RESEARCH ARTICLE OPEN ACCESS

Energy Analysis for New Hotel Buildings in Egypt

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ABSTRACT
This paper summarizes the results of energy simulation analysis to determine the effectiveness of building characteristics in reducing electrical energy consumption for hotel buildings in Egypt. Specifically, the impact on building envelope performance is investigated for different strategies such as window size, glazing type and building construction for two geographical locations in Egypt (Cairo and Alexandria). This paper also studies the energy savings in hotel buildings with 200 rooms for different Lighting Power Densities (LPD), Energy Input Ratios (EIR), Set point Temperatures (SPT) and HVAC systems. The study shows certain findings of practical significance, e.g. that a Window-to-Wall Ratio of 0.20 and reasonably shaded windows lower the total annual electricity use for hotel buildings by more than 20% in the two Egyptian locations.
Keywords- Energy Simulation; Hotel; Insulation; WWR; SHGC; PF; EIR; LPD

I. INTRODUCTION

In Egypt, about 60% of the total electricity consumption is attributed to residential, commercial, and institutional buildings. 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 buildings in Egypt [1]. As part of the development of the energy code, an extensive simulation analysis has been carried for new hotel buildings to determine the most cost-effective energy efficiency measures suitable for Egyptian buildings.

Building envelope and 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 buildings in Egypt. A building simulation tool was used to determine the effects of building parameters on the total electricity use for typical hotel buildings.

II. CLIMATE OF EGYPT

The predominant climate in Egypt is hot and arid, since the moderating effects of surface water are restricted to a small area on the two banks of the Nile. In this region, there is an overheating period lasting about 8 months during which peak temperatures in the shade reach about 42 ^{o}C. The outdoor design temperature for Cairo (30.13 ^{o}N and 31.0 ^{o}E) and Alexandria (31.2^{o}N, 29.95 ^{o}E) are 38.5 ^{o}C and 32 ^{o}C respectively.

III. ENERGY IN EGYPT

The current national energy supply mix in Egypt is; 95% from fossil fuel from petroleum products (38.2%) and natural gas (56.1%); 5% from renewable resources (mainly hydro and limited wind). The increase in the overall energy demands has reached about 140.2 billion kWh with an annual increase of 7.5% [2], of which industry takes about 28.4 %, residential 42.6%, commercial 10.4%, and street lighting 4.4% while agriculture only 4.4%. A previous study [3] showed that electricity is the most widely used form of energy form in Cairo (see Table 1). Air conditioning consumes about 30.8% of the total electricity use while lighting consumes about 36.1%.

Table 1. Energy consumption in the commercial sector for Cairo Governate

Lighting	36.1%
HVAC	30.8%
Refrigeration & Cooking	20.5%
Commercial Shops	51%
Supermarket	12%
Small Hospital & Show Rooms	7%
Banks	4%

IV. ENERGY EFFICIENCY COMMERCIAL BUILDING CODE

The Egyptian Code gives minimum performance standards for building windows and openings, natural ventilation, ventilating and air conditioning equipment, natural and artificial lighting and electric power. A great effort has been made to ensure its applicability to buildings in Egypt. It should be noted that this paper focuses only on the energy use of large hotel buildings. The Egyptian commercial energy code contains 11 chapters and 7 appendices [1].

V. MODELING DESCRIPTION

The base case large hotel building model (named EG_LHOT) is a 200-room hotel that consists of a two-story podium block with support functions in the basement, and a 20 floor tower with double-loaded corridors on each floor. The hotel consists of two main portions:

5.1. Tower: This portion contains the guest rooms and the immediate support services to the guest rooms, such as maid service, etc. There are 20 guest rooms on each floor, each of which is 4.5m by 8.5m. Every facade has 10 3m wide modules that facilitate the definition of 10 windows on each orientation.

5.2. Podium: This portion contains the lobby, restaurants, bars, shops, meeting rooms, plus the central support services. The ground floor of the podium block contains a lobby, two 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. The 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 Fig.1 The same parameters for hotel tower, also were used for the podium.

