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# Energy Conservation in Governmental and commercial Buildings in Egypt

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***ABSTRACT:*** *This paper summarizes the results of Electricity Consumptions and Energy Field Investigation in several Governmental Buildings in Egypt. Specially, the impact of artificial lighting and the use of HVAC systems. The paper also summarizes the Energy Simulation Analysis for New Hotel and Office buildings in Cairo and Alexandria, Egypt. The results of field study shows certain finding of practical significant e.g. Total Electricity consumed in lighting fixtures is about 55%, while the Total Electricity consumed in HVAC systems is about 40%. The simulation results indicate that the window to wall ratio of 0.2 with reasonably shaded and glass type minimize the total annual electricity for Hotel and Office buildings more than 20% in Cairo.*

***Keywords*****:** *Field Investigation, Governmental Buildings, Hotels & Office Buildings, Electricity Consumption, Energy Analysis & Computer Simulation.*

## I. INTRODUCTION

The total electricity consumption in buildings is over 55%. Artificial lighting is estimated to account for 36% of the electricity used in the commercial sector and 31% of the electricity used for HVAC system, see table (1). A significant increase in electricity demand is expected over the next few years with a growth rate of 7.1%. To improve the energy efficiency of buildings, an energy code had been developed for new commercial [1] and Governmental buildings in Egypt [2]. As part of the development of the energy code, an extensive simulation analysis has been carried to determine the most cost-effective energy efficiency measures suitable for Egyptian buildings. Fenestration components are considered one of the fundamental design features of energy-efficient buildings. This paper summarizes results of a detailed simulation analysis on the impact of building and window designs on the energy use for Large Hotel and Office buildings in Egypt. It should be noted that the study in this paper focuses on the impact of artificial Lightning and air conditioning systems consumed and electricity saving.

## II. ENERGY IN EGYPT

The main sources of energy in Egypt include natural gas, petroleum products, and electricity. The electricity is generated mainly from power plants fueled from primary energy sources. The increase in the overall energy demands has reached to about 140.2 Billion kWh with an annual increase of 7.5% [3], where the industry takes about 28.4%, Residential 42.6%, commercial, 10.4%, Street lighting 6.7%, residential buildings 43.14%, Governmental and public services 10.0%, while Agriculture have only 4.1%. A previous study [4] showed that, table (1), the electrical energy form is the most widely used in Cairo. The share of Air Conditioning represents about 30.8% of the electrical energy consumption while lighting consumes about 36.1%. Figure 1 shows the sectral electricity consumption for 2011/2012 and the total increases to 63.85 TWh. The increase in the outdoor air temperature by 1$^{o}$C above 35 $^{o}$C for about 6 hours increases the Total Electricity Consumption (TEC) by 100 MWh; i.e. when the air temperature reaches to 45 $^{o}$C, the TEC reaches to 800 MWh. To produce this amount of electricity, the cost of new power station approximately 4 Billion Egyptian Pounds and it needs about four years to be completed.

***TABLE- 1 Energy Consummation in Commercial Sector for Cairo Governate***

| | |
|---|---|
| Lighting | 36.10% |
| HVAC | 30.80% |
| Refrigeration & Cooking | 20.50% |
| Commercial Shops | 51% |
| Supermarket | 12% |
| Small Hospital & Show Rooms | 7% |
| Banks | 4% |

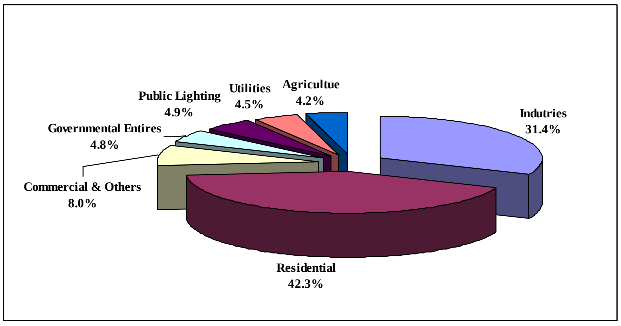


Fig. (1) Electrical Energy Consumed, 2011/12

## III. ENERGY ANALYSIS FOR GOVERNMENTAL BUILDINGS

A field investigation in six different governmental buildings [4] indicate that considerable energy was consumed reached to 32% from all the governmental buildings in Egypt. The study indicates that an increased was observed, from 5.4% to 6.5% from 2010/2011to 2011/2012, see table (2). Table 2 shows an considerable increase in governmental buildings from 5977 MkWh to 6385 MkWh .

