

## **Facing the Growing Problem of the Electric Power Consumption in Egyptian Residential Building Using Building Performance Simulation Program**

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**Abstract:** Egypt has been experiencing recurrent power cuts especially at the summer, with the problem being made worse by the extra demands placed on the electrical grid by the advent of the holy month of Ramadan. Electricity shortages are now a problem in Cairo, Alexandria, Sohag, Qena, Luxor, Aswan, and Nubia, as well as in the Nile Delta governorates of Beheira and Qalioubiya. The aim of this study is to develop a model for the Egyptian residential building using Building Performance Simulation Program and make sensitivity analysis on some variables effecting the electric power consumption in order to help faceting the growing problem in Egypt. The model was created using the IES-VE 2012 (Integrated Environmental Solution <Virtual Environment>).

The simulation model was verified against the survey data for the Egyptian apartment and same model simulated using energy Plus simulation tool. The results of the program describing different situations for energy using profile for the air conditions, lighting and equipments in respect to building layout and construction climate and pattern of use. This model can be used in the future to help in reducing the electric power consumption in the residential building.

**Keywords:** Egyptian residential building, Building Performance Simulation Program in Egypt

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### **1. Introduction**

The effects of energy use in buildings are nationwide, worldwide, and varied. Having a fundamental impact on people's lives, these effects include the economic well-being of the nation, the dependence of the countries on foreign oil, and national security. On an individual basis, even human health can be affected by building energy use when rising energy costs render a conditioned, comfortable, healthy indoor environment unaffordable. On a larger scale, carbon emissions, which are directly tied to building energy use, affect the health of our planet.

Egypt has been experiencing recurrent power cuts since the beginning of summer, with the problem being made worse by the extra demands placed on the electrical grid by the advent of the holy month of Ramadan. Electricity shortages are now a problem in Cairo,

Alexandria, Sohag, Qena, Luxor, Aswan, and Nubia, as well as in the Nile Delta governorates of Beheira and Qalioubiya.

Several Cairo districts have been experiencing regular power cuts, especially Helwan, Shubra, Maadi, Haram, Heliopolis and Nasr City. In Upper Egypt, residents of the town of Sohag protested against the power cuts last week, and the police had to prevent them from attacking the electricity company's offices and governorate buildings.[1]

In Egypt, residential buildings are the major consumer of energy in a country Figure 1 where 45% of the population lives in urban areas. In 2009/2010, the residential building sector consumed more than 48% of the total nationally generated electricity.[2]

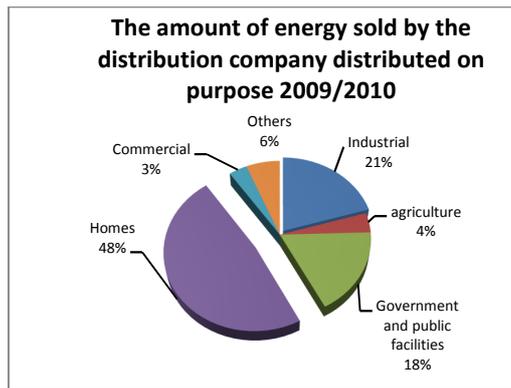


Figure 1 - Percentage of Electric Power Consumption in Different sectors for Egypt 2009/2010

The main scope of the present study is providing a model using building simulation tool for the typical apartment in Egypt and use it to make a sensitivity analysis for this building as to reduce the electric power consumption on peak hours.

#### Literature Review

The PASSYS project was formed in 1986 by the Commission of the European Communities with the aim of increasing confidence in passive solar heating systems. One of the ways chosen to do this was the approval/development of a European validation methodology for building energy simulation programs. Sren Ostergaard Jensen made Model Validation and Development Subgroup within PASSYS.[3]

JOSEPH C. LAM et al. in 1996 made a sensitive analysis for energy performance of office buildings in Hong Kong. Sensitivity methods for the study of building energy performance are explained. The DOE-2 building energy simulation program is used on a generic model of an office building to generate data for the study. Important input design parameters are identified and analyzed from points of view of annual building energy consumption, peak design loads and

building load profiles. It is believed that sensitivity techniques are use full for assessing thermal responses of buildings and data variability in building energy simulation.[4]

J.A. Clarke et al. in 2002 describes the development and testing of a prototype simulation-assisted controller, in which a detailed simulation program is embedded in real-time control decision making. LabVIEW was used as a BEMS replacement and the dynamic simulation program ESP-r was used for control scenario appraisal. This paper described an experiment undertaken with the prototype control system in full-scale rooms within Honeywell's test facility, demonstrating how such a system could be used to generate optimum start times.[5]

Drury B. Crawley et al. In 2008 made an overview of a report, which provides up-to-date comparison of the features and capabilities of twenty major building energy simulation programs: BLAST, BSim, DeST, DOE-2.1E, ECOTECH, Ener-Win, Energy Express, Energy-10, EnergyPlus, eQUEST, ESP-r, IDA ICE, IES/VES, HAP, HEED, PowerDomus, SUNREL, Tas, TRACE and TRNSYS they were found that even among the 'mature' tools, there was not a common language to describe what the tools could do. There was much ambiguity, which will continue to require additional work to resolve in the future.[6]

