International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.6, pp 1104-1125, 2017

Application of Energy Efficiency Techniques & Design of Building Facades by Simulation Model

Shimaa A. Abdel-Majid[1]*, Hesham S. Hussein[2], Mohamed S. Nada[3]

[1]Obour High Institute for Engineering and Technology, Belbees, Egypt.
[2]Department of Architecture, Faculty of Engineering, Cairo University, Egypt.
[3]Department of Architecture, Faculty of Engineering, Beni-Suef University, Egypt.

Abstract : In view of the energy crisis that encounters the entire world, it is inevitable to find new solutions and innovative alternatives to provide other sources in order to generate energy instead of mere dependence on traditional, non-renewable sources of energy that incur huge expenses with the utilization of technological methods, modern technologies and information technology that operate in an integral way to provide a better amount of energy while maintaining it. The building facades cladding technique has been known since a long ago, but its technique differs with different age. In the light of the scientific advancements that we are witnessing in modern times in all areas and fields it is mandatory for architecture to interact with these variables, including the usage of all available technological methods and techniques and their utilization in designing the building facades. The impact of these techniques on the users of the building should be highlighted. This research presents the best methodology for improving energy efficiency by designing building facades within Greater Cairo by evaluating the existing building of the Faculty of Engineering, Architecture Department, Cairo University. This takes place by using the computer and simulation programs in order to develop different and appropriate design alternatives that contribute to the fulfilment of the requirements of comfort and provision of eligible and good environment to determine the extent of the impact of the proposed methodology on energy efficiency.
Keywords : Energy efficiency, buildings' envelopes, building facades, energy consumption reduction.

Introduction:

In fact, energy is the pivot of modern civilization as it is one of the two sides of the equation of progress and economic and social advancement. One of the most important characteristics of the buildings is its consumption of huge amounts of energy due to insufficient study of the facades with thermal leakage from the inside to the outside and vice versa. Hence, the buildings facades separate the outer and internal vacuums and thus it can function as a controller. Hence, it is an effective regulator of the relationship between the exterior and the interior. The modern facade differs from the traditional one in its ability to merge many various devices that control the adaptability of the exterior envelope to carry out its function as a milieu or a medium regulating weather [1].

Experimental:

To achieve the objectives of this research, the following scientific methodology has been adopted for the field study and researches as it depends on the following phases:

1- Theoretical (Desktop) Study (Analytical Criticism):

The researchers study a critical theory in order to determine the main concepts and phases about energy and examples of new applications and standards of the designing of the building facades according to energy saving strategies that are then used in criticizing and analyzing the case study.

Basic Concepts of Energy and its Utilization in Buildings: Definition of Energy Efficiency:

Energy Efficiency means the optimal utilization of energy resources, that is, a set of procedures or techniques that lead to the reduction of energy consumption without affecting or blemishing the individuals' comfort or productivity as energy is used only in case of actual need of it. The improvement of energy efficiency and conservation does not indicate the prevention of energy consumption, rather it means the use of this energy in a more efficient manner.

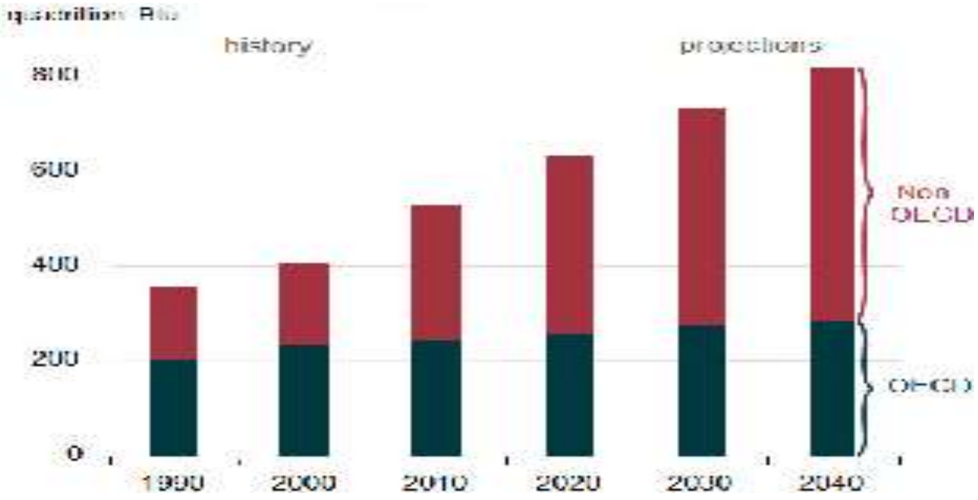

Figure 1. Global energy consumption has been expected to increase by more than 50% over the period of 40 years (from 2000 until. 2040).

It is evident, by studying the increase of worldwide energy consumption, that there are ratios that indicate the shrinkage of renewable sources contribution in global energy supply. The future forecasts indicate an increased demand for energy, as in Figure (1) at an average annual rate of 7.0%, to meet the growing energy needs within a short period of 20-40upcoming years [2].The construction and operation of buildings is one of the most energy and resource consumption operations in the world, as pollution resulting from the lack of control of energy efficiency in buildings and its wastes cause huge environmental damages. This made the utilization of renewable energies an urgent necessity, knowing that building and constructions sector is one of the largest energy and primary resources consuming sectors, as it accounts for around 40%-50% of energy consumption in the world annually. In addition, the resulting carbon emissions are much greater than those in the transport sector [3].

Energy Consumption Rate in Buildings Sector in Egypt:

The buildings sector is the largest energy-consuming sector, in most countries, especially the electric energy, as buildings in Egypt consume more than 60% of total electric energy consumption in buildings in Egypt compared to residential, commercial and governmental buildings. Figure (2) illustrates the distribution of energy consumption in different sectors in the year 2013-2014, with residential buildings consuming the highest ratio, accounting for 43.3% whereas the commercial buildings consume around 12.2%, governmental buildings amount to 5.8% whereas the industrial buildings have 26.1%.

