エジプトにおけるZEBガイドラインの作成に向けた建築エネルギーシミュレーション

アヒメド, シャヒン
九州大学大学院人間環境学府空間システム専攻 : 修士課程

住吉, 大輔
九州大学大学院人間環境学研究院都市・建築学部門 : 准教授

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バージョン：

エジプトにおけるZEBガイドラインの作成に向けた建物エネルギーシミュレーション

Building energy simulation towards developing a guideline for NZEBs in Egypt

アヒメド　シャヒン*，住吉大輔**
Ahmed SHAHIN*, Daisuke SUMIYOSHI**

As a part of a bigger research project to create a detailed strategy to achieve zero energy performance level in Egyptian office buildings, this research mainly focuses on optimizing building envelope design alternatives through integrating various passive and active solar strategies. 116 case-studies were studied in 2 Egyptian cities. Applying the proposed strategies could achieve 68% energy savings in Cairo and 70% in Alexandria. An active solar system was proposed and the building could achieve nearly ZEB level. We also conducted a questionnaire to analyze the perception of Egyptian designers and academics towards ZEBs and early findings are presented and analyzed in this study.

Keywords: *Zero Energy Buildings, Energy Efficiency, Renewables, Office Buildings, Egyptian Building Industry*
ゼロエネルギービル、エネルギー効率、再生可能エネルギー、オフィスビル、エジプト建築産業

1. Introduction

The Zero Energy Building (ZEB) concept is no longer perceived as a concept of a remote future, but as a realistic solution for the reduction of energy usage in the building sector [1]. Goals for the implementation of ZEBs are discussed and proposed at the international level e.g. in the USA within the Energy Independence and Security Act of 2007 [2] and, at the European level within the recast of the Directive on Energy Performance of Buildings (EPBD) adopted in May 2010 [1]. The EISA 2007 authorizes the Net-Zero Energy Commercial Building Initiative to support the goal of net zero energy for all new commercial buildings by 2030. It further specifies a zero energy target for 50% of U.S. commercial buildings by 2040 and net zero for all U.S. commercial buildings by 2050 [3]. The EPBD establishes "the nearly zero energy building" as the building target from 2018 for all public owned or occupied by public authorities buildings and from 2020 for all new buildings [4].

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The Japanese government created a strategic plan in 2014 to promote and enhance zero energy buildings. The plan sets a goal to achieve zero energy level for all new public buildings by 2020. The plan also demands that all new buildings shall achieve zero energy level by 2030 [5]. The number of net zero energy buildings (NZEBs) is increasing worldwide. For example, the International Energy Agency's "Towards Net Zero Energy Solar Buildings" project mapped almost 300 net zero energy and energy-plus buildings worldwide [6]. Up until now Egypt doesn't have any buildings on that international NZEBs list. Residential, commercial and institutional buildings consume more than 55% of the total electricity consumption in Egypt [7]. The Egyptian energy sector is currently facing huge challenges with recent years witnessing regular power outages that fueled social unrests. Reducing buildings energy demands to zero levels will not just help Egypt achieve energy sufficiency but also achieve an energy surplus that can be used to develop the Egyptian industry sector and enhance exports, thus reduce the pressure on Egypt's national budget. Egyptian housing and building national research center (HBRC) has developed commercial building energy code in 2009 to improve energy efficiency in office buildings [8]. Although the current energy code can help improve the buildings energy performance, yet it's far from achieving zero energy goals. Making a clear NZEB strategy for Egyptian office buildings is essential to promote NZEBs. Having that goal in mind this research paper is a part of a bigger research project to provide that strategy.

