Comparison of Traditional and Green Building Designs in Egypt: Energy Saving

Hala M. Abdel Mageed, Ahmed I. Omar, Shady H. E. Abdel Aleem

Abstract**—**This paper describes in details a commercial green building that has been designed and constructed in Marsa Matrouh, Egypt. The balance between homebuilding and the sustainable environment has been taken into consideration in the design and construction of this building. The building consists of one floor with 3 m height and 2810 m^2 area while the envelope area is 1400 m^2. The building construction fulfills the natural ventilation requirements. The glass curtain walls are about 50% of the building and the windows area is 300 m^2. 6 mm greenish gray tinted temper glass as outer board lite, 6 mm safety glass as inner board lite and 16 mm thick dehydrated air spaces are used in the building. Visible light with 50% transmission, 0.26 solar factor, 0.67 shading coefficient and 1.3 $W/m^2.K$ thermal insulation U-value are implemented to realize the performance requirements. Optimum electrical distribution for lighting system, air conditions and other electrical loads has been carried out. Power and quantity of each type of the lighting system lamps and the energy consumption of the lighting system are investigated. The design of the air conditions system is based on summer and winter outdoor conditions. Ventilated, air conditioned spaces and fresh air rates are determined. Variable Refrigerant Flow (VRF) is the air conditioning system used in this building. The VRF outdoor units are located on the roof of the building and connected to indoor units through refrigerant piping. Indoor units are distributed in all building zones through ducts and air outlets to ensure efficient air distribution. The green building energy consumption is evaluated monthly all over one year and compared with the consumed energy in the non-green conditions using the Hourly Analysis Program (HAP) model. The comparison results show that the total energy consumed per year in the green building is about 1,103,221 kWh while the non-green energy consumption is about 1,692,057 kWh. In other words, the green building total annual energy cost is reduced from 136,581 $ to 89,051 $. This means that, the energy saving and consequently the money-saving of this green construction is about 35%. In addition, 13 points are awarded by applying one of the most popular worldwide green energy certification programs (Leadership in Energy and Environmental Design "LEED") as a rating system for the green construction. It is concluded that this green building ensures sustainability, saves energy and offers an optimum energy performance with minimum cost.

Keywords**—**Energy consumption, energy saving, *g*reen building, leadership in energy and environmental design, sustainability.

I. Introduction

NOWADAYS, the world is faced with challenges in sustainable development. Achieving sustainability requires consolidation environmental protection and focusing on green building realm. Green Building (GB) is a building that complies with the technical, economic, environmental and social needs. Its main figure of merits is the low energy consumption, low investment costs, reduced harmful impacts on the environment and people as well [1].

The concept of GB incorporates strategies during design, construction and operation. In other words, GB construction is a method of wisely using resources to create high quality, healthier and more energy efficient homes and commercial buildings [2]. These buildings design involves finding the balance between homebuilding and the sustainable environment with high quality construction and low environmental impact. GB consolidates both materials and procedures manipulations to expand proficiency, sturdiness, and revenues. Using GB materials represent an important approach in the design of a building. Measures of GB include careful building design to reduce heat loads, maximizing natural light and promoting the circulation of fresh air. Also, nontoxic materials and air conditioning with optimum energy consumption are used.

Electrical energy is essential for modern life and it plays a vital role as an infrastructural input for economic development of a country [3]. Energy saving is one of the most important benefits of the GBs that overcomes the peak energy demands. Accordingly, energy efficiency over the whole life cycle of a building is the most significant objective of sustainable engineering. Planners utilize a wide range of static passive and dynamic active methods to lessen the energy needs of structures and increment their capacity to produce their own particular energy [4]. European Union Directive on Energy Performance on Buildings (EPBD) has been proposed in December 2002. The main goal of EPBD is to improve the energy performances of buildings taking into consideration indoor and outdoor environmental conditions [5], [6].

The optimum manner to insure the green trend success is to have an evaluation approach [7], [8]. Accordingly, GB rating systems have been rapidly instituted and introduced in the civilized countries. Energy is one of the considerable categories in the GB rating frameworks all over the world [1]. In 1998, the American LEED is introduced. Quickly, it became one of the most popular GB rating systems throughout the world [9], [10]. It intends to guarantee the best electrical using with optimum energy consumption and facilitates escalating the building sustainability. This credit is one of the most popular credits that is essential to assess different types of buildings in all development stages [1], [11]-[13].