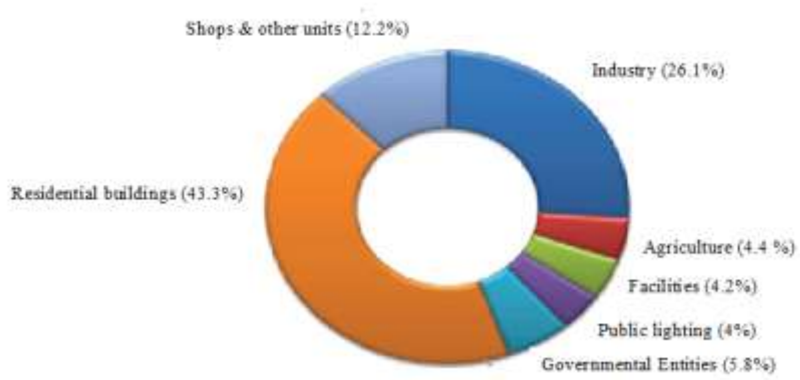

Figure 2. Electricity Consumption Rate in buildings in Egypt for the year 2013-2014.

Egypt is now facing a drastica nd severe challenge of provisioning of sufficient resources of energy sources, especially oil and natural gas, on which Egypt relies for around 95% of its total energy requirements [4].According to Egypt's Energy Strategy 2030 and the current updating thereof to cover the period till 2035, Egypt is expected to become a permanent importer of oil and gas within a period of several years from the beginning of the third decade of this century. This situation presents an additional challenge that encounters the Egyptian economy that is exposed to price disturbances and turbulence in global energy markets that cannot be expected or controlled [5].

The Basic Phases of Energy Triangle of the Design of Low-energy Buildings:

The energy conservation and the improvement ofits consumption efficiency in buildings sectors rely on the procedures and behaviors of users in addition to energy management. It can be divided into three basic phases [6], as in Figure (3):

Phase 1: Energy preservation and conservation related to the design of the building itself (architectural climatic design) and its implementation, particularly the outer envelope and all its requirement of thermal load.

Phase 2: Energy efficiency related to the use of the state-of-the-art equipment, systems and components in the highly- efficient and energy-saving buildings.

Phase 3: the utilization of renewable resources in a way related to the exploitation of resources, their conservation and production costs saving.

Figure (3): Energy Triangle of the Design of Low-energy Buildings

Figure 3. Energy triangle for low-energy building design.

Examples of New Applications of Building Facades to Reduce Energy Consumption:

The building is a consumer of energy and also contains a huge amount of renewable energy that is wasted therein. We have new ideas for the energy production from the outside of the building that are presented below. In the modern buildings there are some heat treatments thanks tothe impact of technical advancements and the development of materials and manufacturing technologies on the buildings facades in particular, including:

Photovoltaic Cells Addition & Integration into Curtain Wall Glass:

according to this technique the photovoltaic cells are added to the curtain wall glass, so that the solar energy is stored during daytime and converted to the media display at night on the glass wall, which reflects the one-day climatic cycle on its display units made of LEED lighting units more than 2200 m^2 to enhance the image [7].The Green Pix in Figure (4) in Beijing's Entertainment Complex interacts. The integrated photovoltaic cells, in the curtain wall, manage to obtain a high-performance envelope that acts as a self-sufficient energy regulator to harvest solar energy during the day and utilize it at night to illuminate the display screen. This reflects the climatic cycle for just one day.

Figure 4.Development of the curtain wall technology and its photovoltaic storage of energy to convert it into a gigantic display screen in Beijing, China.

Aegis Hypersurface:

It is an interactive dynamic wall of double skin structures. Figure (5) illustrates a project that entails a dynamic wall with an interactive 3D surface, whose system consists of triangular metal plates, and is driven by 896 pneumatic pistons, which rely on many environmental stimuli, including sound or acoustic effects, people movement, weather and electronic information. These techniques provide a natural ventilation during the new weather and a new interior environment that is constantly available and convenient [8].

Figure 5.Interactive facade as an example of dynamic facade systems.

Golt Motorized Glass Louvers:

It is a system of communication between automatic shading systems and solar breakers to control the natural and artificial lightings. It is extremely vital for energy conservation through swivel glass slides or by connecting two systems together to increase the distribution of daytime lighting in the vacuum and reduce the artificial lighting, Figure (6) illustrates RWE Building in Germany and how mechanical shading techniques are used, that is, curtains are put on the external facade to control levels of natural light. They are distinguished by their non-obstruction of the occupants' vision of the external scenes, as they move according to the movement of the sun direction [9], in order to make the building an energy saver not consumer.

Figure 6. Mechanical shading techniques used in aluminum and glass curtains in the building.

Photocell Façade:

It is a system of sensors for sunlight which controls the movement of moving sun-breakers cells according to the amount of sunlight required inside the internal vacuum and the amount of required heat [10]. This takes place through the Thermohydraulic System which integrates the components of the facade with each of them (windows - glass– breakers- photo techniques) in an integrated system to track the movement of the sun during the day. It is characterized by the following [11]: (electric energy generation - protection from solar glare and solar radiation - reduction of thermal loads on the building – enhancement of the efficiency of natural lighting guidance). An evident example of this is Hong Kong Science Building as in Figure (7), where it stores solar energy for utilization in the building's electrical purposes.

Figure 7.Hong Kong Science Building with photoelectric facades.

Photovoltaic Cells System:

It is a number of electrical cells connected to one another in a single frame in the form of a plate that converts the sunlight to electricity. The design of this system depends on the use of Photovoltaic cells in the form of a set of optical sensors, that are adjusted in order to give the amount of illumination required for the user. This photovoltaic system constitutes a part of the formation of the building envelope not to mention its ability to generate electric energy as it can be used for shading and the protection from the harmful sunrays. It improves the natural lighting efficiency and creates a working environment that is thermally comfortable [8,9]. As in the Figure (8): it is one of the projects and the designs of James Carpenter as the glass panels are used and placed vertically on the interface to reflect the movement of light in different colors of the building.

Figure 8.An image of James Carpenter's projects and design where theglass panels with different colors.