***TABLE-2 Comparison between Electricity Consumption in Governmental Buildings and Total Energy Consumed between 2010/2011 and 2011/2012***

| Year | Total Electricity Consumed in Governmental Buildings | Percent (%) | Total Annual Electrical Energy Consumption |
|---|---|---|---|
| 2010/2011 | 5977 Million kWh | 8.2 % | 125159 |
| 2011/2012 | 6385 Million kWh | 8.0 % | 133969 |

Table (3) shows the total electrical energy consumed and its cost in six governmental buildings.

***TABLE-3 Energy Consumed and costs during 2003/2004 in six Governmental Buildings in Egypt.***

| No. | Ministry | Electrical Energy Consumption | Cost of Electrical Energy Consumption (Thousand Pounds) |
|---|---|---|---|
| 1 | Ministry of Al-Wakief | 310.7 | 51479 |
| 2 | Ministry of Higher Education & Research | 267 | 53080.1 |
| 3 | Ministry of Education | 239.7 | 43892.8 |
| 4 | State Ministry of Regional Developments | 216.1 | 51574.6 |
| 5 | Ministry of Roads & Transportation | 207.8 | 3843.6 |
| 6 | Ministry of Health | 136.3 | 26676.4 |
| Total | | 1377.6 | 255134.4 |

A survey study was carried out on the governmental building [4] which belongs to the Electricity distributed company indifferent cities in Egypt. Selected buildings were investigated and the results are given in the following tables and figures. Building Energy Analysis was carried out in eight different governmental building in Egypt to identify the parameters which could be applied to high light what should be considered first for energy saving. Table (4) shows that the artificial lighting consumed higher percent and ranges between 20% to 93% while the Air Conditioning (HVAC) consumption ranges from 11% to 69%. There for, we should use compact lamps (**CFL**) and energy efficient air conditioning systems and using equipments that increase the power factors.

### Study Cases

Four Governmental Buildings were selected to carry out the Energy Improvements namely: 1) Income Tax Building; 2) Main Electricity Building in Cairo; 3) Main Electricity Building in Alexandria; 4) Main Electricity Building in North Delta (Bihara).

To reduce the total Electricity Consumption in Governmental Buildings, two phases are considered:

**A: Phase one**: the use of CFL lamps; where three steps is applied: 1) all the tungsten lamps (100Watts) were replaced by CFL lamps (20 Watts) of the same lumens. If these lamps are turn ON for 8 hours daily for 280 days i.e. 2240 hours/year. It will save about 32 L.E. /year per lamp and the pay back period will only 13 months. This lamps, CFL, saves 80% of electricity 2) All the florescent lamps of 38mm diameter were replaced by another lamps with smaller diameters (26mm) i.e. energy saving. 3)All the Magnetic Ballasts were replaced by

Electronic Ballasts, since it saves about 35% from electricity consumption and it works about 50000 working hours.