2. Literature review

Determining zero energy building definition is essential in order to promote them, having that goal in mind the USA Department of Energy (DOE) has set 4 definitions for ZEBs (A) Net Zero Site Energy, (B)Net Zero Source Energy, (C)Net Zero Energy Costs, and (D)Net Zero Energy Emissions [9]. Some researchers have investigated ways to realize ZEB definitions e.g. Xiaodong et al, summarized state of the art approaches for ZEB technologies into three categories: passive energy-saving technologies, energy-efficient building service systems and renewable energy production technologies [10]. While others e.g. Phil Jones et al, developed a strategy for achieving zero carbon office building that considered four main areas: (1) Reducing internal heat loads, (2) Addressing passive design through the building construction, (3) Using efficient and responsive HVAC systems and focusing on chilled (heated) surface systems, and (4) Integrating renewable energy supply systems into the building design[11]. In order to confirm the energy efficiency impacts of applying such strategies. Some researchers have analyzed the actual building performance data e.g. Maximilien et al presented the full year of energy performance data on the 681 m^2 ENERPOS zero energy building combining envelope efficiency, efficient equipment, appliances and lighting, a photovoltaic system, passive and active solar thermal features. This case study demonstrates that it is possible to produce 7 times energy than the building actual consumption in hot climates[12]. In Egypt, commercial building energy code [8] was released to improve energy efficiency in office buildings. In order to evaluate the impacts of applying the new code, George B studied the energy savings achieved through applying the Egyptian energy code compared to the current practice. Around 50% energy savings could be achieved through applying code requirements for walls, windows, roof, shading, orientation and set points[7]. In order to facilitate simulation based research towards improving the current building characteristics and promoting ZEBs, Shady Attia et al developed a database for common materials used in Egyptian residential building envelopes for the sake of energy simulations[13]. Some Egyptian researchers studied ways to improve buildings energy efficiency inspired by traditional Egyptian architecture like Marwa Dabaieh et al, who argued that off-grid vernacular buildings when retrofitted and equipped with renewable energy solutions, they can act as nearly zero energy buildings[14]. Although there are still no ZEBs in Egypt, some have tried to make an actual small-scale ZEB model that can suit the Egyptian situation like the American University in Cairo (AUC) students design team developed a net zero energy 61 m^2 house "Slides" to compete in the European solar decathlon, held in June 2012. Slides is a solar-powered living structure that maximizes the use of natural ventilation and cooling, reduces the need for electrically-powered air-conditioning and uses a grey water filtration system that recycles already used water to function like drip irrigation and toilets[15]. Although there has been many research done on providing strategies to achieve Zero Energy performance level in office buildings, the application of such research in the Egyptian situation is still rare. Previous research done to promote ZEBs in Egypt was more concerned with either small-scale detached houses, residential apartments or touristic chalets. Other researchers handled office buildings from the perspective of improving its energy efficiency but rarely do they consider ZEB. While the rest focused on energy simulation tools that can help in evaluating ZEBs. Thus, the main goal of this paper is to further explore certain strategies that we have developed through our research project in order to deliver specific guidelines for designers to achieve ZEB performance level in Egyptian office buildings. Weather data, building design, commonly used building materials, occupant behaviors, schedules including Ramadan and national holidays were all taken into our consideration according to the current Egyptian situation.

3. Questionnaire Survey

As a part of our research project to create a detailed strategy to achieve zero energy performance level in Egyptian office buildings, we conducted a questionnaire to analyze the attitude of Egyptian professional academics and designers towards zero energy buildings. 50 Egyptian green building experts participated in this survey. The questionnaire participants had different experience levels, education levels and different occupations including research institutions, universities, designing firms and general contracting firms backgrounds. The early results of the questionnaire are shown in this research paper. The findings of the survey show that the majority of Egyptian green building expert's community knows about ZEBs while around 30% of them either only familiar with the definition or never heard of the term as shown in the following graph (Fig 1). Survey results also demonstrated that around 56% of those who know about ZEBs mentioned that they got their knowledge about them through reading a book, attending a session or doing research on the topic by themselves. A fewer percentage of the participating experts, 14% mentioned that they got a chance to visit a ZEB project or even got involved in a ZEB project themselves (Fig 1). Those more privileged 14% got their education in Europe, US, or Japan. Survey findings show that around 56% of the participants strongly agreed that it's essential to build a clear strategy to achieve ZEB that suits Egypt. 32% agreed to a lower extent that such a strategy would be important and 8% disagreed that such a strategy would be of any importance while 4% were neutral (Fig 2). When asked what they think ZEB strategy should focus on, around 32% thought Net-Zero energy costs should be our main target while slightly fewer participants 30% recommended to focus on Net-Zero source energy target. 22% of the participants suggested Net-Zero site energy target and 16 % Net-Zero energy Emissions (Fig 3). Zero energy costs balances building energy bills with the money received from the utility for the exported energy to the grid annually [9]. Since the inflation in Egypt is quite high and price fluctuations is unpredictable we focused our target in this paper on net zero source energy instead where building energy consumption is balanced with generation from renewables accounted for at source annually [9].

Since ZEBs are still in the preliminary research and development stage in Egypt around 82% of the Egyptian green building experts interviewed in this questionnaire were academics. 64% of them hold a PhD degree. 24% of the questionnaire participants were designers and 6% general contractors (Fig 4).

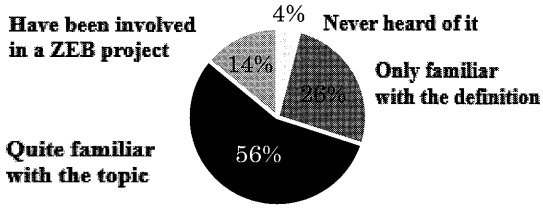

Fig. 1. How familiar are you with the ZEB Concept?

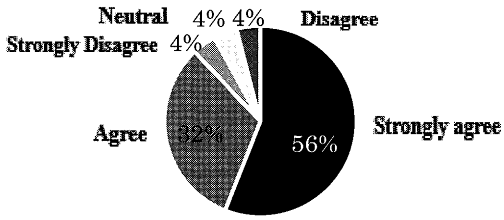

Fig. 2. Do you think it's important to build a clear strategy to achieve ZEB in Your country?

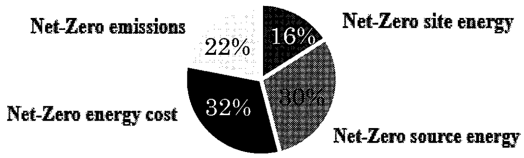

Fig. 3. What do you think our ZEB strategy should focus on?

