# Applying Sustainability Principles on Architectural Design Concepts in Egypt to Enhance Building Performance

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**Abstract:** Sustainability can be defined as the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs. Sustainability is not a new fashion in the Egyptian construction industry. It is mandatory requirement especially with all environmental needs. Fortunately, with the absence of local Egyptian rating system until this moment, the architectural history through thousands of years in Egypt has left practical heritage for building sustainability, which took into consideration indoor environmental quality, the creativity of using local materials plus the innovation in design. Unfortunately, Architecture in Egypt and some other countries in last five decades of the twentieth century missed many environmental solutions. Many buildings have poor performance and affect negatively the environment and our planet.

The research objective is to push architects towards sustainability in their modern design concepts. The methodology will be focused on presenting samples of sustainable buildings and designs done by some of the biggest consulting firms in Egypt considering many items of international rating systems such as LEED and BREEAM. The outcome will be focused on the importance of each rating system evaluation items against Egyptian ecology.

Keywords: Sustainability, Architectural Design; Building Performance

## 1. Introduction

Energy and architecture form a natural marriage if indoor comfort and respect for environment are secured. The role of energy within buildings varies from country to country, climate to climate. Population growth and demand for housing have forced politicians to embark on massive housing schemes without consideration of comfort, energy demand, and environmental issues.

In this paper, we are seeking to understand how previous generations lived in rigid climates and without abundant sources of energy, yet managed to design and build appropriate dwellings providing both comfort and harmony with the environment. We have to look at the Vernacular architecture, which existed in the areas of extreme climate such as India, Africa where indigenous materials were utilized to construct attractive and comfortable homes.

## 2. Background:

### *2.1. Architect objective*

Modern technology has provided us with excellent new materials such as "switchable" material', light but strong structural materials and a variety of insulations. It is now commonly accepted by architects and builders that due consideration must be given to energy conservation; the use of natural lighting and use of solar energy for both heating and cooling; as well as enhanced natural ventilation and minimal impact on the environment.

Architect must approach the architecture-energy combination and its relationship to the environment, thermal comfort, and low energy architecture dealing with various criteria for comfort in different parts of the World.

The planners and architects have a massive responsibility to directing the impact on the environment; have been criticized for their role in accelerating the world's environmental crises. Different governmental reports, papers and studies, have proved that the construction process in the world consumes about 34% of the world's energy in embodied energy (8). Embodied energy is the sum of all energies used in building construction such as; manufacturing of building materials, transportation of construction materials, construction process, and building's energy needed for lighting and air conditioning. Therefore, renewable energy resources provide a motivating factor in the efforts of the planners and architects to discover more environmental urban development.

### *2.2. Sustainability:*

The environmental resources, currently, are facing serious fears regarding its ability to vanishing and ability to remaining, for future generations. This is because the environmental quality, in fact, has been suffering from major crises such as; "Ozone Depletion", "Global warming", "Deforestation", "desert broaden", "Air, land, and water pollution", and "Run out of nonrenewable energy resources".

These issues are mainly a result of international crises and aggressiveness (abuse of the environment), particularly growth rate of world population and, in turn, energy consumption.

It is expected that the environmental impact of these crises will be doubled with the same growth rate of world population and energy consumption. The world population is expected to be doubled during the period of 2003 to 2100 from 5308 million to about 9910 million (1). Consequently, the growth rate of energy consumption will increase from 420 quadrillion (1015) Ton Oil Equivalent to 780 quadrillion TOE (1).

### *2.3. Energy problem:*

For example in the State of Qatar 50% of the energy used in that country can be saved by using low energy buildings with several measures such as shading, evaporative cooling, the use of appropriate thermal mass and natural ventilation coupled with radiative cooling. Contemporary architecture, in some cases, ignores most of these elements and concentrates on using excessive energy to cool or heat buildings.

In the Gulf Region, 70% of the electricity generated is used for cooling the buildings.

The thermal exchange takes place between man and the various parts of the building elements. Some authors developed their own models to evaluate such exchange. The bioclimatic concept in Vernacular Architecture and the impact of climate on the building forms. The climate, which plays a major role at different locations and how this dictates the shape and form of the buildings and save some energy

### *2.4. Vernacular architecture definition*

Vernacular architecture refers to structures built of local materials in a functional style devised to Vernacular structures were built by people not schooled in any kind of formal architectural design. The anonymously built log cabins, barns, and farm outbuildings that can be seen in rural areas are good examples of vernacular architecture. Meet the needs of common people in their time and place. It is sometimes called folk architecture.