**B: Phase Two**: to improvement of the Power Factors (PF) of the condensers where the PF should not be less than 0.9.

### Study Case 1: Tower Office Building (MWRI) [7]

**” Ministry of Water Resources and Irrigation “**

The selected building is a 22-story office complex overlooking the Nile River in Cairo. It covers 3,000 $m^2$ of footprint, of which 1,000 $m^3$ is for the main office tower starting on the fifth floor, while the first four floors occupy the whole area. The building also includes general supporting facilities such as a library, a computer network laboratory, and a multi-purpose conference hall. Simple energy efficiency lighting measures with proven track records and availability in the local market were selected including high efficiency fluorescent fixtures with reflective mirrors, Compact Fluorescent Lamps (CFLs) and electronic ballasts. To reduce the total electricity consumption in governmental buildings, two phases are considered:

Fig. (2) MWRI Office Complex in Cairo

***TABLE-4 Electrical Energy consumed in Eight different buildings in Egypt.***

| Building Type | Ministry | Year | Lighting % | Air Conditioning % | Others |
|---|---|---|---|---|---|
| Cairo Electricity Distribution Building-26 July St. | Ministry of Electricity & Energy | 2003 | 37% | 33% | 30% |
| Cairo Electricity Distribution -Naser City Branch | Ministry of Electricity & Energy | 2003 | 28% | **11%** | 61% |
| El-Behera Electricity Distribution - North Delta | Ministry of Electricity & Energy | 2003 | 49% | 30% | 21% |
| Abu Kier Hospital- Alexandria | Ministry of Health | 2001 | **20%** | **69%** | 11% |
| Faculty of Islamic Studies | Ministry of High Education & Research | 2002 | **93%** | 0 | 7% |
| El_Sharawy Girls Collage | Ministry of Education | 2003 | 83% | 0 | 13% |
| Student Resident-El_Noza-Alexandria | Ministry of High Education & Research | 2003 | 57.5% | 19.5% | 23% |
| Abou-E-Abbas Mosouque-Alexandria | Ministry of Al-Wakf | 2002 | 75% | 0 | 25% |

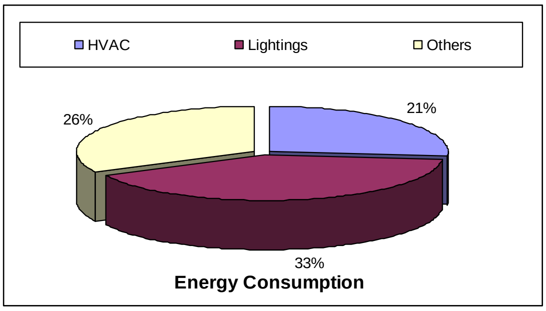


Fig. (3) Energy Consumption in MWRI Office

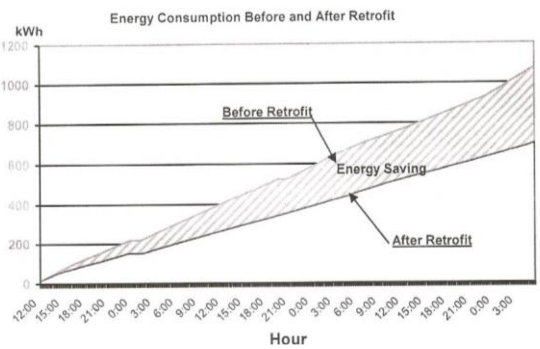


Fig. (4) Energy consumption before and after

**Phase one**: use CFL lamps; where three steps are applied: 1) all tungsten lamps (100Watts) are replaced by CFL lamps (20 Watts) of the same lumens. If these lamps are ON for 8 hours daily for 280 days, i.e., 2240 hours/year, this step will save about 32 Egyptian Pounds/year per lamp and the pay back period will be only 13 months. 2) Replace all florescent lamps of 38mm diameter with more efficient lamps with smaller diameters (26mm). 3) Replace all magnetic ballasts were replaced with electronic ballasts; this should save about 35% in electricity consumption and work about 50000 working hours.

**Phase two**: improve the Power Factors (PF) of the condensers where the PF should not be less than 0.9. The payback period for CFL lamps is only 1.1 years and for electronic ballasts that operate 4 lamps each of 18 Watt only 0.625 year. The analysis is based on the same operating time and the time schedule for the same (tariff) electricity cost, which is 0.18 Egyptian Pounds per /KWh.