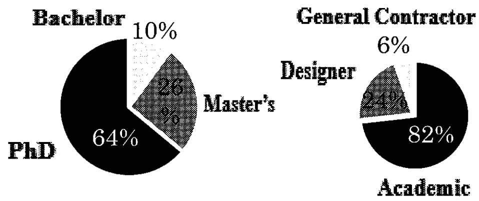

Fig. 4 Participants affiliation and education level.

4. Methodology

The construction and laboratory experiments of zero energy buildings [ZEBs] is a costly way to explore the potential energy saving impacts of various building design alternatives. Computer simulations can provide an initial guide for early stages of design especially for those inexperienced about zero energy building design. Providing a guideline or a strategy that suits the domestic situation is essential to implement and promote ZEBs. Since ZEBs can be defined in several ways, in this research we considered net zero source energy as the main target for this strategy.

4.1 Configurations of the case study;

Weather data: Egypt is situated between latitude 31.33° N and 22 °N and Longitude 26°E & 35 °E. It consists mainly of desert (≅ 94% of Egypt land) except for Northern and Eastern coasts and Nile valley[7]. Egypt is divided into eight climatic zones: Northern Coast zone, Cairo and Delta zone, Northern Upper Egypt zone, Southern Upper Egypt zone, East Coast zone, Highland's zone, Desert zone and Southern Egypt zone. This paper will focus on the situation in Cairo and Alexandria cities located in the first two zones (Fig 5) as defined in the Egyptian residential energy code (EREC) [17]. About 50% of the construction projects carried out in Egypt are located in the two cities [18]. Weather Data Files (EPW) for the two cities were downloaded from the official EnergyPlus website of the US Department of Energy DOE (U.S.D.o.E). Average temperature and relative humidity for the two cities are shown in the following graph (Figs 6 & 7).

Building Model. A Sketchup model for a typical Egyptian office building was created to run the simulations required for this research. Model details are shown in table 1. A plan and an elevation of the building model is shown in (Fig 8) the case studies implemented in this research are shown in Table 2. Recommended cases are highlighted in dark blue.

Table 1. Research model characteristics

Building Area	Total FloorArea	Unconditioned Floor Area	Floor height	No of floors	No of thermal zones	Main Use
1112 m^2	6672 m^2	1073.3 m^2	3m	6	78	Office

Activities and HVAC systems.

A fixed schedule for heating and cooling was used in all the different simulations, and was defined through a fixed activity template, heating and cooling setpoints were assumed as given in Table 3. While the Egyptian code recommends 24°c setpoint for cooling we based our simulation on the actual situation and common lifestyles for the office occupants in Egypt (holidays, work hours, Ramadan schedules, setpoint temperatures etc.) Individual air conditioning system was used ventilation, lighting and internal heat gains were inputted in accordance with the Egyptian energy efficiency code.

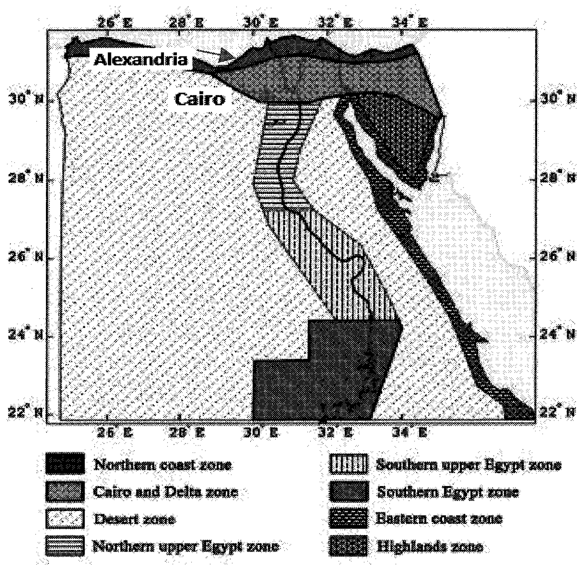

Fig. 5. Egypt's climatic zones classification [16].

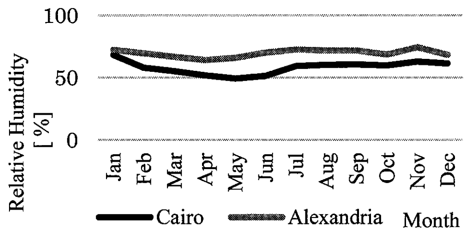

Fig. 6. Relative humidity.

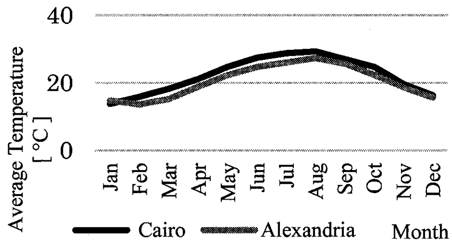

Fig. 7. Average temperature.

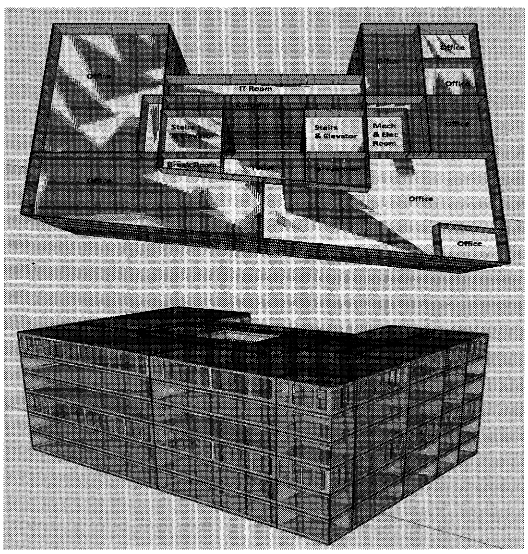

Fig.8.Building model.