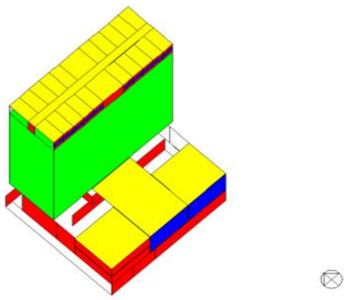

Fig. 1. Large Hotel with 200 Rooms.

The EG_LHOT building model was simulated with the 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 procedure [4] was used in this study of 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 hotel buildings are used to model occupancy, lighting, and equipment. For all the 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. The base case inputs for different building and HVAC conditions are listed on Table 2.

VI. PARAMETRIC ANALYSIS

The analysis presented in this paper encompasses common types of modern hotel buildings. The Window-to-Wall Ratio (WWR) was varied from **0.0** (no openings) to **0.9** (glazed walls). Due to the vast selection of windows, Solar Heat Gain Coefficients (SHGC) for five different glazing types are specified with varying light transmittance were selected and analyzed. The intent was to obtain a wide range of transmittance values to get a broad representation of available products in Egypt. Parametric analyses have been conducted for key energy variables for the large hotel building, across typical ranges of values. The variables analyzed are: 1) building orientation; 2) roof insulation (top floor); 3) wall construction and insulation; 4) curtain wall, with rigid insulation; 5) mass wall, 12 cm brick, rigid insulation on 'outside' between brick and outside mortar layer; 6) Window-to-Wall Ratio (WWR); 7) glass type and Solar Heat Gain Coefficient (SHGC); 8) Solar shading using overhangs and fins; 9) Lighting power density (LPD), and 10) HVAC System type. The results and possible implications are discussed here under.

VI.1 Building Orientation

The Base Case for the large hotel building in Egypt uses North ORIENTATION as shown in Figure 2. Since the building being studied has a 2:1 aspect ratio, this means that when N is specified, the long sides face N/S. Conversely, when E is specified, the long sides face E/W.

The parametric analysis has been done for eight orientations for Cairo and Alexandria. The results are shown in Figure 2. The analysis was done for one façade building at mid-floor, and for the whole building. Figure 2 indicates that hotel building with aspect ratio of 2:1 with a N/S orientation will use

22% less energy than the same building with long sides facing E/W.

Table 2. Base Case Parametric Inputs for Large Hotel

No.	Parameter	Value
1	ANALYSIS_TYPE	Tower
2	NUMBER_ROOMS	200
3	ORIENTATION	N
4	WALL_CONSTRUCTION	12cm_Brick
5	WALL_INSULATION	None
6	WALL_ABSORPTANCE	0.7
7	WINDOW_TYPE	1P_SHGC_61
8	WWR_TOWER	0.4
9	EX_SHADE_OH_PF	0
10	EXT_SHADE_FIN_PF	0
11	ROOF_INSULATION	None
12	ROOF_ABSORPTANCE	0.7
13	LPD	Medium
14	DAYLIGHT	NO
15	EQUIPMENT	Medium
16	COOL_SPT_TOWER	23
17	COOL_SPT_PODIUM	20
18	HEAT_SPT	21
19	MAX_SUP_TEMP	40
20	MIN_SUP_TEMP	10
21	OUTAIR_PERSON	10
22	COOL_CTRL_TYPE	CONSTANT
23	FAN_CTRL_TYPE	CONSTANT-VOLUME
24	SYS_TYPE	FPFC
25	BASEBOARD_SOURCE	ELECTRIC
26	CHILLER_TYPE	HERM-CENT-CHLR
27	CHILLER_SIZE	-290
28	NBR_CHILLERS	2.0
29	CHILLER_EIR	0.22
30	CHLR_HEAT_REJECT	AIR
31	TOWER_WBT	29.0
32	THERMAL_COMFORT	No

Figure 2 shows the total electricity/year for 8 orientation for the hollow building, and it save less energy by about 1.6% for Alexandria and 2.2%.