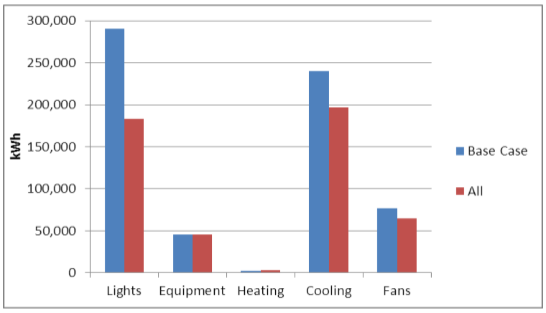


Fig.(5) Energy consumed between different sectors.

### Study Case 2: Sales Tax Building

The total area of 6620 $m^2$, the first floor up till the ninth floors have the same floor is of 440$m^2$, and three external façade where the fourth share with the next building of the income Tax. Every floor consists of two apartments and two light wells. The tenth and eleventh floor are extended to the next building with four external facades. The working hours started from 7:00 a.m. until 17:00 p.m. five day a week. The annual electricity consumptions is approximately 655 GWh /year. The total electricity consumption is 495 kW representing 47% for HVAC and 28.6% for artificial lightings. The EPD is about 20.7% which includes printers, fax machines, computers while water pumping and elevators chair 3.7%. Three different approaches could be applied to consume energy could be applied**.**

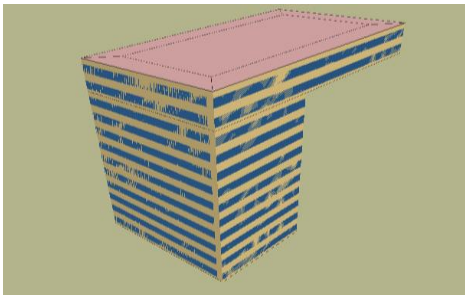

Fig.(6) 3D view of Income Tax building at Naser City, Cairo

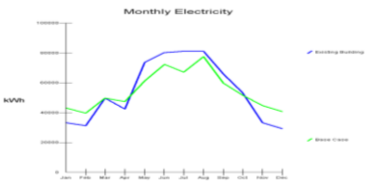


Fig.( 7) Comparison between actual electricity bills and VDOE

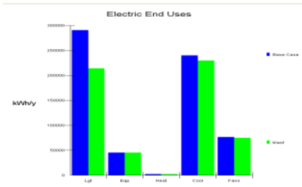


Fig.(8) comparison between Base Case and after replacing magnetic Ballast

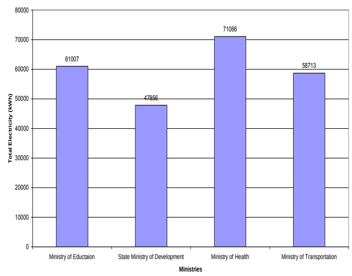


Fig. (9) Total Electricity Consumptions for Cairo Electricity Distribution Companies (M. KWh) 2003/2004

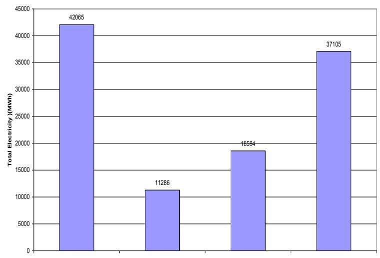


Fig. (10) Total Electricity Consumptions for Alexandria Electricity Distribution Companies (M. KWh) 2003/2004

The payback period for the CFL lamps is only 1.1 years and for Electronic Ballast which operates 4 lamps each of 18 Watt is only 0.625 year. The analysis is based on the same operating time and the time schedule for the same (tariff) electricity cost, which is 0.18 L.E. per /KWh, (2003/2004).

## IV. ENERGY SIMULATION ANALYSIS

Two typical commercial buildings consumer were analyzed namely: 1) New Hotel Buildings; 2) New office Buildings.