Robotic Membrane System:

It is a smart surface (i.e. Pixel skin 01) that generates energy to optimize human comfort. In other words, it is an air-plate filled with colored dry air. These air plates are eight thousandth of an inch of polymer (TEFE) mounted on a steel structure to form a building envelope (in the form of a lozenge) in the vacuum. Each air plate can be controlled by means of certain techniques in terms of changing the color of the air which fills it to be white or red or blue color according to the color distinguishing the administrative spaces [10], as in Figure (9).

Figure 9. The robot envelope system and power generation generated on the exterior surfaces of the building.

Criteria for High-Tech Buildings Design Requirements and Energy Conservation Strategies:

Smart building envelopes technique is the suitable solution for all the problems related to the building's exterior envelope concerning the environment and the building's users and even the economic aspects. The technique or approach is not absolute. Smart buildings envelopes, like all building envelopes, make a balance between the sometimes contradictory and sometimes competing requirements imposed by the changing requirements of building users or environmental conditions [11].The dynamics of smart buildings reflect the building's capacity for adaptation in order to reduce energy consumption, whereas many smart systems and concepts of different design attempt to augment energy conservation rates so that the building is equipped with many characteristics and features to create a robust interaction between the building's exterior envelope and the building itself, through the façade:

Exterior Envelope Level includes:

A- Design of external walls to achieve the required heat resistance.
B- Design of external openings to achieve the Solar Heat Gain Coefficient (SHGC) and theShaded Glass Ratio (SGR) required by the surface ratio.
C- Type of glass to achieve the required Shading Coefficient(SC).

Natural Lighting Level includes:

A- The light window area compared to the outer wall area should be no less than 20% of the service spaces and 15% for commercial spaces.
B- The permeability coefficient of the glass used in the opening should be no less than 40%; and the opening efficiency should be no be less than 0.1
C- The increasing dependence on the natural lighting during daytime, and subduing the strong and poor lighting through smart control systems, with the utilization of more efficient lighting sources.
D- The utilization of of design elements such as (light shelves - solar tubes - fiber optics).
E- mprove the performance of the facade using external shading and selection of appropriate materials.
F- The enhancement of the façade performance by using external shading techniques and selecting the appropriate materials.

Applied Study (Criticism and Analysis of the Case Study):

The need for electric energy of any building varies from one building to another, depending on the varying type of use, the activity practiced within it and the used devices. There are many software used to measure the energy efficiency and conservation of the building. In order to prove the validity of the research hypothesis concerning the necessary adoption of the integrated methodology in the design process in order to construct buildings that have positive economic and environmental gains that benefit the owner and the state at the lowest cost. Therefore, the "Design Builder" program was selected to measure the energy conservation criteria in buildings to optimize the buidling efficiency with minimal energy consumption and self-sufficiency to generate the electric energy needed to cover the required energy loads, represented by integration of the various systems of insulation, ventilation, solar gain, natural lighting, thermal mass, cooling systems, etc. after the entry of climatic data in the area, under study, to enable the researcher to have a simulation that is more realistic of the case study.

Results and Discussion.

Case Study: Building of the Faculty of Engineering, Department of Architecture, Cairo University.

Table 1.Application of modern techniques for energy efficiency in the case study.

Natural Lighting Inside drawing halls	**Control of Heat transmission from and to drawing halls**	
On Natural Lighting Level	**On External Envelope Level**	**Techniques Application Level**
• Area of openings • Types and design of openings • Type of glass • Design elements – integration of natural and artificial lighting	• External walls treatment: 1. Insulation Materials 2. Wall Thickness 3. Shading • External openings treatment: 1. Type of glass 2. Shading	**Proposed Design Treatments**

Climatic analysis:

Located in the Delta and Greater Cairo. The Drawing Rooms are located 15 degrees west of the north, at a temperature where the cooling starts at 26 °C and the temperature at which the heating starts is 18 °C. The weather data file has been inserted in the Design Builder software.

Delta & Greater Cairo	Climatic region
Giza	Location
17800 m^2 (2240 m^2)	Building area (floor)
Basement & 7 floors	No. of floors
Lecture halls- drawing halls- seminar theatres- teaching staff- labs- library-	Spaces types
1400 persons	Average number of persons
15 ° north-west	Instructions
Concrete shafts permeated by glassy aluminum panels	External walls
Grids Slabs Paneled Beam	Ceilings

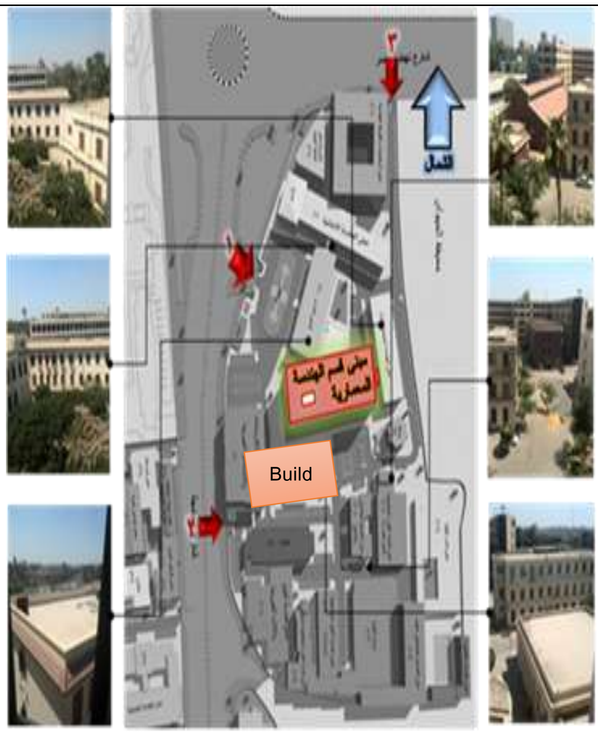

Figure 10. Data of the study model and the general site of the Faculty of Engineering, Cairo University, illustrating the building of the Architecture Department

Location :

The building, under study, is located at Giza, bordered to the north by Al- Nahda Street and to the west by Cairo University street, and to the south and east by the Giza Zoo.All the activities data has been inserted in the Design Builder program as these activities take place in the space (that is, the university lecture hall), and the number of users is determined in the third and fourth floors of each of the first and second halls. There are around 125 students in each of them with an area of 565 square meters for each, that is 0.22 students / m^2. As for the third hall, in the fourth floor, it accommodates 240 students with an area of 1095 m^2, i.e. with the same ratio of 0.22 students / m^2, as for the intensity of lighting needed for the space activity is 300 lux, which is proportionate to the drawing rooms and engineering drawing activity.