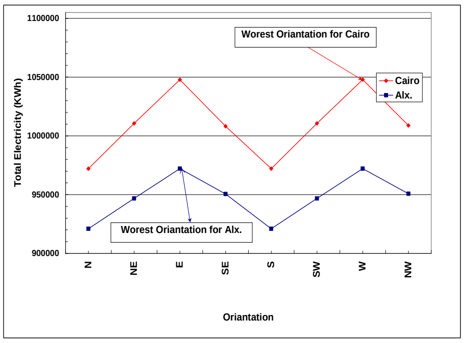

Fig. 2 Effect of building orientation on the total hotel energy consumption, kWh

VI.2 Roof Absorptance

The value of roof absorption was changed from 0.3 (light color) to 0.7 (dark color) as shown in Fig.3. The results indicates that the color of the roof surface has great influence on the total energy consumption by about 4% and has great influence on Alexandria than Cairo by about 5%.

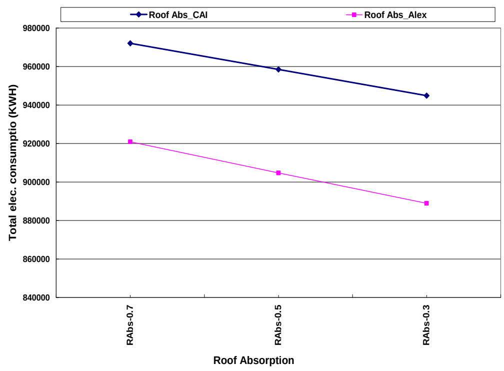

Fig. 3 Effect of roof absorptivity on the

VI.3 Roof Insulation

A single concrete roof construction was examined. Four insulation options were examined: 1) rigid polystyrene (25& 50mm thick), 2) Celton (150mm), 3) perlite (25 mm) and 4) vermiculite (25 thick). The resulting annual energy results are shown in Figure 4. The results indicate that the use of 75mm of polystyrene roof insulation has the largest savings, but the difference in the total electricity used between 75mm and 50mm of polystyrene is very small. An annual electricity saving of 30% has been found for Cairo, and 22% for Alexandria. The same saving in the total electricity use could also be reached, using ether 150mm_of Celton (foam concrete), or 50mm of perlite.

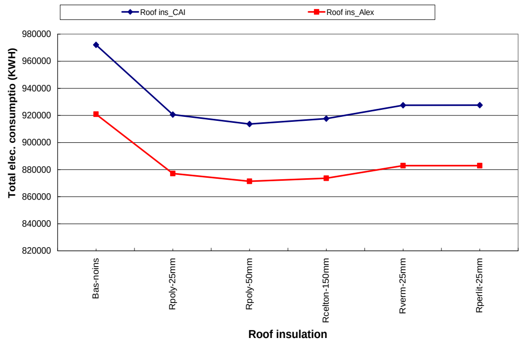

Fig. 4. Effect of roof insulation on total electricity consumption of the hotel tower.

VI.4 Wall Construction

Three types of construction were examined: Curtain wall, CMU and 120 cm thick brick.

(1) Curtain wall: With aluminum or glass on the outside, then insulation, then an air space, then a layer of gypsum board on the inside.

(2) 12cm_Mass wall: Hollow clay brick of 12cm, with mortar on both side.

(3) 12_CMU: Concrete massive unit with mortar on both sides.

The energy results shown in Fig.5 indicate that the use of 12 cm Brick has much more impact than the curtain wall or 12 cm CMU.

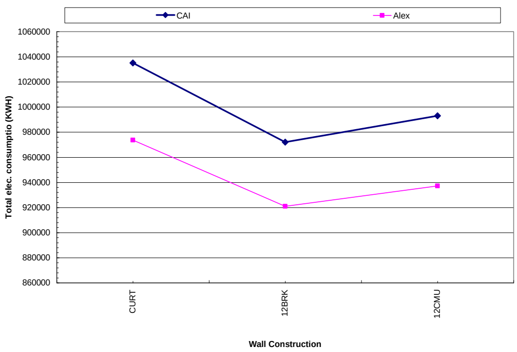

Fig. 5 Effect of wall construction on total electricity consumption of the hotel tower.