Table 2 Case studies implemented in this research. **Notes *1*2**

Research Case Studies							
Step 1: Orientation		North	N.East	East	South	S.west	West
Step 2: Blinds		Case 1: No Blinds	Case 2:	Case 3	Case 4	Case 5	Case 6
Step 3: *1*2 Window types	Single	SHGC_0.82_ U_5.8	SHGC_0.62_ U_5.8	SHGC_0.4_U_5.1	SHGC_0.26_U_4.7		
	Double	SHGC_0.62_ U_3.1	SHGC_0.37_ U_1.5	SHGC_0.28_ U_1.3			
	Tripple	SHGC_0.47_ U_0.79	SHGC_0.31_ U_1.21	SHGC_0.2_ U_1.2			
Step 4: Wall types		Fired Clay 125 mm	Solid Cement Brick 200 mm		Single Red Brick 125 mm		
		Hollow Cement Brick 200 mm	Limestone brick 250 mm	Double Red Brick with AirGap 380 mm		Double Red Brick with Glass wool 380 mm	
Step 5: Roof Insulation		No insulation R 0.52	Pertile 25 mm R 1	ExpPoly 12.5 mm R 0.78		ExpPoly Molded 25 mm R 1 .24	
		ExpPoly Molded 75 mm R 2.65		ExpPoly Extruded 100 R 3.51		ExpPoly Extruded 150 R 4.93	
Step 6: Daylighting sensors		With Daylighting sensors		No Daylighting sensors			
Step 7: HVAC setpoint	Cooling	22°c	23°c	24°c	25°c	26°c	
	Heating	22°c	21°c	20°c	19°c		
Step 8: PV		No Pv	0.2 PV Roof	0.2 PV Roof +Blinds	0.4 PV Roof	0.4 PV Roof +Blinds	
		0.6 PV Roof	0.6 PV Roof +Blinds		0.8 PV Roof	0.8 PV Roof +Blinds	
Step 9: BIPV		BIPV 1			BIPV 2		

Table 3. HVAC setpoint temperatures.

Heating Setpoint	22°c
Cooling Setpoint	22°c

5 Results and discussion.

5.1 Effect of building orientation.

Building orientation has a huge impact on cooling and heating loads thus, its energy consumption is greatly affected by its orientation. This research studied the impact of 6 different orientation scenarios [North, North east, East, South, South West and West]. Cooling and heating energy decreased by around 8% and 9% when choosing North orientation compared to South West orientation in Cairo and Alexandria as shown in the following graph (Figs 9& 10).

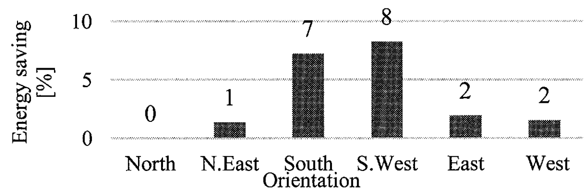

Fig.9 Energy consumption Vs N Orientation Cairo

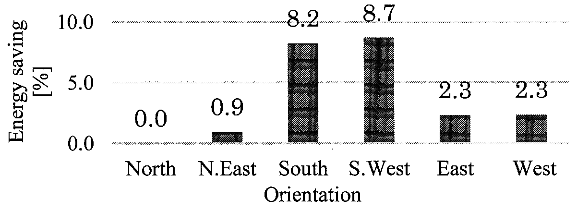

Fig.10 Energy consumption Vs N Orientation Alexandria

5.2 Effect of shading system.

Using optimized shading systems plays a significant role in reducing the solar radiation effect on buildings which will reduce cooling demands and enhance indoor thermal comfort. In this research 6 shading scenarios were studied as shown in (Fig.11) and Table 4. Around 14% energy savings were achieved in Cairo and 15% in Alexandria as shown in (Fig 12) through installing the proposed shading system.

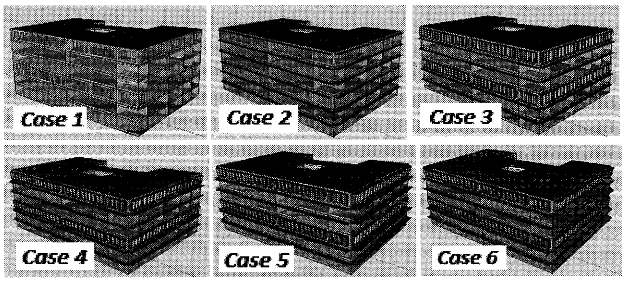

Fig.11 shading system case-studies.