D.J. Sailor in 2008 developed and integrated into the EnergyPlus building energy simulation program a physically based model of the energy balance of a vegetated rooftop. This green roof module allows the energy modeler to explore green roof design options including growing media thermal properties and depth, and

vegetation characteristics such as plant type, height and leaf area index. The model has been validated by applying it to data gathered from a detailed field study in Florida. Throughout the study it is found that Increasing vegetation density had the expected result of reducing summer electricity usage, but increasing winter heating energy use due to the shading effects that are more useful in summer, but detrimental in winter. Finally, increasing summer irrigation also had the expected results, being more effectively in the less humid of the two climates.[7]

Shady Attia et al. In 2012 developed representative simulation building energy data sets and benchmark models for the Egyptian residential sector. Through the study a recent field survey for residential apartment buildings in Egypt. Two building performance simulation models are created reflecting the average energy consumption characteristics of air-conditioned residential apartments in Alexandria, Cairo and Asyut. Aiming for future evaluation of the cost and energy affects of the new Egyptian energy standard this study established two detailed models describing the energy use profiles for air conditioners, lighting, domestic hot water and appliances in respect to buildings layout and construction. Using Energy Plus simulation tool the collected surveyed data was used as input for two building simulation models. The results presented in this paper, can provide a good basis for investigating the potential energy savings of applying the new Egyptian energy standard.[8]

Shady Attia presents in 2012 energy-oriented software tool that both accommodates the Egyptian context and provides informative support that aims to facilitate decision making of

zero energy buildings. A residential benchmark was established coupling sensitivity analysis modeling and energy simulation software (EnergyPlus) as a means of developing a decision support tool to allow designers to rapidly and flexibly assess the thermal comfort and energy performance of early design alternatives. Validation of the results generated by the tool and ability to support the decision making are presented in the context of a case study and usability testing.[9]

## **2. Methodology**

The methodology implemented in this paper includes aspects which determine the energy consumption characteristics of air conditioned residential buildings in Egypt. The methodology followed is similar to other recent international energy consumption study. The first step was to validate the new model made by the IES-VE with another one made in resent research. The second step was to make sensitivity analysis for some variables which affect the electric power consumption and discusses the results of these modifications. Hourly weather readings for the year 2008 for Alexandria was obtained from The EPW format used in EnergyPlus (Shady Attia, Arnaud Evrard and Elisabeth Gratia). The following sections describe in detail the steps undertaken.

### **2.1. Validation**

Validation is a complex process which can be defined as follows: a rigorous testing of a program comprising its theoretical basis, software implementation and user interface under a range of conditions typical for the expected use of the program.

In practice it is not possible to perform a complete validation of a program - there are, especially for building energy simulation programs, too many interlinked factors and too many possible applications to test all combinations. It is, however, possible to increase the confidence in a simulation program by applying a well documented and comprehensive validation methodology combining several validation techniques.

Validation methodology should be comprehensive, i.e., it should include both non-empirical as well as empirical validation techniques, which are to be applied both at the level of single processes as well as at the level of whole models. A comprehensive validation methodology should consist of a literature review, code checking, analytical verification, intermodal comparison, sensitivity studies and empirical validation.

## 2.2. Building Description

The block shown in Figure (3,4), was found to model for residential buildings in the Alexandria Figure (2). The block is of base 25 m \* 11 m\* 18 m with a 2.3:1 aspect ratio. The total area of one apartment is 122 m<sup>2</sup> with a net conditioned area of 60 m<sup>2</sup>, representing three rooms per apartment.

The basic building construction is a reinforced-concrete post and beam structure with 0.15 m thick brick infill walls without insulation. Windows are single glazed, transparent and have a 0.003 m thick glass pane. The total amount of glass in the North and South facades is estimated to be between 45% and 35% of the total wall area. There is no solar protection for the

facades and most wooden windows are draughty.

All the building description are given in table (1) and the room occupancy and lighting variation are given in the figure (5).



