated that payback period of this additional initial investment is three years. Based on the tariff of Islamabad Electric Supply Company, the first year saving return is 178728/- PKR. These measures can be applied with considerable ease and more economically in new construction ventures. This study can be helpful in providing energy efficient measures for the new office buildings in the initial design phase. This study shows that applying small measures can gives a huge saving. It is evident that applying the simple measure of setting thermostat at 26^{o}C higher point saves 12% of energy without any additional investment and without disturbing the comfort level.

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