Table 4 Shading system case-studies. **Note*3**

Blinds *3	
Case 1	No Blinds
Case 2	0.4 PF Overhangs
Case 3	3rd and 6th floors [0.25 PF+ Louvers]+ 1st,2nd,5th floors [0.4 PF]
Case 4	3rd and 6th floors [0.25 PF+ Louvers]+ 1st,2nd,5th floors [0.5 PF]
Case 5	3rd and 6th floors [0.4 PF+ Louvers]+ 1st,2nd,5th floors [0.6 PF]
Case 6	3rd and 6th floors [0.45 PF+ Louvers]+ 1st,2nd,5th floors [0.7 PF] 30' tilted on West and East

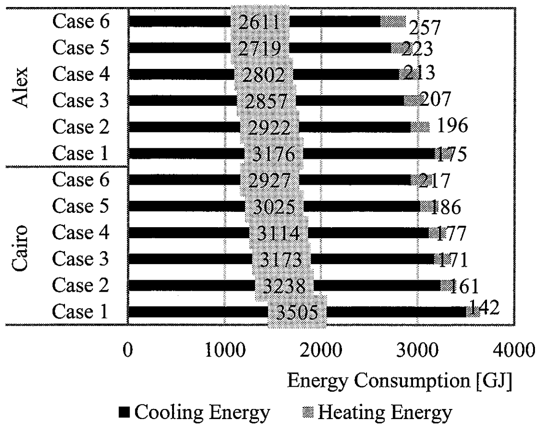

Fig.12 Effect of shading system.

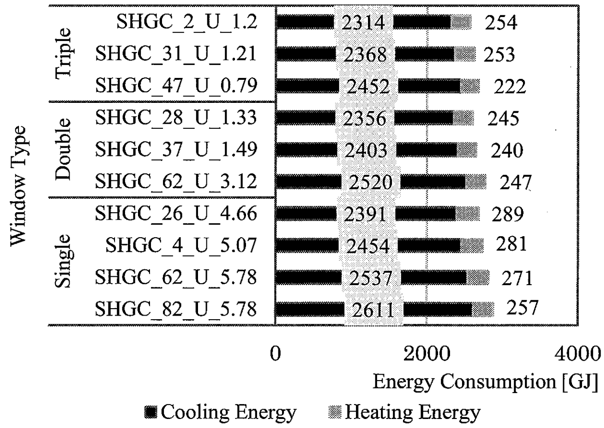

Fig.14 Effect of window type Alexandria

5.3 Effect of window types.

Façade configuration and window type has a huge impact on cooling, heating and lighting energy demands. It also influences the indoor thermal comfort and it can provide a pleasant work environment through daylighting. In this research 10 window type scenarios were studied. The impact of window type on energy consumption for cooling and heating in Cairo and Alexandria is shown in (Fig 13 & 14). Tinted double low E glazing of the following characteristics SHGC 0.28 and U-Value 1.33 W/m²K was chosen for our model since it confirms with the Egyptian code for both SHGC and VT requirements and achieved the best simulation results. Energy consumption dropped down more than 10% in Cairo and 9% in Alexandria.

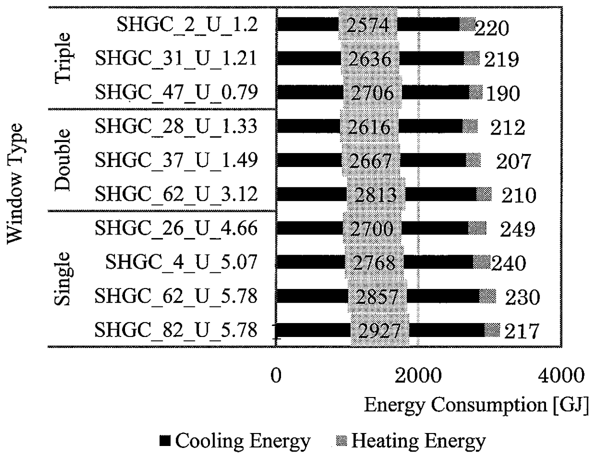

Fig.13 Effect of window type Cairo

5.4 Effect of wall types.

While the current situation in Egyptian building walls are rarely insulated , around 8% energy savings where achieved when using double red bricks with glass wool insulation and increasing wall R value to 3.1. The proposed wall section is shown in (Fig 15). In this research 7 wall insulation scenarios were studied, the impact on cooling and heating energy in Cairo and Alexandria is shown in (Fig 16 &17). The findings clearly show the importance of wall insulation on energy savings.

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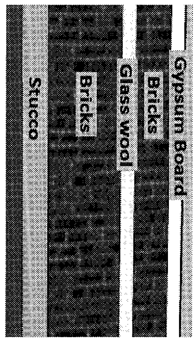

Fig.15 Wall section

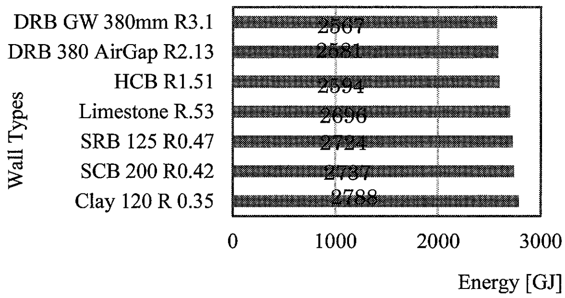

Fig.16 Effect of wall types, Cairo.