**4.1: Large Hotel Buildings**

The base case EG_LHOT building used is a 200-room hotel that consists of two-story podium block (support functions are in the basement level), and a ten story tower with 20 rooms off a double-loaded corridor on each floor. The ground floor of the podium block contains a lobby, 2 levels of stores, administrative offices including a business center, store, lounge, public and private dining rooms, a coffee shop, kitchen, bakery, and general storage areas. A basement level of the podium contains a laundry, HVAC room, maintenance room, staff locker and dining areas, and storage. The general configuration of the 200-room hotel can be seen in the DrawBDL image shown in Figure (11). The analysis is based on a prototypical Hotel building in Egypt. The hotel consist of two parts:1) **Tower**: This portion contains the guest rooms and the immediate support services to the guest rooms (maid service, etc). For the large hotel there are 20 guest rooms on each floor. Each guestroom is 4.5m by 8.5m. Every facade has 10 modules of 3m wide that facilitate the definition of 10 windows on each orientation **2) Podium**: This portion contains the lobby, restaurants, bars, shops, meeting rooms, plus the central support services. (i.e. same parameters for hotel tower, also were used for the podium.

**4.2: Large Office Buildings**

The analysis is based on a prototypical Large Office (LOF) building in Egypt. The base case EG_LOF building used for this study is a twenty story building with a typical floor area of rectangular shape ($A_f$ =900m$^{2)}$. The dimension of the building is 45m by 20m with a floor-to-floor height of 3.0m. Every facades has 10 modules of 3m wide that facilitate the definition of 10 windows on each orientation. The characteristics of the office building were developed based on the results of a survey conducted as part of the efforts to develop an energy code for commercial buildings in Egypt [1]. To study the effect of orientation on the wall construction and WWR or roof insulation, the LOF_One façade is used for Mid_Floor and using HVAC system SUM. SUM is simply accumulates results from the loads program and only used when the envelope parameters are investigated.

**4.3Common Parameters**

To study the effect WWR, the LHOT_One façade or LOF_One is used for Mid_Floor using HVAC system SUM. The HVAC system SUM is simply accumulates results from the loads program and only used when the envelope parameters are investigated. The DOE2Parm simulation models were used in this study for typical hotel buildings in Egypt. Parametric inputs are provided by an MS Excel spreadsheet that is used to create a parametric input text file. Each row of the text file will generate a separate parametric run with a specific set of variables and script. Typical densities and schedules for an Office or Hotel buildings are used to model occupancy, lighting, and equipment. For the entire hotel building floors, fluorescent luminaries were used to represent standard commercial installations. Lighting density was set at 15 W/m$^2$. Typical Egyptian hotel building occupancy schedules are used to define the operation patterns for the electrical lighting system.

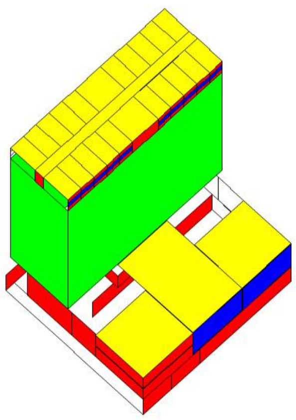

Fig. (11) Large Hotels of 200 Rooms.

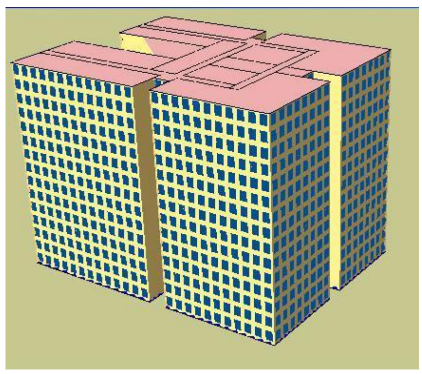

Fig. (12) 3D office Building (Electricity Building in Cairo.