Figure 2 - Egypt Map

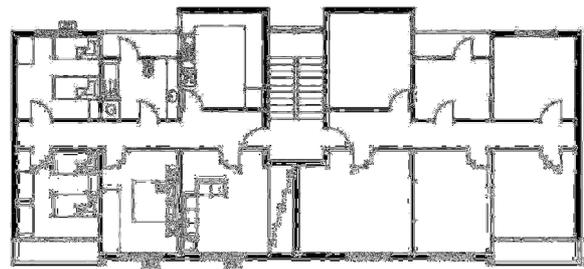


Figure 3 - Typical Floor Plan of the model

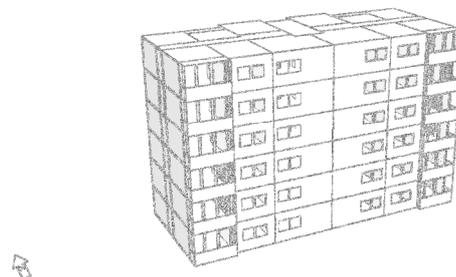


Figure 4 - Building Layout

Table 1 - Building Description of the Simulation Model

<b>Building Description of the Simulation Model</b>		
	<b>Model Inputs</b>	<b>Value</b>
<b>Envelope</b>	U <sub>Wall</sub> (W/m <sup>2</sup> K)	1.732
	Wall Surface Absorption, CCF	0.7
	U <sub>Roof</sub> (W/m <sup>2</sup> K)	1.39
	Roof Surface Absorption, CCF	0.6
	U <sub>Single Glazing</sub> (W/m <sup>2</sup> K)	6.25
	Shading Coefficient for Glazing, SC	0.7
	Solar Heat Gain Coefficient, SHGC	0.5
<b>Ventilation &amp; air Conditioning</b>	COP	2
	SEER	6.8
	Outside Air (m <sup>3</sup> /h per person)	20
	Temperature Set Point (°C)	24
	Relative Humidity Set Point (%)	60
<b>Occupancy</b>	Density (m/person)	26
<b>Lighting</b>	Installation Power Density (W/m <sup>2</sup> ) Living Room	17
	Installation Power Density (W/m <sup>2</sup> ) Bedroom	13
	Installation Power Density (W/m <sup>2</sup> ) Other	9
<b>Plug Loads</b>	Average Installation Power Density (W/m <sup>2</sup> )	6
<b>DHW</b>	( October - April ) (l/h)	1.779
	( May - September ) (l/h)	0.254

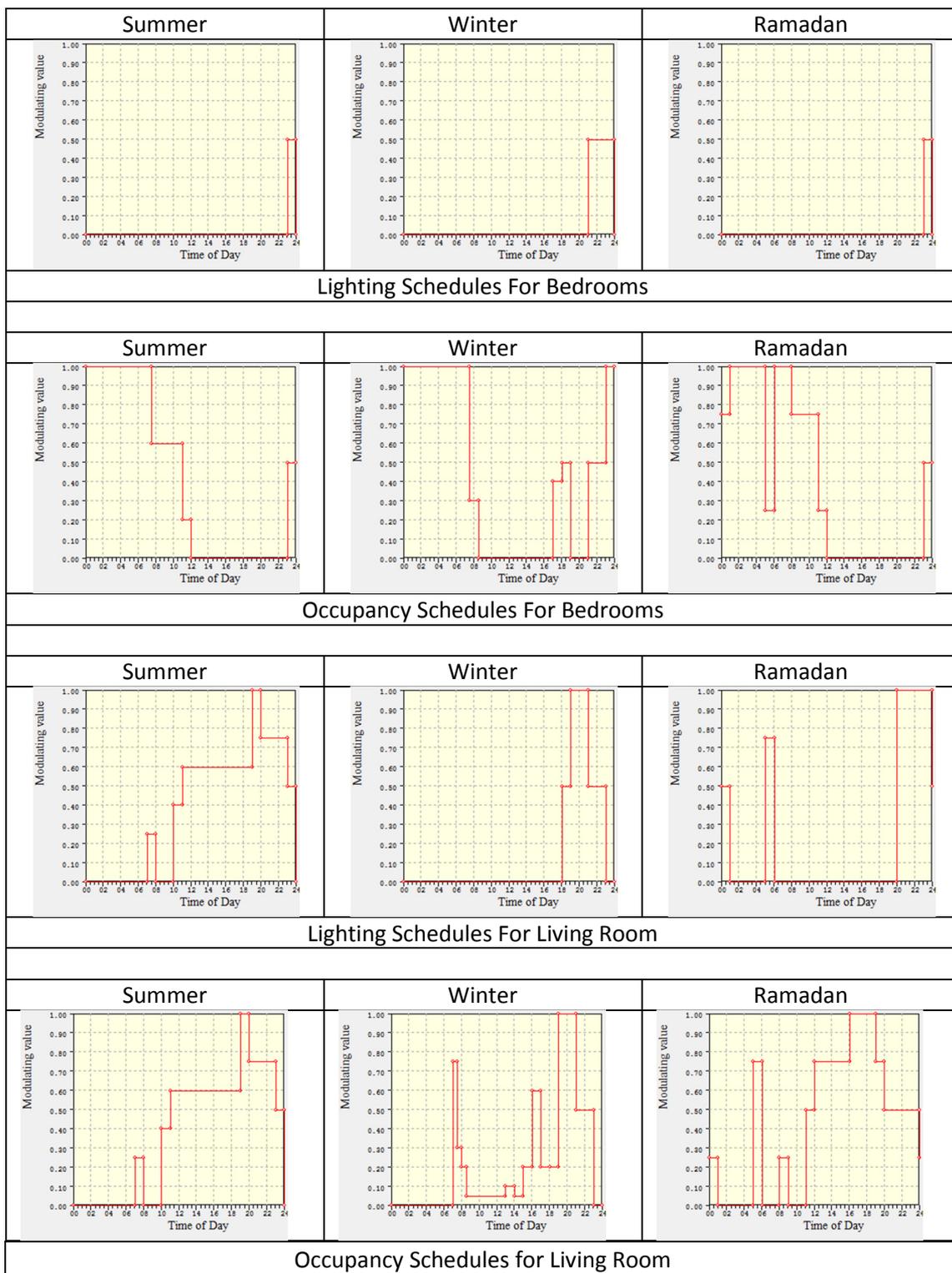


Figure 5 - Occupancy and Lighting Schedules for Bedrooms and Living room

In order to help in solving the regular power cuts problem development of verified model was required. First of all the model made by IES-VE was verified by the same model made by Energy Plus tool. Figure (6) shows the monthly electricity consumption for the both models. The electricity consumption patterns of residential apartments would be significantly affected during the extended summer period (April – October).