In this work, a commercial GB has been designed and constructed in Egypt. The total energy consumption of this

Hala M. Abdel Mageed is with the National Institute of Standards (NIS), 12211 Giza, Egypt (e-mail: halaabdelmegeed@yahoo.com).
Ahmed I. Omar is with the High Institute of Engineering, El-Shorouk Academy El-Shorouk City, Egypt.
Shady H.E. Abdel Aleem is with the 15th of May Higher Institute of Engineering, 15th of May City, Helwan, Cairo 11731, Egypt.

building has been discussed. Site selection in sustainable way, environmental friendly ideas and material selections have been taken into consideration. The energy consumption of the green commercial building has been assessed and compared with a non-green one energy consumption.. The total annual energy cost has been calculated. HAP model has been used to evaluate the comparison results. LEED has been applied as a powerful and common rating system to evaluate the building electrical performance.

Fig. 1 The Plan of the new commercial building

Fig. 2 The new commercial building Photo

II. The New Building Design and Construction

A new commercial building in Marsa Matrouh, Egypt has been designed as a case study for GBs. The building is only one floor with 3 m height and 2810 m^2 area. It consists of two entrances, administration rooms, classrooms, restaurant, restaurant, meeting rooms, cabins, offices, labs, kitchen, storage areas, toilets, and corridors. The envelope area of the building is 1400 m^2. The plan of the building and its photo are shown in Figs. 1 and 2, respectively. Windows are placed to maximize the input of heat creating light and minimize the heat loss. Glass curtain walls and low emissivity coatings have been used to provide much better insulation. The area of the windows is 300 m^2 and the glass curtain walls are about 50% of the building. Double glassy and shaded windows are used. The building and its envelope have been designed and constructed to fulfill the natural ventilation requirements. Four in face brick layer walls with 25 mm R-7 board insulation are used. The roof is built-up with 25 mm R-14 board insulation. Materials with high thermal mass and strong insulation are used to prevent heat escape. Passive solar design and well insulated building have been applied to harness the energy of the sun efficiently without the use of any active solar mechanisms.

Safety gray glass of 6 mm thickness is used for inner and outer board lite of curtain walls. Windows plates of 16 mm thickness and specific air spaces are applied in the building. Furthermore, windows with minimum visible light transmission, 0.26 solar factor, 0.67 shading coefficient and 1.3 W/m^2.K thermal insulation are used.

Lighting system with ideal electrical distribution and high power quantity lamps has been implemented. The lighting system of the building has been divided into different types of lamps according to each area requirements. These types are 9 W eco-lamp; 36 W, 45 W fluorescent lamps and some decorative lamps. There are automatic lighting controls and the lighting power allowance is a maximum of 0.9 multiplied by the values determined in accordance with ASHRAE/ IESNA Standard 90.1 [14]. Power and quantity of lamps and energy consumption has been investigated on a monthly basis over one year.

An efficient heating, ventilating, and air conditioning (HVAC) system has been installed. VRF technology has been followed for the HVAC system [15]-[17]. Eight air source pumps are used as the cooling supply source in summer and seven heat pumps are used in winter. The VRF outdoor units are located on the roof and connected to indoor units through refrigerant piping. VRF indoor units have been distributed in all zones of the building and served them through duct works and air outlets to insure efficient air distribution. All indoor units are complete with drain pumps. The preliminary outside design of the HVAC system is based on the outside conditions criteria. The temperature in summer is about 35 ^{o}C for dry bulb and 26.7 °C for wet bulb. In winter, it is 7.3 ^{o}C for dry bulb and 6.1 ^{o}C for wet bulb. Kitchens, stores and electrical rooms are ventilated by separate exhaust systems using fan sections and duct works. Three VRF out door units are located in the roof. The green concept of designing and building in our case study is compared with the traditional one. Table I illustrates this comparison.

III. Results and Discussion

The HAP model has been used for the comparative analysis between the green and traditional designs. The comparative results show that green alternative exhibits huge savings in energy costs. Table II lists the monthly energy consumption and cost of HVAC and non-HVAC systems for the traditional design while Table III lists these parameters for the green one.