Architectural Description of the Building

Figures (12 A, B and C) illustrate typical models of horizontal projections. The two drawing rooms located at the third floor and the drawing room of the fourth floor were chosen to apply the applied study methodology. Each of the drawing rooms is different in terms of the amount of energy needed to make the occupants comfortable, and the amount of energy according to the nature of the activity within each of them, according to the number of occupants and the intensity and type of the natural light, air conditioning systems, building materials and external envelope of each of them.

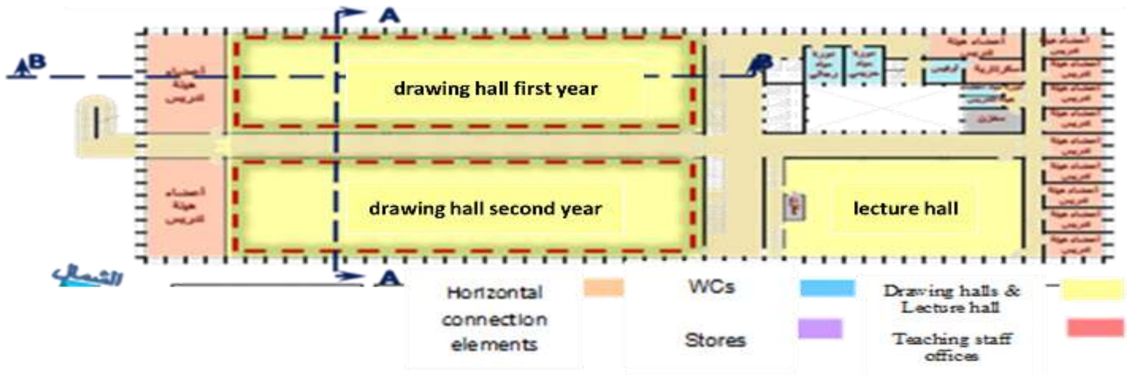

Figure (12-a).horizontal projection of the third and fourth floors, illustrating the drawing halls of the first and second years.

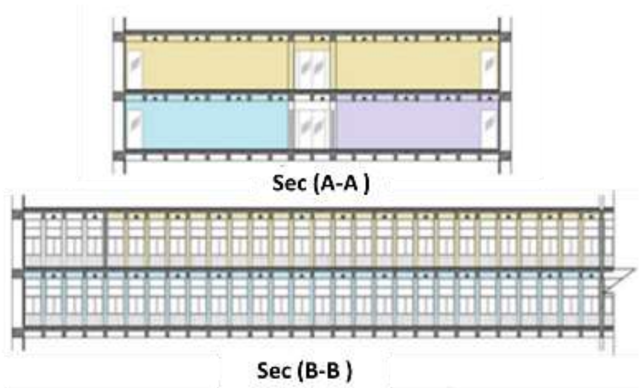

Figure (12-B). two cross-sections of the third and fourth floors, passing through the drawing halls of the first and second years.

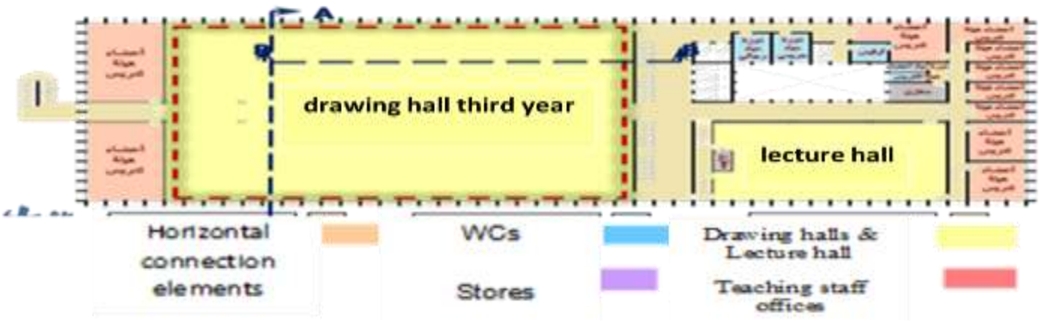

Figure (12-c): horizontal projection of the fourth floors, illustrating the drawing hall of the third year.

Table 2. Basic data of the case study of the building of the Faculty of Engineering, Department of Architecture, Cairo University.

Number of students	Percent	Area	instruction	External envelope	floor	Drawing Hall
125	44.4%	485 m^2	15 ° east-south	One wall	3rd floor	Drawing Hall (1)
125	44.4%	485 m^2	15 ° west-north	One wall	3rd floor	Drawing Hall (2)
240	44.4%	1095 m^2	15 ° east-south 15 ° west-north	Two walls	4th floor	Drawing Hall (3)

The table shows the direction, area, the percentage of openings in the halls and the number of students accommodated in each of the three drawing rooms in the case study.

Annual Energy consumption in the three halls of the case study:

Comparison between the amounts of energy consumed in cooling, heating, lighting and electric equipment used in the three drawing rooms during the different months of the year in the current situation.