### 3. Sensitivity Analyses

When performing building energy simulations, certain energy changes from the input variables are more significant than others, implying that selected inputs should be given particular attention during modeling. Also, high-sensitivity elements are important from both technical and economic points of view and should be designed with utmost care if optimization of the system performance is to be achieved. Therefore, a great deal of engineering work is devoted to testing the sensitivity of systems. These studies are collectively called sensitivity analysis and may involve a range of different analytical methods.

Sensitivity theory has been used for assessing the thermal response of buildings and their energy and load characteristics. The aim of sensitivity analysis is to observe the system response following a modification in a given design parameter. For example, one may want to know to what extent building loads and energy consumption are responsive to changes in the coefficients of material properties, design of building envelope, selection and operation of heating, ventilation and air-conditioning (HVAC) systems, and so on. If we can understand the relationships and relative importance of these parameters, we will be able to

achieve optimum building energy performance through proper selection of design variables and conditions.

However, there are no formal rules and well-defined procedures for performing sensitivity analysis for building design because the objective of each study may be different and building descriptions are quite complicated.

In most cases, perturbation techniques and sensitivity methods are being used to study the impacts of input parameters on different simulation outputs, as compared to a base case situation. Then, the results are interpreted and generalized so as to predict the likely responses of the system.

### 4. Discussion

Some variables will be discussed as to study their effect on the total electricity consumption; first variable to be discussed was the number of occupancy. Figure (7) shows the monthly electricity consumption at different occupancy. Second variable to be discussed was using Fluorescent lamps instead of the tungsten lamps. Figure (8) shows the amount of saving each month due to using fluorescent lamps instead of tungsten, while Figure (9) shows the monthly electricity consumption using the fluorescent lamps with different occupancy number. Third variable was using heating system during winter season. Figure (10) shows the monthly power consumption when heating system was added to the same model with different number of occupancy. Figure (11) the monthly power consumption when heating system was add to the same model and using fluorescent lamps instead of tungsten lamps with different number of occupancy shows.