## 3. Literature review:

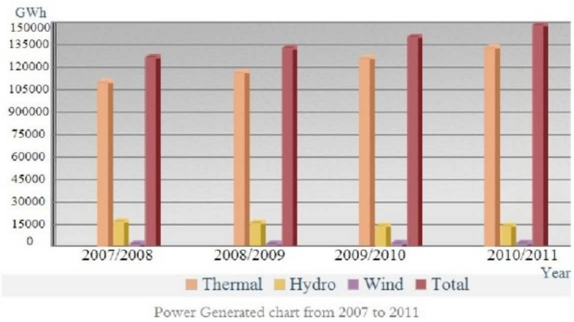
Nowadays we have knowledge, elements and strategies to obtain comfort in buildings and treat with recourses such as the air movement, the Sun effect, the thermal mass, the vegetation, day lighting to conserve and reduce heat gain into buildings, ventilation strategies, the air flow principles, air leakage in buildings, natural and solar induced ventilation and mechanical ventilation, integrated ventilation, ventilated roofs, active curtain walls, the use of greenhouses, movable shading devices, light ducts, cooling elements, shading devices and the use of water and moisture in improving living conditions in a arid climate.

In this paper, we will focus on building and architecture scale and role of architect and methodology to sustainable thinking and design.

### 3.1. *Facts:*

- Buildings sector consumes 20 % of total Energy in developing Countries. (8)
- Building Construction consumes 33 % of Primary Energy Consumption. (8)
- 60% of national budget is invested in buildings.
- 40% of Primary Energy Consumption is used in buildings.

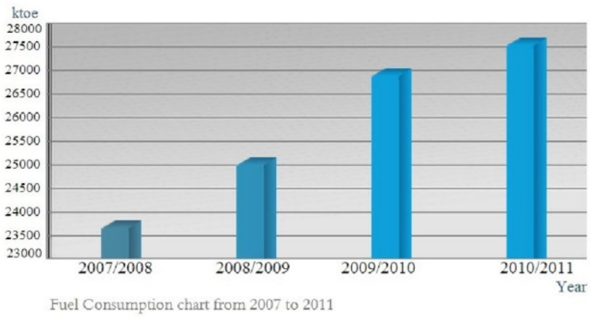
### 3.2. *Egyptian energy statistics:*




| Year | Thermal | Hydro | **Wind** | **Solar** | **Total** |
|---|---|---|---|---|---|
| 10/11 | 132045.3 | 13046 | 1485 | 219.4 | 146796 |
| 9/10 | 125004 | 12863 | 1133 | 0 | 139000 |
| 08/09 | 115427 | 14682 | 931 | 0 | 131040 |
| 07/08 | 108788 | 15510 | 831 | 0 | 125129 |
| 06/07 | 101866 | 12925 | 616 | 0 | 115407 |

*Fig. 1. Power Generated chart from 2007 to 2011, Egyptian ministry of electricity an energy statistics.*

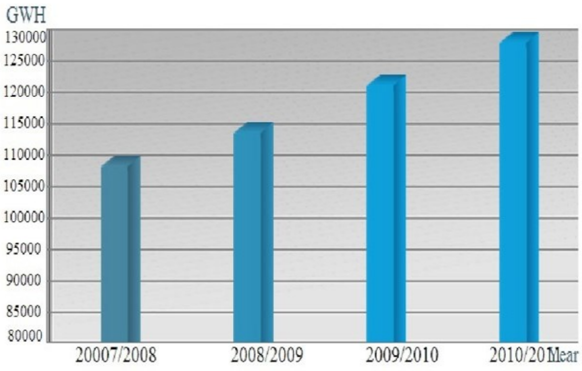
From Fig (1) (according to Egyptian Electricity Holding Company Annual Report 2010/2011), we have many indicators like energy that there is a new renewable recourse in Egypt like solar power. New developing in wind power field, which doesn't meet the consumption and the leak age in hydropower which will be increase throw next year due to water problem in Egypt. Thermal recourses depending on increased so there is unwise using for nonrenewable recourses.