**4.4 Window-to-Wall Ratio (WWR)**

The window-to-wall ratio (WWR) is the ratio of the total glass area to the total building wall area (including the glass area) for all elevations of the building together. WWR directly affects the amount of solar heat gain entering the building, thus it has a great impact on energy consumption of the whole building. The Base Case (**BC**) for large office or hotel buildings in Egypt uses WWR=0.4. For the parametric analysis, single variable, has been changed across a wide range of values from 0.1 till 0.9. The resulting annual energy results of LHOT are shown in Figure 13, while the energy analysis for LOF is shown in Figure 14. The results illustrate that increasing the WWR increases the Total Electricity Consumption significantly.

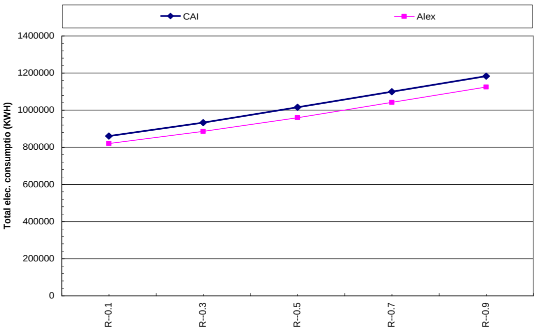


Fig. (13): Effect of WWR on Total Electricity Consumption for Tower Hotel.

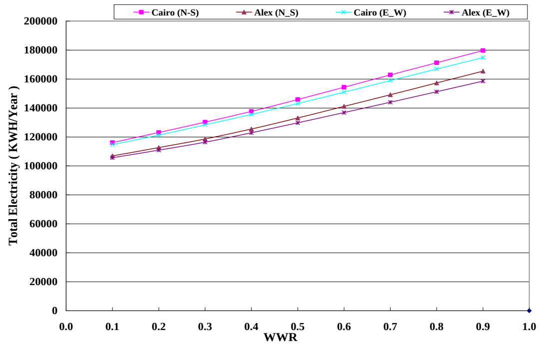


Fig. (14) Effect of Window to Wall Ratio on the total electricity consumption (KWH),

## 4.5 Solar Heat Gain Coefficient (SHGC)

The Base Case for large Hotel building and Large Office Buildings in Egypt uses Glass Type 1P_SHGC_61. For the parametric analysis the SHGC, single variable, has been changed across a wide range, from 0.81 to 0.23. Nine fenestration options was used for an Office Building and only five options was used for Large Hotel Building. Four of the nine options use a single pane of glass, while two options use double-pane, or two panes of glass. The double-pane options have a low emissivity coating on the inside pane of glass.

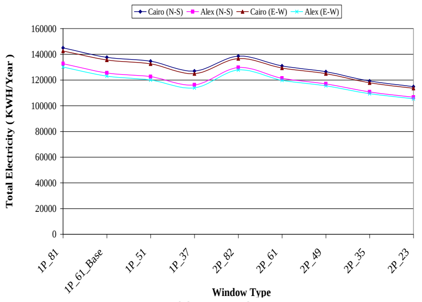


Fig. (15.a): Effect of window type on the total electricity consumption (KWH), Mid.

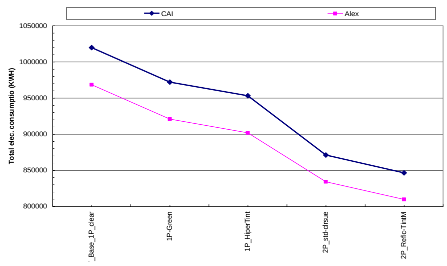


Fig. (15.b): Effect of Windows Type on Total Electricity Consumption for Tower Hotel.

The resulting annual energy results are shown in Figure (15.a) for an Office Building and Figure (15.b) for Large Hotel Tower. The results indicate that the type of glass used in large buildings is an important variable. The range of SHGC values examined resulted in change in the total building electricity use of about 20%. In Cairo, reducing the SHGC from 0.81 to 0.23 will reduce the total electricity use by 20% and 18% in Alexandria.

## 4.6 Installed lighting Power Density (LPD)

Lighting Power Density (**LPD**) is one of major part of energy consumption in Large Office and Large Hotel buildings. This section investigates the magnitude of influence of lighting power density on the building consumption. The Base Case of Large office building uses 15 W/m$^2$ where the variable being changed from 0 to 30 W/m$^2$. The annual energy results obtained are shown in Figure (16.a) and Figure (16.b).