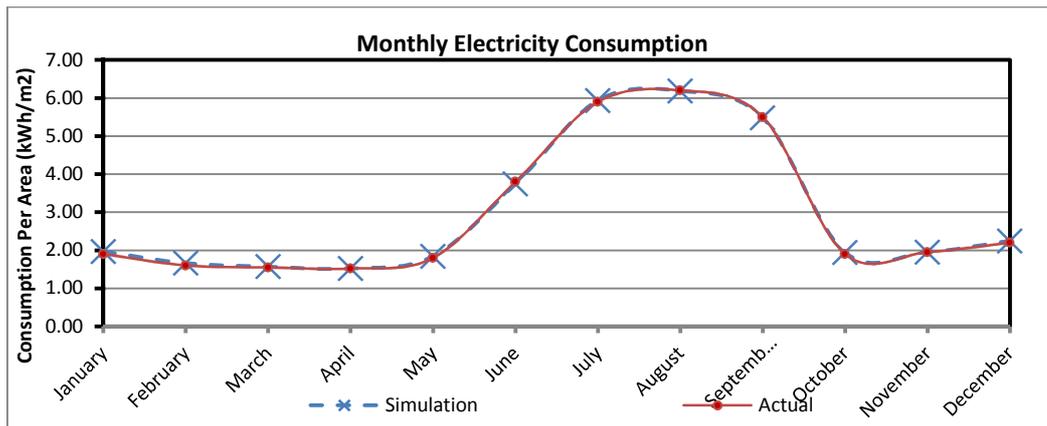


Figure 6 - Results for Validation

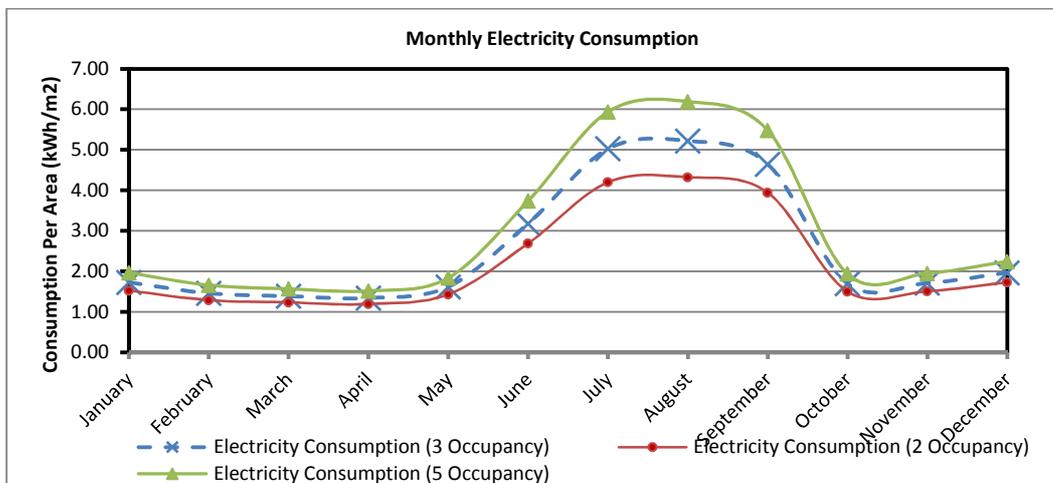


Figure 7 - Monthly Electricity Consumption at Different Occupancy

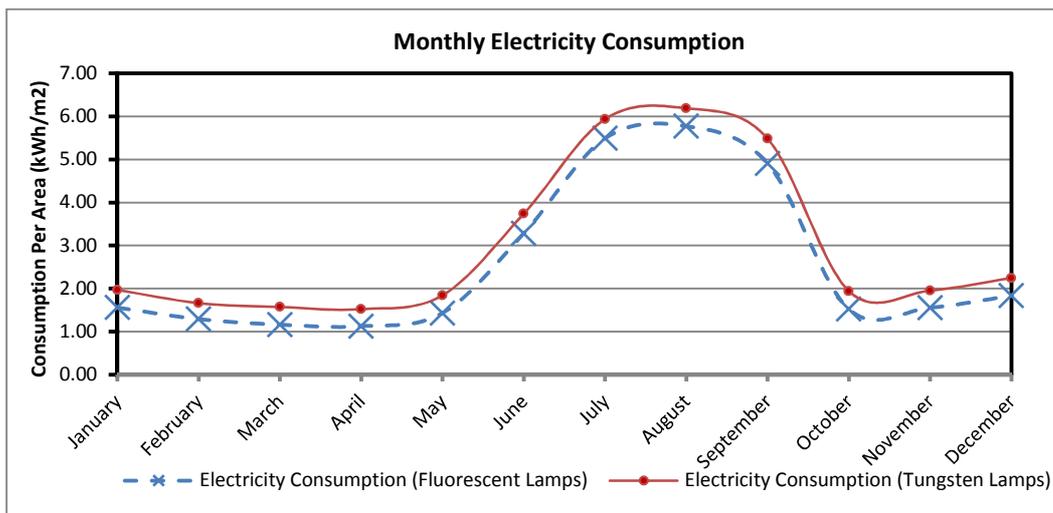


Figure 8 - Monthly Electricity Consumption Using Different Types of Lamps

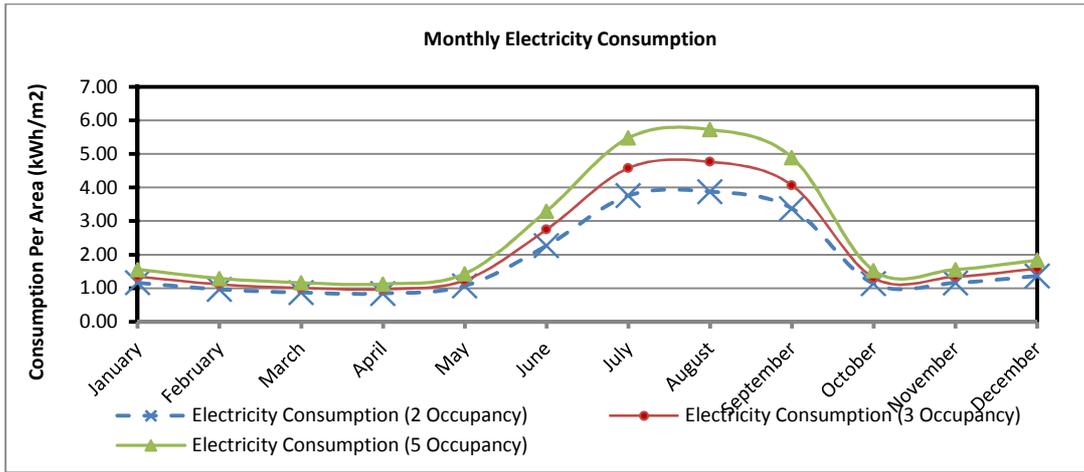


Figure 9 – Monthly Electricity Consumption at Different Occupancy & Using Fluorescent Lighting Lamps