VI.5 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) for all elevations of the building together. The WWR directly affects the amount of solar heat gain entering the building, and thus has a large impact on the energy consumption of the whole building. The base case (BC) large hotel building has a WWR=0.4. For the parametric analysis, this variable has been changed across a wide range of values from 0.1 to 0.9. The resulting annual energy results are shown in Figure 6. The results illustrate that increasing the WWR increases the total electricity consumption significantly

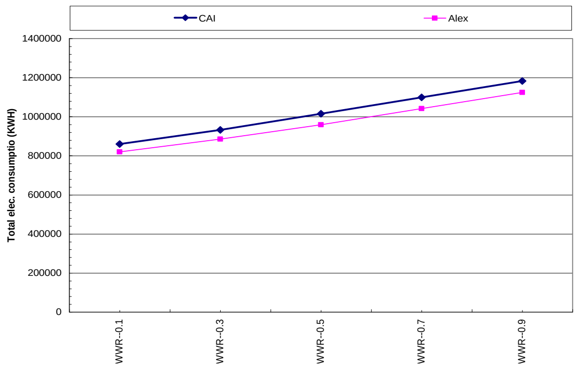

Fig. 6 Effect of WWR on the total electricity consumption of the hotel tower

VI.6 Glass Type: Solar Heat Gain Coefficient

The base case large hotel building is modeled with a glass type of 1P_SHGC_61, which is single-pane glass with a Solar Heat Gain Coefficient of 0.61. In the parametric analysis, the SHGC has been changed across a wide range. All nine fenestration options use regular aluminum frames with no thermal breaks. Four of the nine options are single-pane, while two are double-paned. The double-pane options have a low emissivity coating on the inside pane of glass, [4].

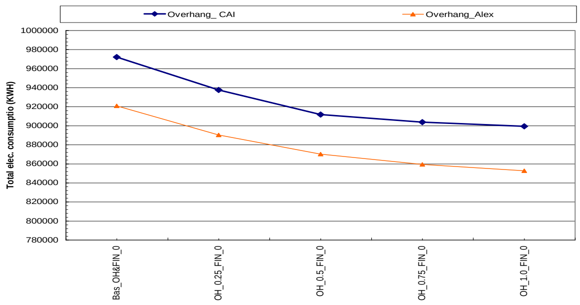

Fig. (6. a) Effect of overhang shading on total electricity consumption.

The resulting annual energy results are shown in Figure 7. These indicate that the type of glass used in large office buildings is an important variable. The range of SHGC values examined changed the total building electricity use by 20%. In Cairo, reducing the SHGC from 0.81 to 0.23 will reduce the total electricity use by 20% and 18% in Alexandria.

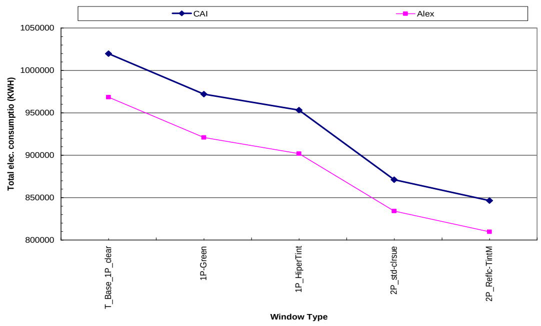

Fig. (7) Effect of windows type on total electricity consumption for the hotel

VI.7 Solar Shading: Overhangs & Fins

The base case large hotel building in Egypt has been modeled with the following values (0, 0.25, 0.5,0.75,1.0) for both overhang projection factor and fins. In addition, the building is modeled with two different orientations. The resulting annual energy results for overhangs and fins are shown in Fig. 8. The results indicate that the projection factors of

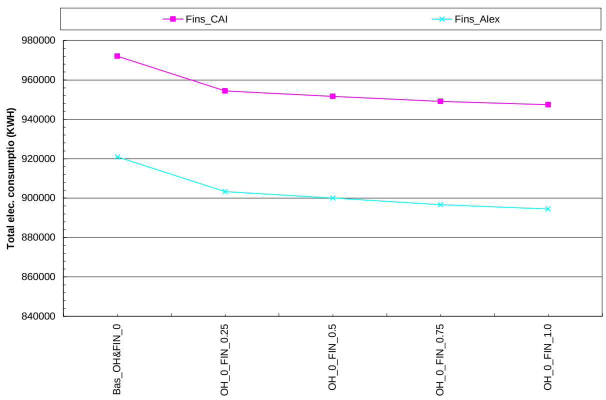

Fig. 8 Effect of solar shading sing fins on total electricity consumption for the hotel tower.

overhang and fin in a large office building are an important variable and can produce 6%-18% annual energy reduction depending on the building location, orientation and the type of exterior shading.