| Year | H.F.O Ktons | N.G. Million M3 | **L.F.O tons** | **Coke Kton** | **Nafatia Ktons** | **Special L.F.O Ktons** | **Total Ktoe** |
|---|---|---|---|---|---|---|---|
| 10/11 | 5302 | 25894 | 3300 | 0 | 0 | 81.7 | 27430 |
| 9/10 | 5929 | 24314 | 4400 | 0 | 0 | 170.81 | 26772 |
| 08/09 | 5321 | 23013 | 5100 | 0 | 0 | 116 | 24895 |
| 07/08 | 4774 | 21907 | 2700 | 0 | 0 | 102 | 23562 |
| 06/07 | 4348 | 21008 | 3700 | 0 | 0 | 49 | 22286 |

*Fig. 2. Fuel Consumption chart from 2007 to 2011 Egyptian ministry of electricity an energy statistics.*

Fig (2) shows fuel consumption chart from 2007 to 2011. The increasing in consuming nonrenewable recourse year by year in addition to the quantity of energy consuming in fuel extraction are not reasonable. In addition, the treatment to be in last state world consumes recourse without any consideration to future generation's destiny. There is no any effort to depend on renewable recourses and wise treating with current recourses.




Energy Sold Chart from 2007 to 2011

| Year | Value GWH |
|---|---|
| 10/11 | 126934 |
| 9/10 | 120180 |
| 08/09 | 112617 |
| 07/08 | 107226 |
| 06/07 | 98812 |

*Fig. 3. Energy Sold table from 2006 to 2011 Egyptian ministry of electricity an energy statistics.*

Fig (3) energy sold table from 2006 to 2011 shows the growing need to electricity in all views in life due to fast massive jumping in technologies, industry..

### *3.3. Energy consuming:*

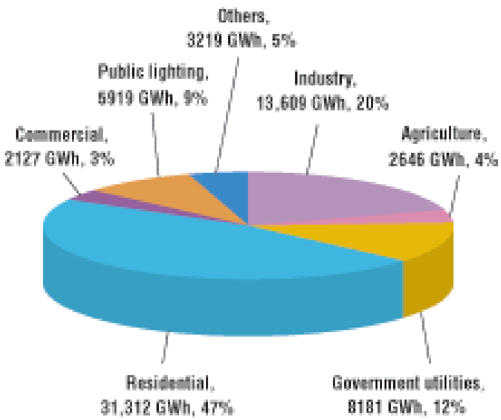
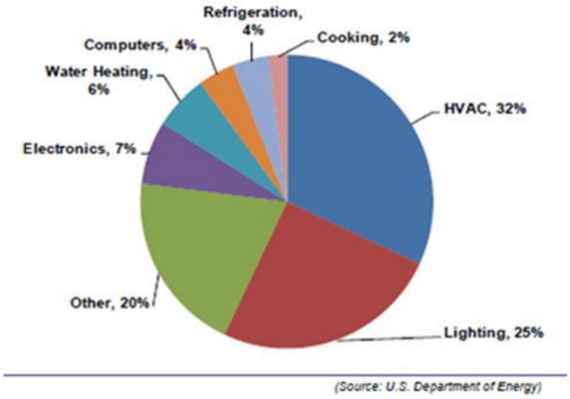



*Fig.4. Energy consuming faces according to Egyptian Electricity Holding Company Annual Report2010/2011, Fig. 5 energy consuming faces in residential building U. S. department of energy*




In Egypt Fig (4) illustrates that energy residential building is the biggest energy consumer with 47% (6). Industry is in second stage with 20%. Therefore, we have to rethink about kinds of industrial projects in Egypt and its profits in conjunction with the energy problem and its growing cost.

Building operating consumes over 50% from all over electricity consumption. When we focus on building energy consumption and major consumer in the building is HVAC system. It consumes 32% (6) from over all energy consumption.

Second aspect is lighting which consumes 25% from over all energy consumption. Water heating consumes 6% so the total energy consumption, which architect can control in building design and operating reach up to 63% from over all energy consumption. Due to previous numbers and architectural design and planning have, the full control to solve or reduce energy problems and save resources for next generations.

### *3.4. water problem:*

Nowadays many problems started to rise related to water due to Nile riverhead countries political situation. They are trying to decrease Egyptian share of water so we have to review Egyptian water consumption.