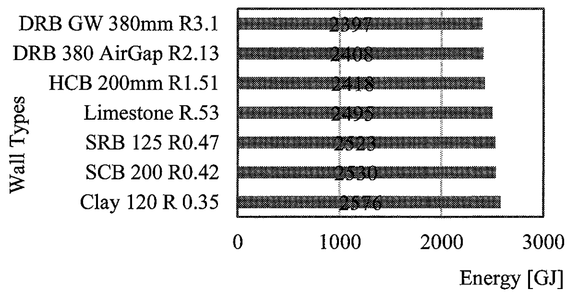

Fig.17 Effect of wall types, Alexandria.

5.4 Effect of roof types.

In this research 7 roof insulation scenarios were studied, no insulation, expanded polystyrene extruded 1.25, 2.5, 12, 15 cm and expanded polystyrene molded 2.5, 7.5 cm, perlite 2.5 cm. The roof components are shown in the following (Fig 18). The impact on cooling and heating energy in Cairo and Alexandria is shown in (Fig 19 & 20). As shown in the following graph energy consumption dropped down by around 4% in Cairo case and 3% in Alexandria when increasing roof R value to 3.5 K. m²/W.

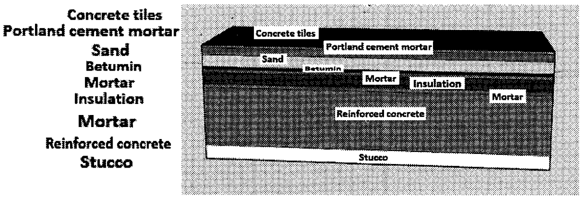

Fig.18 Roof section

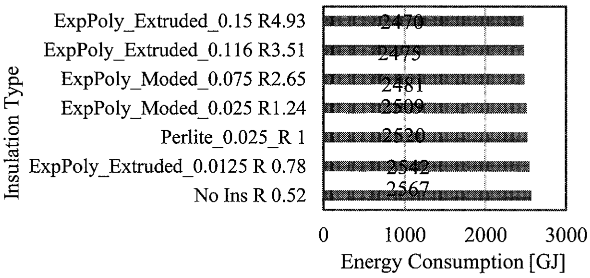

Fig.19 Effect of roof insulation, Cairo.

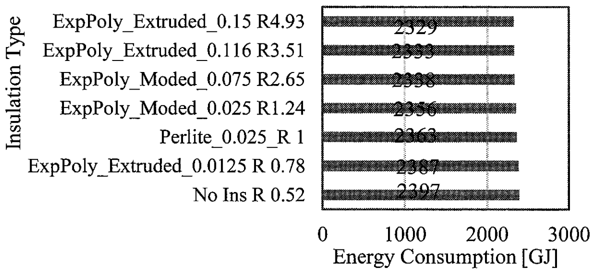

Fig.20 Effect of roof insulation, Alexandria.

5.5 Effect of daylighting sensors.

The application of daylighting sensors and lighting controls not only reduces building energy consumption significantly through reducing the load on artificial lighting system and reducing heat generation in the room caused by artificial lighting equipment but also it improves visual comfort and well-being of building occupants. We simulated the effect of applying daylighting sensors to our model with automatic on/off Controls with lighting setpoint at 300 Lux as recommended by the Egyptian code for commercial buildings. Configurations of the case study are shown in (Fig 21). As shown in (Fig 22), around 56% energy savings for lighting in Cairo and 54% in Alexandria were achieved and cooling loads dropped by 17% in Cairo and 19% in Alexandria while heating increased by 48% in Cairo and 44% in Alexandria although heating energy value is not significant in the case of the two cities.

Table 5. Configurations of the case study. Note*4

Glazing Type *4	Tinted Double Glazing SHGC_0.28_VT_0.41_U_1.33
Shading System	Case 6 Blinds
Lighting Setpoint	300 Lux
Lighting Heat Generation	14 w/m²

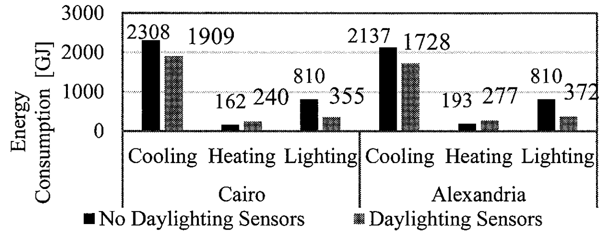

Fig.21 Effect of Daylighting sensors.

5.6 Effect of HVAC setpoints. Note*5

Heating and cooling setpoints have a huge impact on building energy consumption for cooling and heating. However, occupants thermal comfort level is highly affected by the cooling and heating setpoints In this research we simulated the impact of changing cooling setpoint between 22°-28°C and heating setpoint between 19°-22°C in Cairo and Alexandria. (Figs 23 & 24) shows the impact of HVAC setpoints on heating and cooling energies in Cairo. In this paper we proposed to set HVAC temperature for cooling at 26°C and heating at 20°C and we compared to reference case [22°C for cooling and heating]. As shown in (Fig 25) around 47% energy savings were achieved in Cairo and 52% in Alexandria.