TABLE I
COMPARISON BETWEEN GREEN AND TRADITIONAL CONCEPT OF DESIGNING AND BUILDING

Item	GB	Traditional Building
Walls	Four in face brick layer walls with 25 mm R-7 board insulation	Single brick layer with no insulation
	Glass curtain walls (50% of the walls)	No glass curtain walls
	low emissivity coatings	Ordinary coating
Roof	built-up with 25 mm R-14 board insulation	Reinforced Concrete with no insulation
	High thermal mass roof	Ordinary roof
Windows	Double Glazed with Blinds	Single Glazed
	Clear and safety glass	(No specified requirements)
	50% minimum transmission for visible light	
HAVC	VRF System	Packaged rooftop VAV with reheat
Lighting	Optimum lighting distribution &Automatic lighting controls	Ordinary lighting distribution & no automatic lighting controls

TABLE II
COMPARISON BETWEEN HVAC SYSTEM AND NON-HVAC SYSTEM FOR TRADITIONAL DESIGN

Month	Non-HVAC		Non-HVAC	
	Energy (kWh)	**Electric ($)**	**Energy (kWh)**	**Electric ($)**
Jan.	16,870	1,362	115,228	9,304
Feb.	14,967	1,209	106,242	8,583
March	19,732	1,594	119,325	9,632
April	23,314	1,882	115,221	9,301
May	27,374	2,210	114,821	9,268
June	39,213	2,656	115,245	9,301
July	35,227	2,842	119,719	9,660
August	34,891	2,816	114,828	9,265
Sept.	31,971	2,580	115,229	9,300
Oct.	27,830	2,247	115,229	9,301
Nov.	22,771	1,839	114,828	9,270
Dec.	18,558	1,498	119,719	9,664
Total	**306,422**	**24,733**	**1,385,635**	**111,848**

TABLE III
COMPARISON BETWEEN HVAC SYSTEM AND NON-HVAC SYSTEM FOR GREEN DESIGN

Month	Non-HVAC		Non-HVAC	
	Energy (kWh)	**Electric ($)**	**Energy (kWh)**	**Electric ($)**
Jan.	10,999	888	75,129	6,066
Feb.	9,759	788	69,270	5,596
March	12,865	1,039	77,800	6,280
April	15,201	1,227	75,124	6,064
May	17,848	1,441	74,863	6,043
June	21,459	1,732	75,140	6,064
July	22,968	1,853	78,057	6,298
August	22,749	1,836	74,868	6,041
Sept.	20,845	1,682	75,129	6,063
Oct.	18,145	1,465	75,129	6,064
Nov.	14,847	1,199	74,868	6,044
Dec.	12,100	977	78,057	6,301
Total	**199,787**	**16,126**	**903,434**	**72,925**

The annual energy consumption and cost of both traditional and green designs are calculated and listed in Table IV. It is clearly shown that, the total energy consumed per year in the GB is about 1,103,221 kWh while the non-green energy consumption is about 1,692,057 kWh which means that the annual energy saving is 588,836 kWh. Furthermore, the total money saved per year using the green energy design is 47,530 $. This means that the percentage savings in energy and cost is about 35%.

TABLE IV
ANNUAL ENERGY CONSUMPTION AND COST OF TRADITIONAL AND GREEN DESIGNS

Comparative Analysis	Green Design	Traditional Design
Annual Non-HVAC Energy (kWh)	199,787	306,422
Annual HVAC Energy (kWh)	903,434	1,385,635
Total Annual Energy(kWh)	1,103,221	1,692,057
Annual HVAC Cost ($)	16,126	24,733
Annual Non-HVAC Cost ($)	72,925	111,848
Total Annual ($)	89,051	136,581
Annual Energy Saving (kWh)	588,836	
Annual Cost Saving ($)	47,530	
Annual Energy / Cost Saving (%)	34.8 % ≈ 35 %	

To ensure the optimal performance and maximum energy saving, LEED has been applied. LEED is one of the most popular GB certification programs used worldwide. 13 points awarded for this GB design according to the LEED rating system as shown in Table V.

TABLE V
POINTS AWARDED IN LEED RATING SYSTEM

%Cost Savings	Points Awarded
12%	1pt
14%	2pt
16%	3pts
18%	4pts
20%	5pts
22%	6pts
24%	7pts
26%	8pts
28%	9pts
30%	10pts
32%	11pts
34%	12pts
36%	**13 pts**
38%	14pts

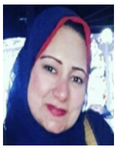
IV. CONCLUSION

Energy saving is one of the significant benefits of the green and sustainable buildings. This research put emphasis on energy and costs savings as they are considered main indicators to investors. It also shows that GB design has economic benefits and more life-cycle saving since adopting green approaches. A GB design in this paper is presented to aid design experts to select customized and optimum GB design with least costs. This work could be perceived as a platform to introduce more sustainability concerns in GB realm.