VI.8 Installed lighting Power Density (LPD)

Lighting Power Density (**LPD**) is another major part of energy consumption in hotel buildings. This section investigates the magnitude of influence of lighting power density on the building consumption. The base case large hotel uses 15 W/m^2, which has been varied between 0 to 30 W/m^2. in the parametric analysis.

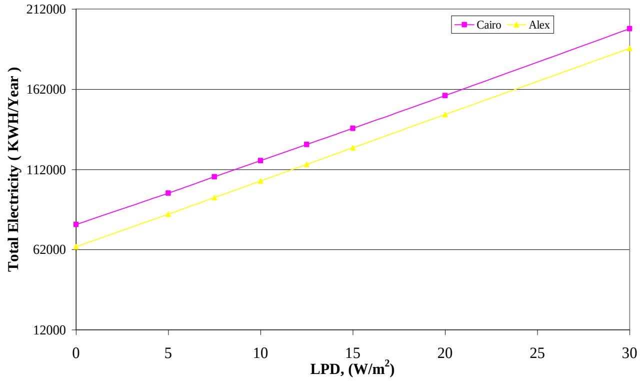

Fig. 9 Effect of LPD on the total electricity consumption (kWh), Mid Floor

The annual energy results obtained are shown in Figure 9. The results indicate that the LPD has a great impact on the annual energy use of hotel buildings. The energy consumption increased by about 80% when the light power level was increased from 5 to 25 W/m^2.

VI.9 Air-Conditioning Systems (HVAC)

Five different HVAC system types have been analyzed: **SUM**, **RESYS** (Residential System), **PSZ** (Package Single Zone), **TPFC** (Two Pipe Fan Coil), and **VAV** (Variable Air Volume). In Egypt, the two most common HVAC systems are the **PSZ** and **TPFC**. For the analsis described earlier on the envelope and lighting loads, we have used the **SUM** system, which tallies the loads on the HVAC system but does not include any system efficiency consideration. HVAC system selection can have a significant impact on building energy use, often producing total annual energy use variations in the range of 30%, as shown in Figure 10.

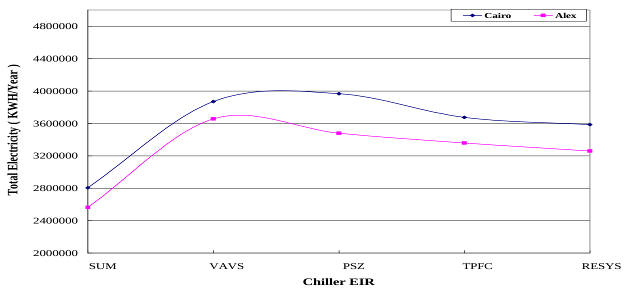

Fig. 10 Effect of system type on the total electricity consumption (kWh)

VI.10 Air-Conditioning Chiller Efficiency (EIR)

The Base Case Chiller EIR is 0.25 for the large hotel building. In the parametric analysis, this is varied from 0.286 to 0.16 for Cairo and Alexandria. The annual energy results are shown in Figure 11. 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.

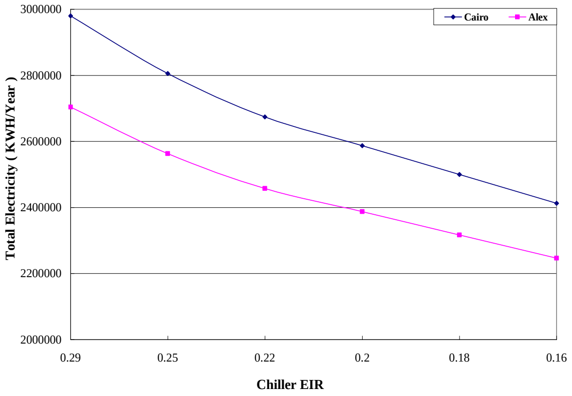

Fig. 11 Effect of chiller EIR on the total electricity consumption (kWh)

VI.11 Space Set-point Temperatures (SPT)

The base case for the large hotel building in Egypt has 23°C for the cooling set point during the occupied periods. In the parametric analysis, the set point temperature is changed over the range of 18-29°C. The annual energy results are shown in Figure 12. 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 °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.