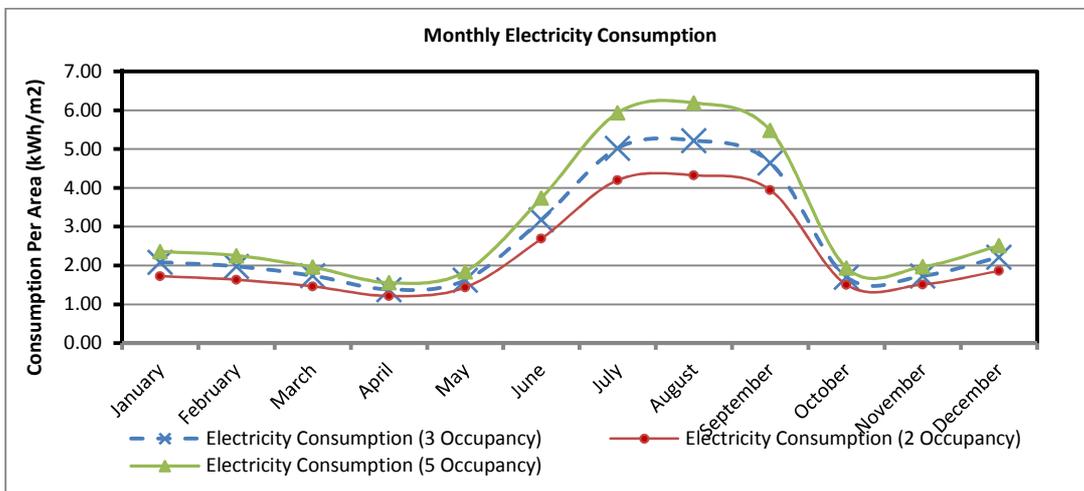


Figure 10 - Monthly Electricity Consumption at Different Occupancy & Using Heating Systems

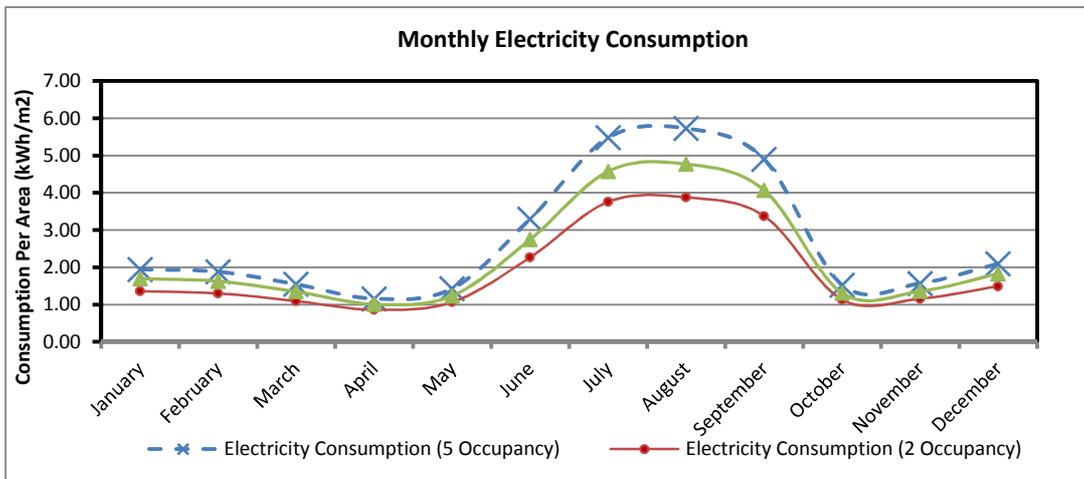


Figure 11 – Monthly Electricity Consumption at Different Occupancy, Using Heating Systems and Fluorescent Lamps

Fourth variable to be discussed was changing the glazing shading coefficient in addition to open the window according to schedule. Figure (12) shows the monthly electricity consumption when the windows are opening according to a schedule and the Shading Coefficient of the glass using inside Curtin are applied. There is no imperceptible saving this due to mainly the air condition working after

noon and during night. Figure (13) shows the monthly electricity consumption when changing the set point temperature of the air conditioning units while Figure (14) shows the electricity consumption when changing Coefficient Of Performance (C.O.P) of the air conditioning units.

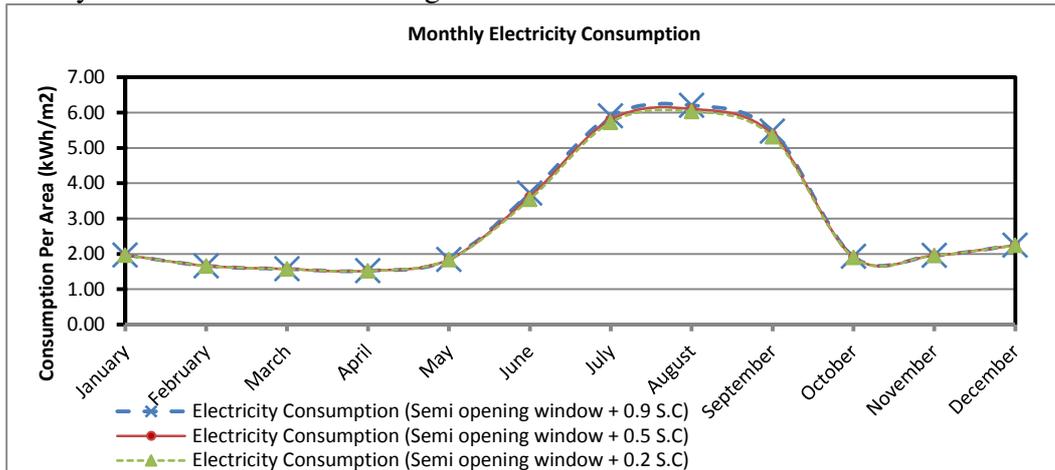


Figure 12 - Monthly Electricity Consumption while the Windows are Simi Opening according to schedules with different shading Coefficient