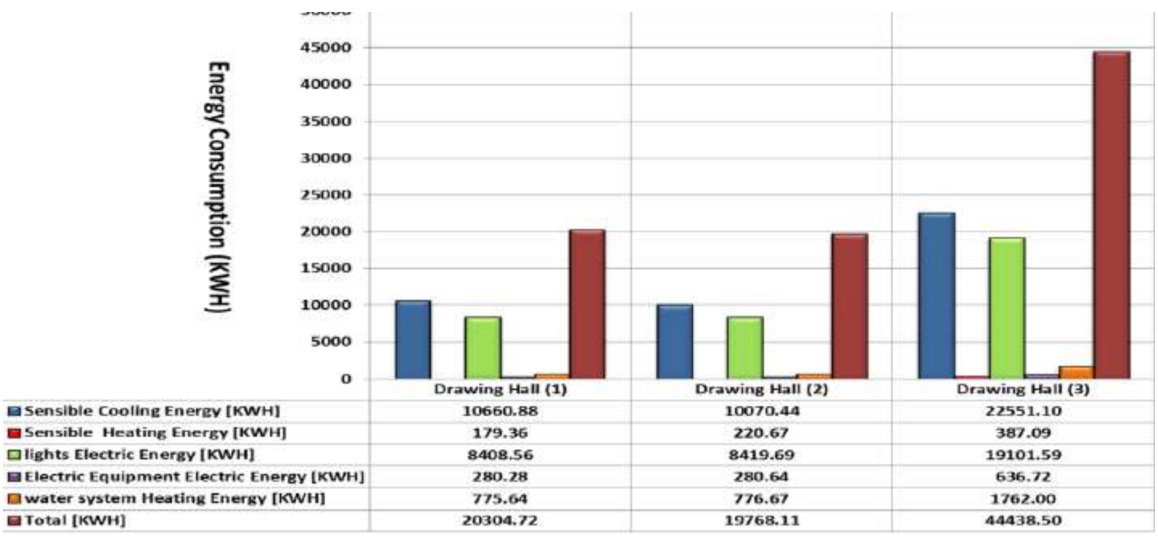

Figure 15.A graph showing the energy consumption in the three halls annually in case study.

Techniques for Controlling Heat Transfer to and from the Three Drawing Rooms Through:

1- **The treatment of the exterior walls by adding the insulating material (expanded polystyrene)** in the main and secondary north and west walls, and the main south-east walls (2 cm space layer - reinforced concrete layer 20 cm – space layer of 2 cm) and the secondary walls (aluminum layer of 5 cm).

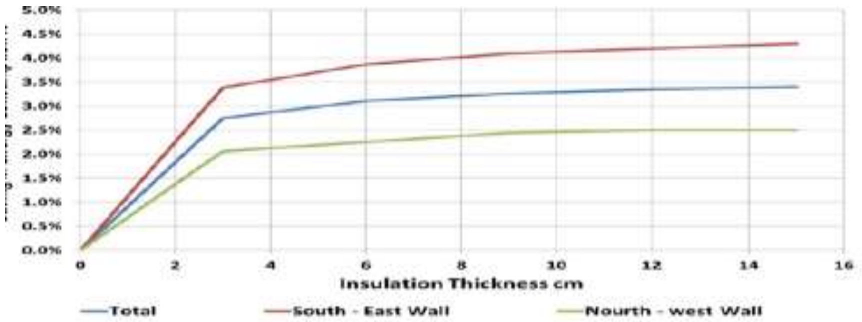

Figure 16. A diagram showing the energy consumption by treating the external walls by adding the insulation material to the building (i.e. the case study).

Figure (16) illustrates the thickness effect of the insulating layer (expanded polystyrene) on the energy consumption inside the drawing halls where the energy saving increases with the increased thickness of the insulation. But beyond the thickness of 5 cm the saving ratio starts to decrease to a certain point limit. The following table illustrates the amount of Energy conservation due to exterior wall treatment of the building, under study.The table shows the ratio of energy saving in the three drawing rooms of the building (in Cairo University) in the first case study of the 3mm insulation material, the second case study of the insulation material of 6 mm thick, and the third case of the 9 mm insulation material for the walls, as in Figure (3).

Table 3. The ratio of the energy consumption of the three drawing halls according to the thickness of the insulation material for the treatment of the external walls of the building

Percentage of energy saving	Total annual energy consumption in the drawing halls after treating the external walls	Total annual energy consumption of the drawing halls before treating the external walls	Building of Deaprtment of Architecture, Cairo University
2.7%	82188.1	84511.4	Case 1
3.1%	81886.2	84511.4	Case 2
3.3%	82755.3	84511.4	Case 3

2- The treatment of windows:

We find that the Department of Architecture Cairo University has external facades and have windows of 44% of the area of the façade. These openings have an effect on the transfer of heat to and from the drawing rooms and are processed so that the Solar Heat Gain Coefficient (SHGC) does not exceed, or the shaded Glass Ratio (SGR) does not be less than value set forth in by the Egyptian energy code. The treatment of windows is modified accordingly by modifying the glass tyoe (SHGC).

Table 4.Type of glass used to treat the windows before and after the modification in the type of glass to save energy consumption in the case study.

Before modification				After modification			
Egyptian Code	**Solar Heat Gain Coefficient (SHGC)**	**Light permeability coefficient (VT)**	**Type of glass**	**Solar Heat Gain Coefficient (SHGC)**	**Light permeability coefficient (VT)**	**Type of glass**	**facades**
0.4	0.36	0.535	Triple LOE Film 66 Cir 6mm/6mm Air	0.62	0.534	Single bronze 6mm	Northwest facade
0.3	0.27	0.322	Triple LOE Film 66 Cir 6mm/6mm Air	0.62	0.534	Single bronze 6mm	Southeast facade

Table 5.Energy saving ratio for the three drawing halls before and after modifying the type of glass of windows treatment.

Percentage of energy saving	Total annual energy consumption of drawing halls in KWH after modifying the type of glass in external walls	Total annual energy consumption of drawing halls in KWH before modifying the type of glass in external walls
4.5%	80689.8	84511.4

3- Treating the windows by using Sun Louvers:

The ratio of the openings in each façade, and the type of the type of protrusion of each façade, the protrusion coefficient resulting from it (ensuing from the structural elements of poles, roof slab, the shaded Glass Ratio (SGR) resulting from this protrusion and SGR of each facade which is stipulated in the Egyptian code.

Table 6. Study of the glass used in the windows before treating the modification to save energy consumption in the case study.

Before modification				
Egyptian Code	**Shading Glass Ratio (SGR)**	**Protrusion factor**	**Type of protrusion in the facade**	**Facades**
40%	35% 40%	0.31% 0.36%	Horizontal Vertical	Northwest façade
70%	45% 26%	0.31% 0.36%	Horizontal Vertical	Southeast facade

Based on the table, it is evident that the southwestern façade requires sun breakers so that the shading ratio reaches the ratio set forth in the Egyptian code. Therefore, the horizontal sun louvers are designed for windows with such facade to reduce thermal acquisition in the summer and allow it in winter.