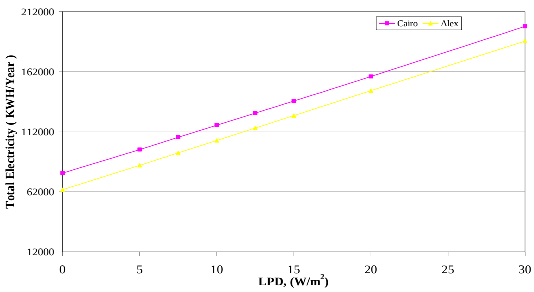


Fig. (16.a): Effect of Installed LPD on the total electricity consumption of LOF, ( kWh).

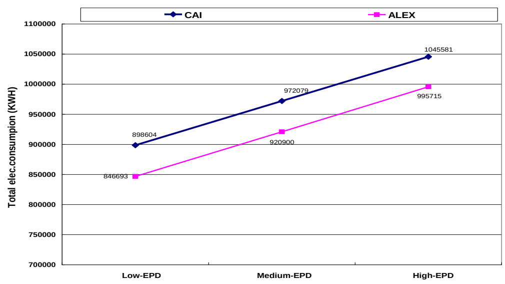


Fig. (16.b): Effect of Installed LPD On total electricity consumption For LHOT, (kWh), Mid-Floor.

The results indicate that the lighting power density level has a great impact on the annual energy use of both buildings. The energy consumption increased by about 80% when the light power level was increased from 5 to 25 W/m$^2$ [6].

### 4.7 Air-Conditioning Systems (HVAC)

Five different HVAC system types are analyzed namely; **SUM**, **RESYS** (Residential System), **PSZ** (Package Single Zone), **TPFC** (Two Pipe Fan Coil), **VAV** (Variable Air Volume). Two typical systems in Egypt (**PSZ** and **TPFC**) were used. For the building loads analyses above (envelope and lighting), we have used the SUM system, which tallies the loads on the HVAC system but does not include any system efficiency consideration.

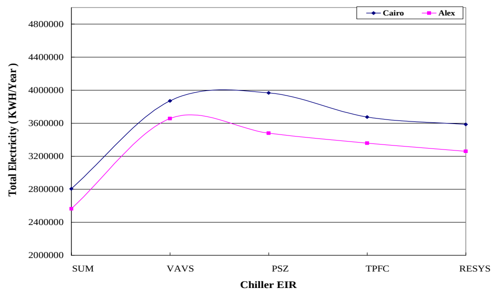


Fig.17: Effect of System Type on the total electricity consumption (kWh)

### 4.8 Air-Conditioning Chiller Efficiency (EIR)

The Base Case Chiller for large Office building EIR is 0.25 and for large Hotel is 0.22. The parametric analysis is varied from 0.286 to 0.16 for Cairo and Alexandria.

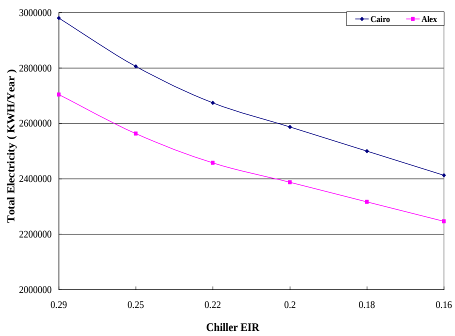


Fig. (18.a): Effect of chiller EIR on the total electricity consumption (kWh)

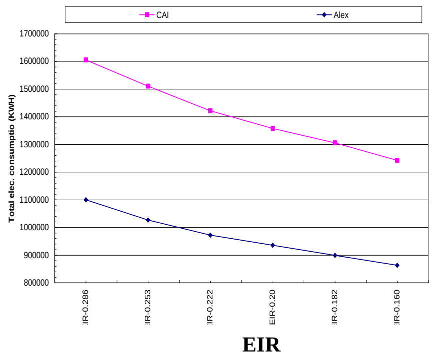


Fig.(18.b): Effect of Air-conditioning chiller efficiency (EIR) Of Total Electricity Consumption for Tower Hotel.