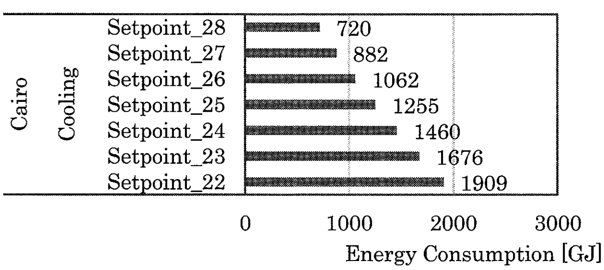

Fig. 22 Effect of Cooling Setpoint, Cairo.

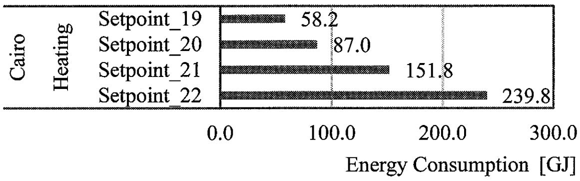

Fig.23 Effect of Heating Setpoint, Cairo.

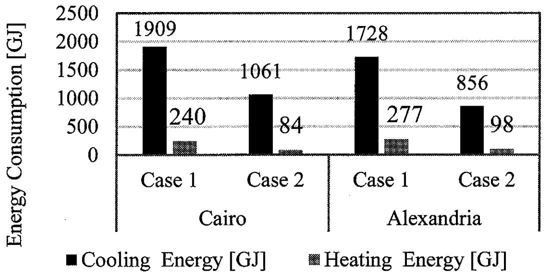

Fig.24 Proposed case Vs Base case, HVAC setpoints.

5.7 Effect of PV.

Using PV panels has a great potential since Egypt has 2,400 hours annually for potential solar operations. In this research 9 PV scenarios were studied, (1) No PV. (2) 20% of roof area covered with PV. (3) 20% of roof area plus blinds covered with PV. (4) 40% roof area. (5) 40% roof area with blinds. (6) 60% roof area. (7) 60% roof area with blinds. (8) 80% roof area. (9) 80% roof area with blinds. On-site generation Vs total source energy and Net source energy/m2 in Cairo case are shown in the following (Figs 26 &27). (Fig 28) shows the model with PV panels installed on its roof.

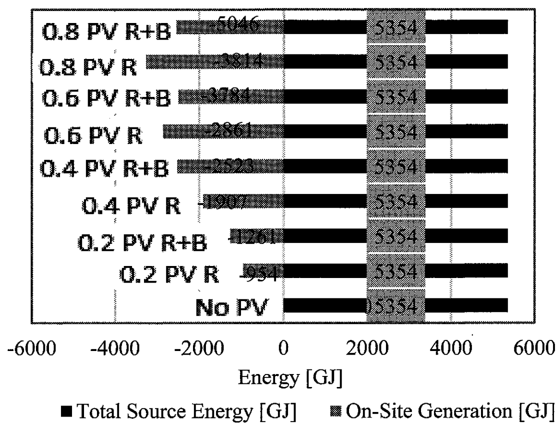

Fig.25 Total source energy vs PV energy generation. Cairo. Notes *6 *7 *8

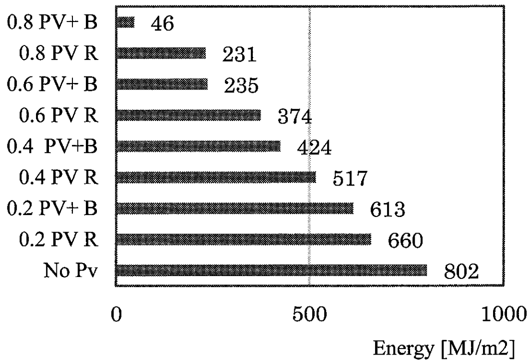

Fig.26 Net Source Energy /m2, Cairo.

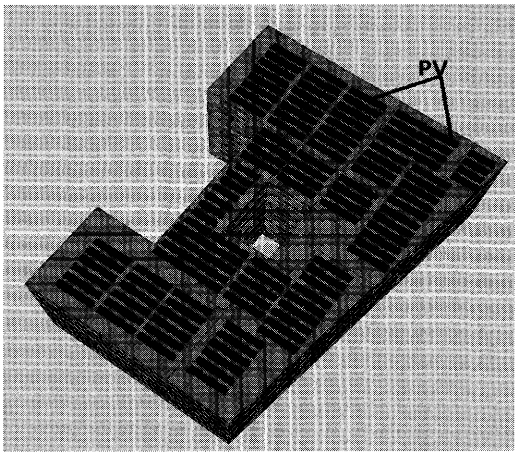

Fig.27 OpenStudio model with roof PV.

5.7 Effect of BIPV. Note*9

Integrating PV in the building design can have significant impact on harvesting renewable energy from the sun and covering the building energy needs from environmentally friendly sources. We simulated the effect of integrating PV cells in the building south façade for 1 floor BIPV1 and two floors BIPV 2 as shown in (Fig 29) and calculated total source energy versus on-site generation and the building could reach positive energy performance level using this strategy as shown in (Fig 26).