Table 7.Energy saving ratio for the three drawing halls before and after the addition of sun breakers for windows treatment.

Percentage of energy saving	Total annual energy consumption of drawing halls in KWH after adding sun breakers in external walls	Total annual energy consumption of drawing halls in KWH before adding sun breakers in external walls
3.0%	80189.5	84511.4

Techniques for reducing Lighting Loads within the drawing rooms of Architecture Department Building, Cairo University:

1. Integration of natural lighting with artificial lighting

Natural lighting is integrated with artificial insulations to benefit from natural lighting in the drawing area to minimize the artificial lighting load of the naturally-lit areas by means of sensors. These sensors are placed in the drawing halls. The artificial lighting is lit in the absence of sufficient natural light or when it does not reach the intensity of natural lighting.

Table 8.Energy saving ratio for the three drawing halls before and after integrating natural lighting with artificial lighting.

Percentage of energy saving	Total annual energy consumption of drawing halls in KWH after integrating natural lighting with artificial lighting	Total annual energy consumption of drawing halls in KWH before integrating natural lighting with artificial lighting
16.9%	70203.0	84511.4

2- Using natural light (Sun Tube or fiber optics):

There should total dependence on the natural light of the morning by using fiber optics, which in turn introduce the natural lighting inside the drawing halls to determine the energy consumption. A sector in the drawing rooms of the building and explain how to light using fiber optic, did not use the solar tubes because the drawing rooms do not have an external ceiling, is most suited to fiber optic.

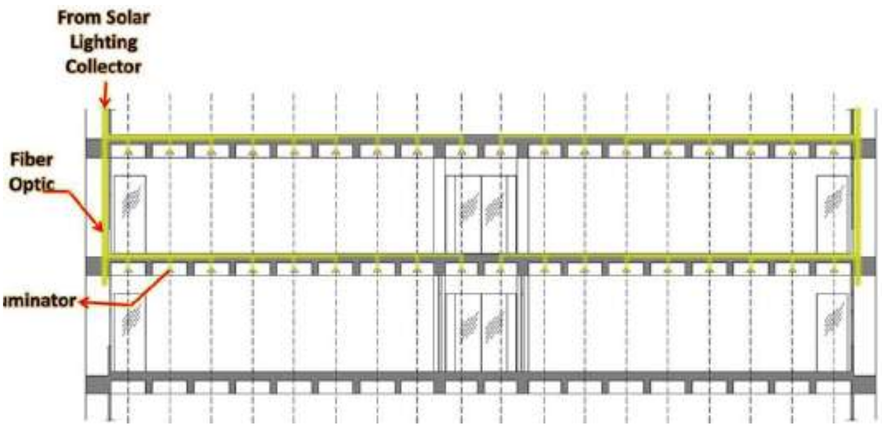

Figure 17. A section in the drawing halls of the building of Architecture Department, Cairo University and the lighting of the hall using fiber optics.

Table 9.Energy saving ratio for the three drawing halls before and after using fiber optics lighting.

Percentage of energy saving	Total annual energy consumption of drawing halls in KWH after using fiber optics lighting	Total annual energy consumption of drawing halls in KWH before using fiber optics lighting
40.5%	50324.9	84511.4

Table 10.techniques used in drawing halls of the case study to save energy before and after applying the technique.

comments	Energy saving Ratio	Hall consumption of energy after applying KWH	Techniques used in drawing halls to save energy				Hall consumption of energy		Area	hall	university
							M^2	Total KWH			
Drawing hall in middle floor	0.0%	--	Ceiling treatment			Controlling techniques of heat transmission from and to drawing halls	35.94	20304.72	485 m^2	Drawing hall 1	Building of architecture department, Cairo university
Heat insulation increases energy saving to a certain limit then the effect decreases gradually till it vanishes	3.4%	19616.5	1st case: insulation thickness= 3 cm		External walls treatment						
	3.9%	19519.9	2nd case: insulation thickness= 6 cm								
	4.1%	19473.2	3rd case: insulation thickness= 9 cm								
Natural lighting decreases by 43.5 %	5.8%	19136.5	Type of Glass (SHGC)		Windows treatment						
Natural lighting decreases by 72.5 %	5.1%	19259.5	4 Louv.	Sun Louvres							
Natural lighting decreases by 50.0%	5.3%	19229.5	2 Louv.								

Depends on the existence of lighting sensors	16.5%	16955.6	Integration of natural lighting with artificial lighting			Controlling techniques of lighting load in the drawing halls					
Introducing natural lighting to the depth of drawing room	39.3%	2317.9	Using sun tubes or fiber optics								
Drawing hall in middle floor	0.0%	--	Ceiling treatment			Controlling techniques of heat transmission from and to drawing halls					
Heat insulation increases energy saving to a certain limit then the effect decreases gradually till it vanishes	2.1%	19360.0	1st case: insulation thickness= 3 cm		External walls treatment						
	2.3%	19323.2	2nd case: insulation thickness= 6 cm								
	2.4%	19284.7	3rd case: insulation thickness= 9 cm								
Natural lighting increasesby 1.0 %	3.9%	18987.7	Type of Glass (SHGC)		Windows treatment						
Drawing hall façade is northwest and does	0.0.%	--	4 louv. 2 louv.	Sun louvres			34.99	19768.11	485m²	Drawing hall 2	

not require sun breakers											
Depends on the existence of lighting sensors	17.5%	16310.1	Natural lighting integrated with artificial lighting			Controlling techniques of lighting load in the drawing halls					
Introducing natural lighting to the depth of drawing room	41.0%	11672.9	Sun tubes or fiber optics								
Drawing hall in the middle floor	0.0%	--	Ceiling treatment			Controlling techniques of heat transmission from and to drawing halls	40.58	44438.5	1095 m^2	Drawing hall 3	
Heat insulation increases energy saving to a certain limit then the effect decreases gradually till it vanishes	2.8%	43211.6	1st case: insulation thickness= 3 cm		External walls treatment						
	3.1%	43043.1	1st case: insulation thickness= 6 cm								
	3.2%	42997.4	1st case: insulation thickness= 9 cm								
Natural lighting decreases by 43.5 %	4.2%	42565.6	Type of Glass (SHGC)		External walls treatment						
Natural lighting	2.3%	43404.3	4 louv.	Sun louvres							

decreases by 72.5 %											
Natural lighting decreases by 50.0 %	2.6%	43264.3	2 louv.		Windows treatment						
Depends on the existence of lighting sensors	16.9%	36937.3	Natural lighting integrated with artificial lighting			Controlling techniques of lighting load in the drawing halls					
Introducing natural lighting to the depth of drawing room	40.7%	26334.1	Sun tubes or fiber optics								