The annual energy results are shown in Figure (18.a) and Figure (18.b). The results indicate that annual energy consumption is reduced by about 8.5% for Cairo and 9% for Alexandria, when the Chiller EIR is changed from 0.286 to 0.16. HVAC system selection can have a significant impact on building energy use, often producing total annual energy use variations in the range of 30%.

### 4.9 Space Set-point Temperatures (SPT)

The Base Case for EG_LOF building and EG_LHOT building uses 23$^o$C for the cooling set point during the occupied periods. The set point temperature is changed over the range of 18-29$^o$C. The annual energy results are shown in Figure (19.a) and Figure (19.b). The results indicate that total annual building energy consumption is reduced by about 10% when the cooling set temperature is increased from 18 to 29 $^o$C. Thus for each degree C in set-point temperature there is 1% reduction in total building energy use and a 2% reduction in loads on the cooling system.

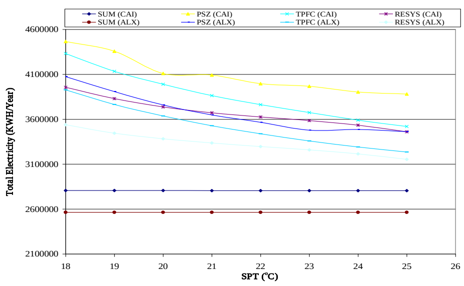


Fig. (19.a): Effect of cooling SPT on the total electricity consumption (kWh), LOF 20, Different HVAC Systems.

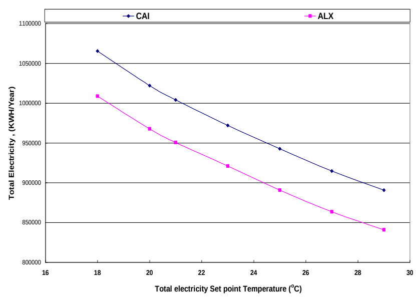


Fig.(19.b): Effect Of Set-point electricity Consumption For Tower Hotel.

## V. CONCLUSION

The achievement of replacing the Incandescent lamps with smaller diameter fluorescent lamps (26mm) and Electronic Ballast and CFL and using efficient condensers with higher PF systems saves conferrable amount of electrical energy in the four governmental buildings more than 20% . The simulation results for Office and Hotel Buildings proved considerable amount of electricity could be saved if we used glass type SHGC_0.37 and external shading device with WWR not greater 20% . The essence of this paper is to prove that considerable amount of electricity could be saved if we replace specific items and the pay back period is only one year.

## REFRENCES

[1]. Energy Efficiency Commercial Building Code, Housing & Building National Research Center, Ministry of Housing, Utilities & Urban Communities , Egypt, (2005)
[2]. Energy in Egypt (2002/2003), Organization for Energy Planning, Ministry of Planning, Egypt.
[3]. Residential Energy Survey and Environmental Indicators in Great Cairo, Cairo University, (ECEP/DRTPC) and Organization Energy Planning (OEP), (2000)
[4]. Field Investigation on Energy Consumed in Governmental Buildings in Egypt, MOEE, (2003).
[5]. ECEP/DRTPC & OEP," Residential Energy Survey & Environmental Indicators in Great Cairo", UNDP/GEF, (**2000)**.
[6]. Moustafa A. El-Mohimen, George Hanna & Mocef Krarti," Analysis of Daylighting Benefits for Office Buildings in Egypt"; J. of Solar Energy Engineering, pp.366-370, Vol.127, No. 3, **(2005).**
[7]. United stated agency for international development," Lighting efficiency Improvements Proves Success in Reducing Operating Costs at the Ministry of Water Resources and Irrigation in Egypt", August **2008**.