REFERENCES

[1] Shady H.E. Abdel Aleem, Ahmed F. Zobaa, Hala M. Abdel Mageed, "Assessment of energy credits for the enhancement of the Egyptian Green Pyramid Rating System," Energy policy, 87, 2015, pp. 407-416.

[2] (IGBC), Indian Green Building Council. Abridged Reference Guide for New Construction & Major Renovations (LEED-India), India
[3] Md. Asif Uddin Khan, Rakiba Rayhana, Ratan Datta, "Development of An Energy Audit Tool for Commercial Buildings in Bangladesh," BSc. Thesis in Electrical and Electronics Engineering, BRAC University, Aug. 2015
[4] M. DeKay & G.Z. Brown, Sun Wind & Light, Architectural Design Strategies, 3rd edition, Wiley, 2014
[5] Energy Performance of Building Directive (EPBD) compliance study, Written by ICF International, December 2015
[6] Energy Audit of Building: A Case Study of a Commercial Building in Shanghai. s.l. : U.S. Government work, 2011
[7] Elgendy, K., 2010. Comparing Estidama's Pearls Rating System to LEED and BREEAM. Carboun: Advocating Sustainable Cities in the Middle East. Available at: http://www.Carboun.com/sustainable-urbanism Accessed on 19/1/17
[8] Choongwan, K., Taehoon, H., Minhyun, L., Hyo, S.P., 2014. Development of a new energy efficiency rating system for existing residential buildings. Energy Policy 68, pp. 218–23, Available at: http://dx.doi.org/10.1016/j.enpol.2013.12.068 Accessed on 23/1/2017
[9] Yudelson, J., Green Building through Integrated Design, first edition, McGraw-Hill, New York, 2008
[10] U.S. Green Building Council, 2012. Available at: http://www.usgbc.org Accessed on 18/01/17.
[11] Abdel Aleem, S.H.E., Balci, M.E., Sakar, S., "Effective utilization of cables and transformers using passive filters for non-linear loads". Int. J. Electr. Power Energy Sys., 2015, 71, pp.344–350.
[12] Diaa A. Madboly, S.H.E. Abdel Aleem, A.M. Ibrahim, "Optimal Sizing of Different Configurations of Renewable Distributed Generation Systems for a Green Building in Egypt", *18th International Middle - East Power Systems Conference*, MEPCON' 2016, December 27-29, 2016.
[13] Younan, V.A., "Developing a Green Building Rating System for Egypt," M.Sc. Dissertation. School of Sciences and Engineering, The American University in Cairo, Cairo, Egypt, 2011
[14] Standard 90.1-2001 (I-P Edition) -- Energy Standard for Buildings Except Low-Rise Residential Buildings (IESNA cosponsored; ANSI approved; Continuous Maintenance Standard)
[15] American Society of Heating, Refrigerating and Air-Conditioning, Standard 189.1P for the Design of High-Performance Green Buildings, ASHRAE® Standard. Atlanta, 2011
[16] Goetzler, "Variable Refrigerant Flow Systems," ASHRAE Journal, April 2007, pp. 24-31
[17] Thornton, Brian, "Variable Refrigerant Flow Systems," General Services Administration Report, US Federal Government, 2013



Hala M. Abdel Mageed received M.Sc. and Ph.D. degrees in Electrical Power and Machines from the Faculty of Engineering, Cairo University, Egypt in 2004 and 2010 respectively. She is an associate professor in the National Institute of Standards (NIS), Egypt. She is an author of many refereed journal and conference papers. Her areas of expertise are electrical measurements, electrical metrology, renewable energy and green energy. Currently she is the head of high voltage lab and proficiency testing lab at NIS, Egypt.

Shady H. E. Abdel Aleem received the B.Sc. and M.Sc. and Ph.D. degrees in Electrical Power and Machines from the Faculty of Engineering, Helwan University, Helwan, Egypt, in 2002, and the Faculty of Engineering, Cairo University, Egypt, in 2010 and 2013 respectively. He is working in the field of electric machines, renewable energy, and power quality. He is a member of IEEE and a member of IET. He is author of many refereed journal and conference papers. Areas of research include harmonic distortion, electromagnetic interference, power quality, renewable energy, electric machines, and green energy