The percentage of energy saving upon using modern technologies in the first, second and third drawing halls of the Architecture Department building, Cairo University, in the 6 proposed alternatives, which include the combination of different techniques on the outer envelope and the level of natural light, and energy saving resulting from each alternative. We find out eventually that the sixth alternative is the best one as shown in Table (11).

Table 11.The percentage of energy saving and the proposed six alternatives in the three halls of the case study.

Techniques for decreasing lighting load in drawing halls		**Controlling Techniques of heat transmission from and to the drawing halls**				**Proposed alternatives**
Sun tubes or fiber optics	**Natural lighting integration with artificial lighting**	**Windows treatment**		**External walls treatment**	**Ceiling treatment**	**First alternative**
		Sun louvers	**Glass type (SHGC)**		**---**	**Second alternative**
	16.9%	3.0%		3.3%	---	Third alternative
	16.9%	3.0%	4,5%	3.3%	---	Fourth alternative
40.5%		3.0%		3.3%	----	Fifth alternative
40.5%	16.9%	3.0%	4.5%	3.3%	-----	Sixth alternative

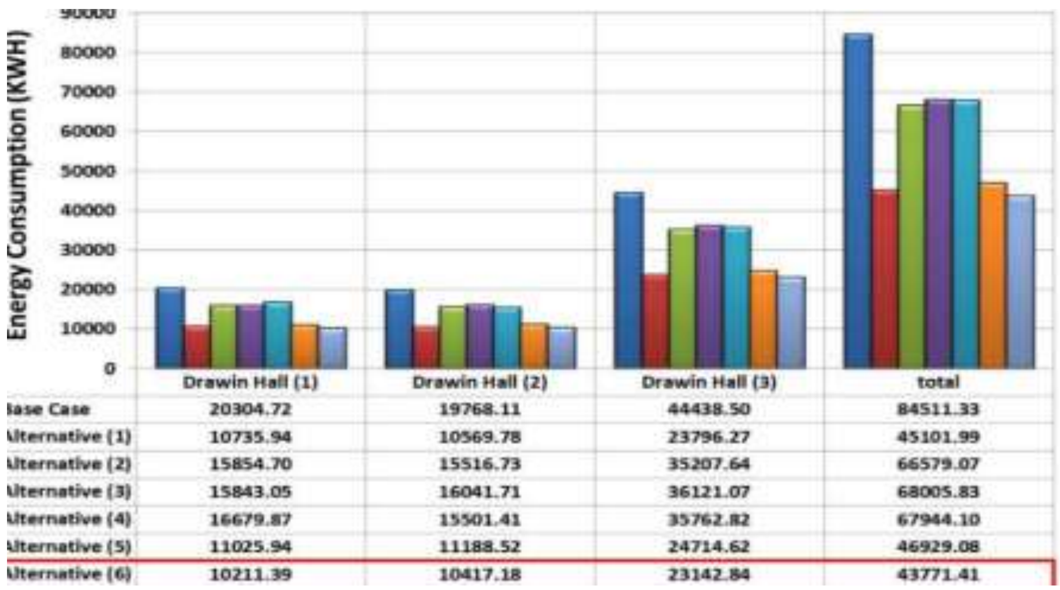

Figure 18. Energy consumption in the drawing halls of the building of Architecture Department, Cairo University in the normal case and in the six alternatives proposed for the three drawing halls.

Figure (18) illustrates the energy saving ratio resulting from implementation of first alterative in the drawing halls is 46.6%, as for the second alternative it is 21.2%, the third alternative is 19.5%, the fourth alternative is 19.6%, the fifth alternative is 44.5% and the optimal and best alternative is the sixth alternative, that is, 48.2%.

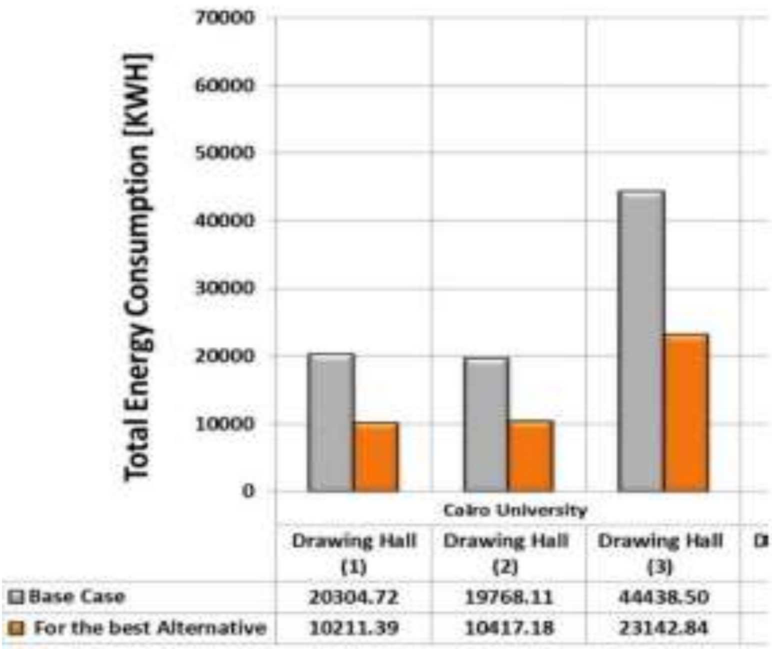

Figure 19. Total energy consumption in the halls annually in the normal case and the optimal alternative for the drawing halls in the case study building.