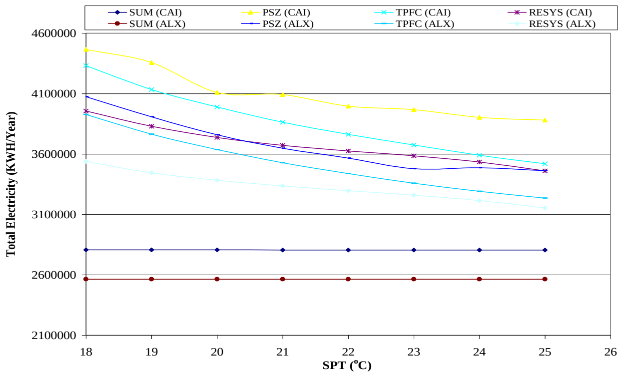

Fig. 12: Effect of cooling SPT on the total electricity consumption of different HVAC Systems.

VII. CONCLUSION

The energy consumption of large hotel buildings are major part of energy usage in Egypt, and this study reaches to significant findings results. A "base case" large hotel building ("EG_LHOT") was defined, and sets of potential energy saving measures are determined. The energy saving of each of these measures based on DOE-2 parametric simulations, are shown in Table 5 and Figure12. The estimated results illustrates a considerable energy savings would reached by (1) starting with the base case large hotel building that represents current practice, and then (2) changing the key energy-related features to comply with the requirements of the energy code, as shown in column 3. The items that we identified include: 1) roof insulation; 2) wall insulation; 3) Window-to-Wall Ratio (WWR); 4) Lighting Power Density; 5) Chiller EIR; and 6) Glass Type (Solar Heat Gain Coefficient –SHGC). The essence of this paper has illustrated how significant energy saving in large hotel buildings can be achieved by judiciously selecting materials with appropriate design technique of windows, HVAC system and loads.

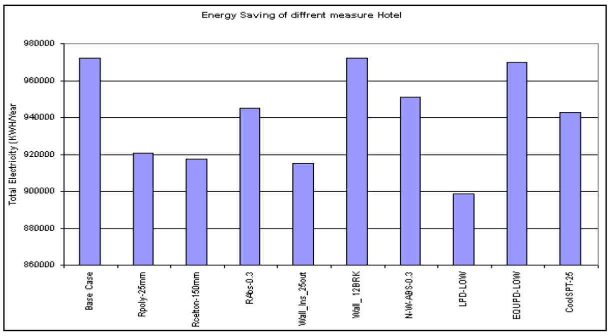

Fig.12 Energy savings of different measures

Table 5 Energy efficiency measures for large hotel with 200 rooms

	Measure	Current Practice	Energy Code
WALL	WALL INSULATION	None	25mm Polystyrene out
WALL	CONSTRUCTION	- Curtain Wall – 12 cm brick	12 cm Brick
WALL	WALL ABSORPTANCE	0.5 - 0.7	0.3
ROOF	ROOF INSULATION	50 mm Polystyrene	25mm Polystyrene or 150 celton
ROOF	ROOF ABSORPTANCE	0.7	0.3
WINDOW	GLASS TYPE	1P_Grn (SHGC_6	2P_Hpt-Std-ClrSue (SHGC 35)
WINDOW	WWR	Above 0.6	0.3
WINDOW	FINS & OVERHANG	- No fins - No overhang	- Fins 0.25m - Overhang 0.5m
LOADS	LIGHTING POWER DENSITY	Medium	Low
LOADS	EQUIPMENT POWER DENSITY	Medium	Low
HVAC SYSTEM	CHILLER EIR	.22	.22
HVAC SYSTEM	COOLING_SPT	23	25
HVAC SYSTEM	OUT AIR PER PERSON	10	7.5

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