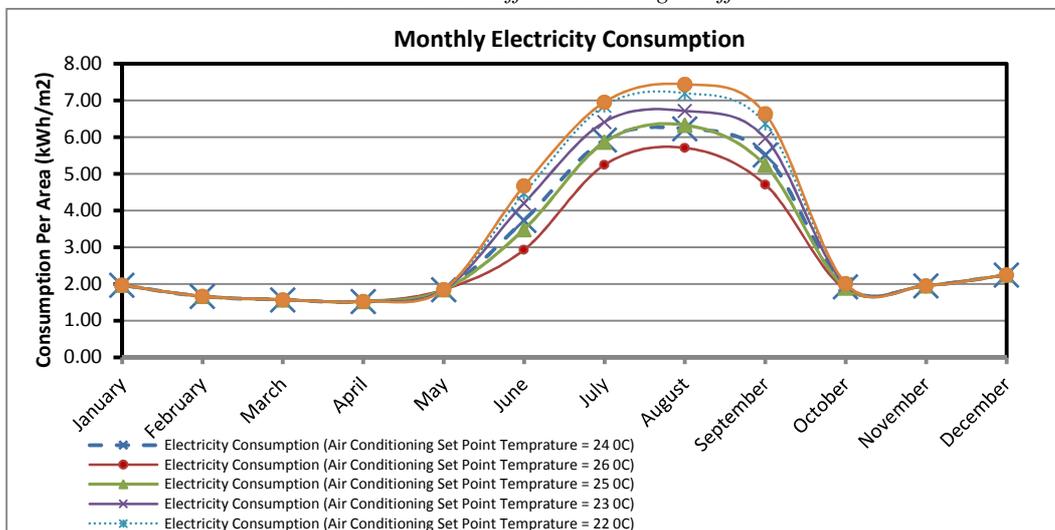


Figure 13 - Monthly Electricity Consumption with Different Set point Temperature for the Air Conditioning Systems

Finally by study some modification on the model made for the residential Egyptian building found that when applying GLASSWOOL as insulation for external walls and to the roof, change the glazing of the external

windows to new one with shading coefficient 0.2 and changing the lighting lamps type to use fluorescent lamps instead of tungsten lamps the annual electricity consumption will decrease by 7.45 kWh/m<sup>2</sup> about 21 %.

This percentage will help in solving the problem of power cut off due to the over load of the electricity consumption on the peak hours

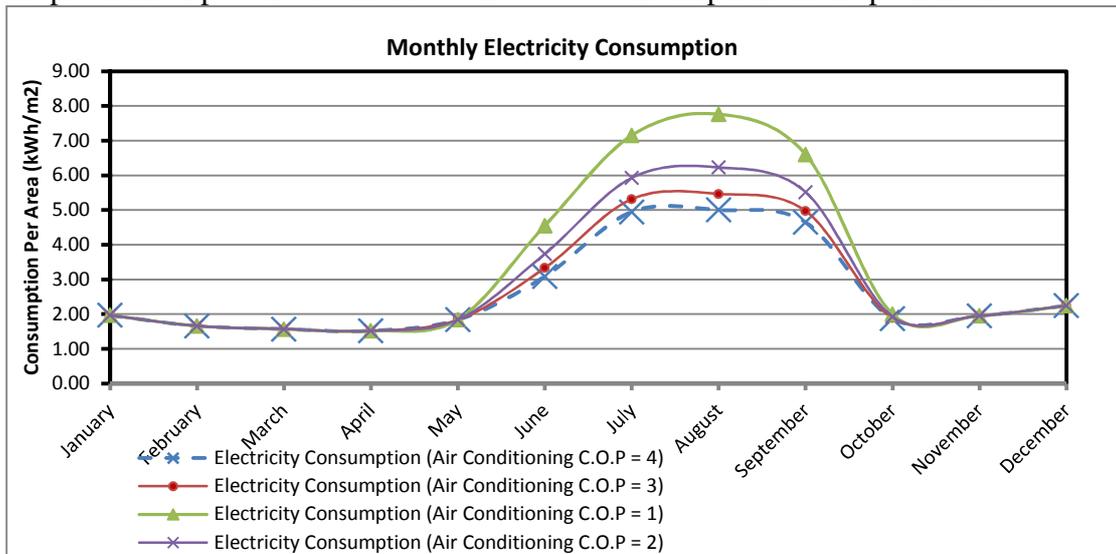


Figure 14 - Monthly Electricity Consumption with Different C.O.P for Air Condition Units