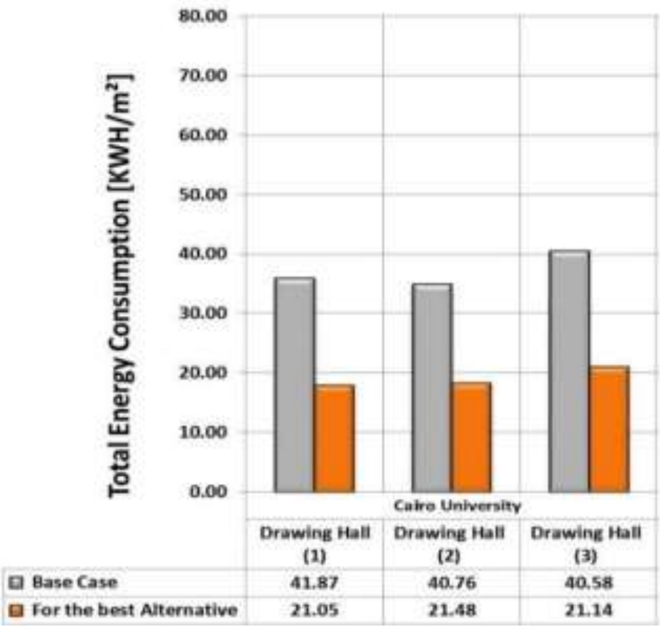

Figure 20.square meter share of energy consumption annually in each of the drawing halls in the normal case and the optimal alternative in the case study building.

Table 11.Rates and percentages of energy consumption after the application of modern techniques for the optimal alternative in the three halls of the building of the Architecture Department, Cairo University.

Drawing hall 3	Drawing hall 2	Drawing hall 1	Differences of drawing halls
23142.8	10417.1	10211.3	Annual energy consumption of optimal alternative (KWH)
21.14	21.48	21.05	Annual energy consumption per square meter of optimal alternative (KWH / m^2)
47.9%	47.3%	49.7%	Percentage of annual energy saving resulting from the optimal alternative

Based on the afore mentioned overview ofthe application of energy efficiency techniques for the design of building facades by the simulation model, the results can be summed up as follows:

1- When evaluating the local university buildings, there is a lack of energy conservation in the building of Architecture Department, Cairo University and the use of modern technologies to reduce the building's energy consumption.

2- A simulation was made of the building, under study, by using the Design Builder software and the simulation PVsyst program in order to resolve the shortcomings, under study, and demonstrates the efficacy of the environmental design options in achieving thermal and light comfort inside the drawing halls and measuring the extent of supply of these options for the used energy.

3- The external walls of the building of the Architecture Department were treated through the application of the Egyptian Code to save and conserve energy consumption in commercial buildings (3.3% treatment of walls)

4- As a result of the windows shading (of 2.7%), and changing the type of glass (by 4.5%) according to the requirements mentioned in the Egyptian code.

5- Lighting is one of the most energy-consuming factors in the drawing halls after air conditioning, as it reaches 42.5% of the energy consumption in the Building of Architecture Department, in Cairo University. Therefore, there was greater dependence on natural lighting through the integration of natural lighting with artificial lighting or the use of special systems for natural lighting such as: fiber optics. All this led to energy saving as follows:
   a- The amount of consumed energy in the drawing halls (of the building of Architecture Department, Cairo University) through the integration of natural lighting with artificial lighting (by 19.8%).
   b- The amount of the consumed energy in the drawing halls of the said building as a result of the use of fiber optics (by 40.5%).

6- This resulted in the best alternatives that were rejected and the selection of the optimal alternative, that is, the sixth one, which includes the treatment of external walls and windows and the integration of natural lighting with the artificial lighting and the use of fiber optics to achieve energy saving of 48.2% of the total consumed energy in the halls of building, under study.

Conclusion:

This research or study concluded that the comfortability of the users or occupants of the drawing halls in the university buildings can be achieved by attaining the energy efficiency and reduction of energy consumption through the innovative architectural treatments on the outside of the building to make the building produce energy. It is worth mentioning that the optimal alternative to the use of modern techniques in the drawing rooms in the said building has led to the reduction of energy consumption in these halls by 48.2%. The consumption of energy per square meter per in these halls has become around 21.20 kWh.

References:

1. Mohamed S.H.H., The role of facades in attaining heat comfort in administrative buildings in Egypt, Ph.D. thesis, Faculty of Engineering, Alexandria University, Egypt, 2011.
2. Salem A., Layers of sustainable Architecture, Journal of Engineering, 2008; 4.
3. Ahmed F.I., Role of Building Systems and Materials in Achieving Economic and Environmental Considerations to Attain Sustainability in a Comfortable Housing, Conference of Technology and Sustainability in Urbanization, College of Architecture and Planning, King Saud University, Riyadh, 2010.
4. Bassili G.H., Green Energy and Green Buildings in Egypt, International Journal of Engineering Research and Application, 2013; 3(4), 466-470.
5. Mohamed Q., Energy Conservation and Enhancement of efficiency in Educational Buildings Sector in ESCWA member states, The Third Scientific Seminar on Energy and its Sources in the Arab World and Sustainable Development, Syrian Arab Republic, Damascus, October 2000.
6. Lamis S.M.A., The Role of Technology in the Development of Traditional Architectural Factors, PhD thesis, Faculty of Fine Arts, University of Alexandria, 2011.
7. RaolL., Climate Adaptive Building Shells: What can we simulate?MSc-thesis, Architecture, Building and Planning Eindhoven University of technology, 2010.
8. Baker N., Steamers K., Energy and Environment a Technical Design Guide, E, FN Spon, an Imprint of Taylor &Francis, New Fetter Lare, London, 2001.
9. Loncour X. et al.,Ventilated Double Façade. Classification &Illustration of Façade Concepts, Belgian Building Research Institute& Ministry of Economic Affairs in Belgium, P231, 2004.
10. Bound B.A., Lighting Design in Building, Peter Peregrines Ltd, London, P16, 2002.
11. Abdul Rahim H.A., Building Technology and its Role in Achieving Thermal Comfort in Architectural Spaces, Master Thesis, Faculty of Engineering, Cairo University, 2008.

*****