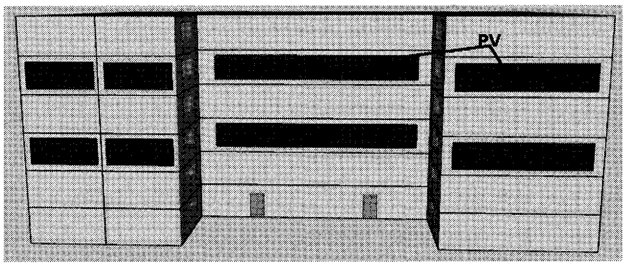

Fig.28 BIPV 2

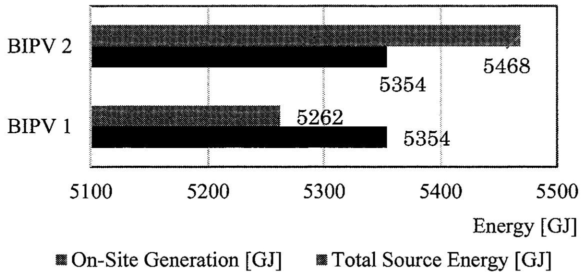

Fig.29 Total source energy vs PV energy generation.

6. Conclusions.

In this paper, the impact of various building envelope design factors have been evaluated 68% and 70% energy savings were achieved through passive strategies before applying an active solar strategy in Cairo and Alexandria cases. Final proposed cases compared to the base case are shown in Table 6 The effect of using an optimized shading system, automatic daylighting controls and HVAC setpoint for cooling were quite high. Cooling loads decreased by around 12 ~ 15% with every 1°C temperature higher for HVAC cooling setpoint. We could recommend higher cooling HVAC setpoint to save more energy but given the thermal comfort level for office building occupants in Egypt. It's hard to realize such a recommendation since the current situation goes between 20~22°C and we recommended 26°C as there are other factors to be considered like social customs that require certain patterns of clothing like Hijab or Niqab that provides higher level of clothing insulation. Applying daylighting controls decreased energy usage by 47% not just because of the significant energy savings from artificial lighting but also due to slightly decreased cooling loads due to the decrease in heat generation in the room from artificial lighting equipment. The use of efficient low-E glass and an appropriate shading system had significant impact on decreasing building cooling energy by around 24%. Even though that it's still uncommon to add thermal insulation to walls in Egyptian office buildings but the findings of this research proves that it can reduce building cooling energy by around 8%. Roof insulation is essential to improve the building envelope energy efficiency. Around 4% savings to the building cooling energy were achieved by adding a layer of 10 cm expanded polystyrene insulation to the roof. Increasing roof and wall insulation had a reduction effect on cooling energy, having that trend we could have applied more insulation to achieve more energy savings but we took into our consideration to have a more realistic and achievable strategy that can suit the domestic situation. The combinations provided in this research proves that achieving zero energy level in Egyptian office buildings can be possible if some proposed strategies were to be followed. As a part of our research project, we conducted a questionnaire to analyze the attitude of Egyptian academics and designers towards zero energy buildings. Around 30% of Egyptian experts who participated in the survey are either familiar only with the ZEB concept or even never heard of it.

Table 6. Proposed Cases Vs Base case energy savings

	Cairo		
Component	Base Case	Proposed case	Energy saving
Building Orientation	-	North	8%
Shading system	No overhangs	Blinds Case 6	14%
Window type	Single SHGC_819_VT_881_U_5.778	Double SHGC_283_VT_408_U_1.333	10%
Wall type	Clay 120 R 0.35	Double Red brick with glass wool 380mm R3.1	8%
Roof Insulation	No insulation	Expanded polystrene extruded 10 cm	4%
Daylighting sensors	No daylighting controls	With daylighting control	24%
HVAC Setpoints	22°C Cooling & 22°C Heating	26°C Cooling & 20°C Heating	47%
Total Energy for Cooling, Heating and Lighting [GJ]	4742	1501	68%
	Alexandria		
Component	Base Case	Proposed case	Energy saving
Building Orientation	-	North	9%
Shading system	No overhangs	Blinds Case 6	15%
Window type	Single SHGC_819_VT_881_U_5.778	Double SHGC_283_VT_408_U_1.333	9%
Wall type	Clay 120 R 0.35	Double Red brick with glass wool 380mm R3.1	7%
Roof Insulation	No insulation	Expanded polystrene extruded 10 cm	3%
Daylighting sensors	No daylighting controls	With daylighting control	24%
HVAC Setpoints	22°C Cooling & 22°C Heating	26°C Cooling & 20°C Heating	52%
Total Energy for Cooling, Heating and Lighting [GJ]	4461	1326	70%

Also 88% of the participants thought that providing a ZEB guideline that suits Egypt is essential. This research shall be followed by more detailed research, on-site experiments case studies and, with life cycle cost analysis to create a full strategy to achieve zero energy level in Egyptian office buildings.

Notes

*1 SHGC: Solar Heat Gain coefficient. [-]
*2 U: U factor. [W/m²K.]
*3 PF: Projection factor. [-]
*4 VT: Visible Transmittance [-]
*5 HVAC: Heating, Ventilation, and Air conditioning Unit.
*6 PV: Solar Photovoltaic panel.
*7 PV R: PV on the Roof.
*8 PV R+B: PV cells on both roof and Overhangs.
*9 BIPV: Building Integrated photovoltaic system.

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