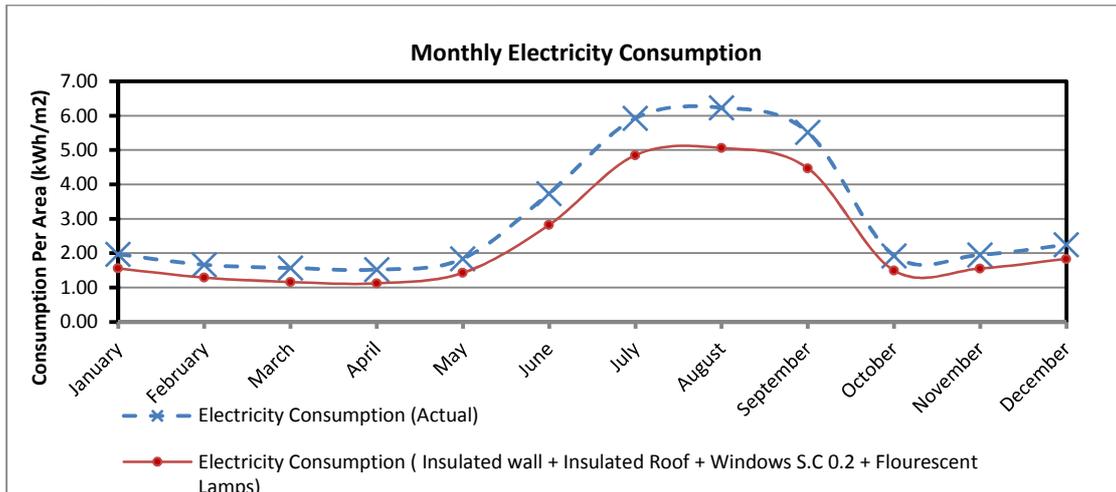
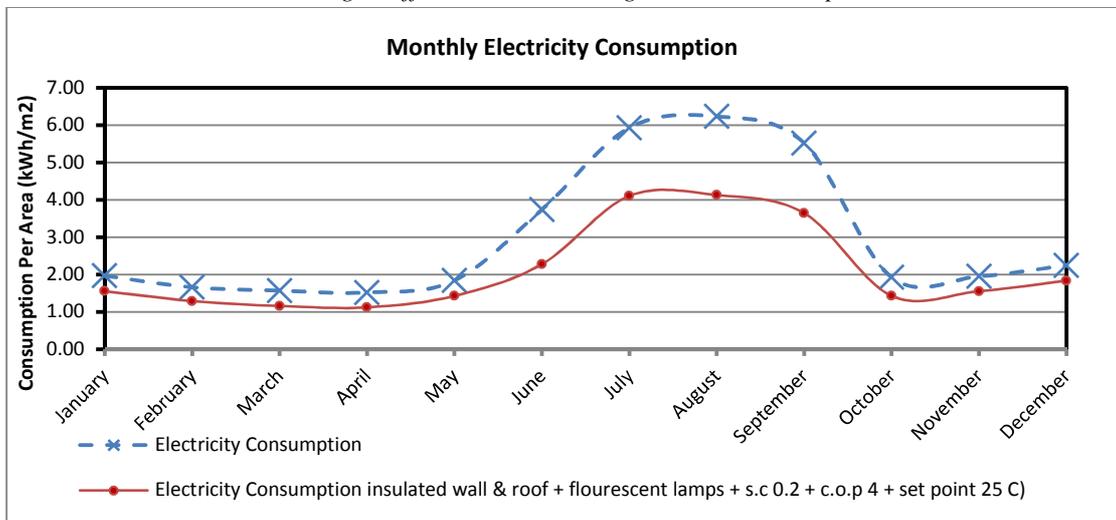


Figure 15 – Monthly Electricity Consumption When Insulating the Walls and the Roof, Windows Shading Coefficient 0.2 and Using Fluorescent Lamps



*Figure 16 – Monthly Electricity Consumption When Insulating the Walls and the Roof, Windows Shading Coefficient 0.2, Using Fluorescent Lamps, Temperature Set Point 25 °C and Air Conditions units C.O.P is 4*

specially during summer time as shown in figure (15) in addition to that if the Set point of the temperature increased to 25°C and change the air conditioning units with higher efficiency one with C.O.P 4 the amount of saving in the annual electricity consumption will be 10.57 kWh/m<sup>2</sup> about 29% as shown in figure (16).

## 5. Conclusion

The beauty of sensitivity analysis lies in the fact that it helps designers spend their time where it matters most and it helps decision-makers determine how much they can rely on simulation predictions. Sensitivity analysis for building thermal design can provide insights about the building system as a part of the simulation process and can present opportunities for improved handling and analysis of data so that energy estimates can be improved and uncertainties can be quantified.

It has been found that the annual building energy consumption will be affected directly and reduced by a percentage which must be taken as appoint of study for the new designers as to help in solving the problem of increase in demand and peak loads when the wall insulation, lighting system, set point temperature, air condition units C.O.P and windows shading coefficient are changed.

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