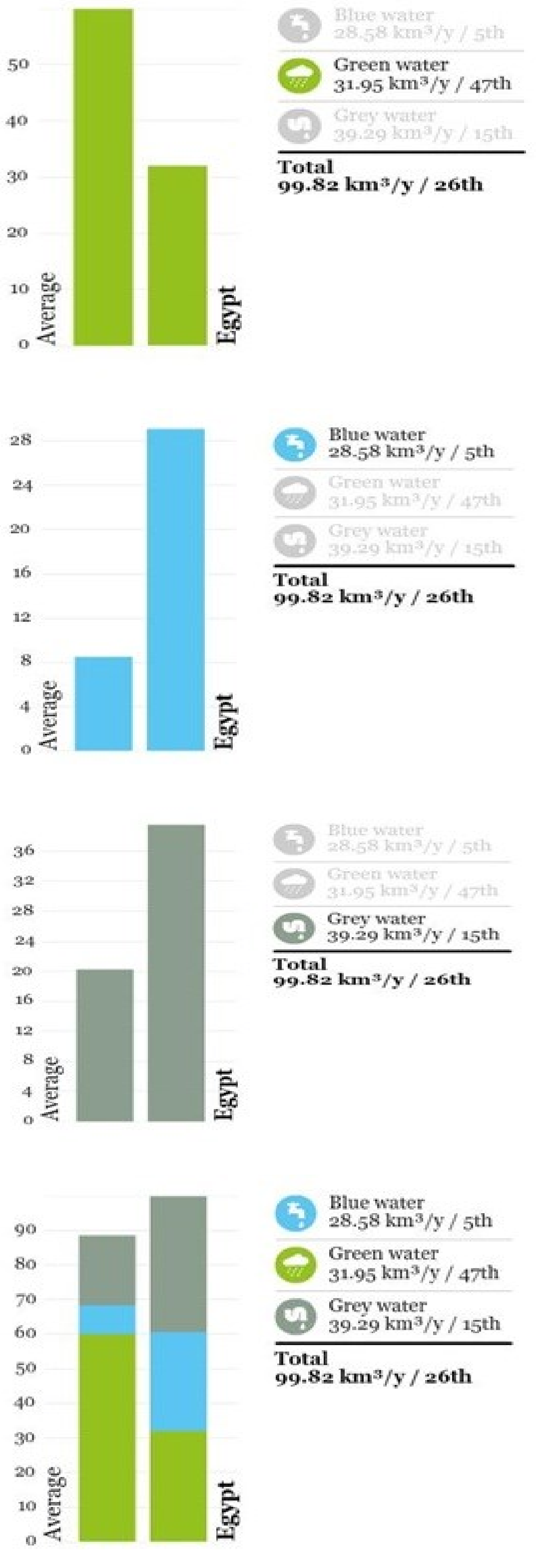



*Fig.5. Water consuming faces according to living plant Report2012.*

According to announced data Fig (5), Egypt share 55 km3/y. This portion will be decreased in next year's. Egyptian consumption over all is 99.82 km3/y. When we check water consumption charts, Egypt consumes 28.58km3/y in drink and daily use. The world average is 9 km3/y. Therefore, we have to rearrange Egyptian water consumption in drink and daily use.

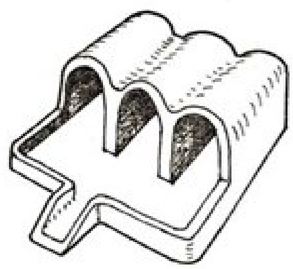
We consume 31. 95 km3/y in irrigation, however, the world average is 60 km3/y. This rate is too small. Egypt is agrarian country. Egypt grey water production is 39.29 km3/y. For industrial zones, the world average is 20.5 km3/y.

From previous statistics, we have to rearrange water consumption and gray water treatment to face water problem. Otherwise, Egypt will face a real disaster with irrigation and agriculture. Developing new strategies in irrigation and drainage and for storm water harvesting in north coast to consolidate agriculture there and make self-sufficiency in water need in this region

## 4. Methodology:

All previous studies are motivators for architectural designer and planner to rethink positively. Sustainable design and green buildings are tools that can push the building performance a step forward towards better energy and water efficiency. We can learn from our heritage and previous experiments. They give us wonderful lessons for climatic treatment, social needs, environmental and indoor quality by using local materials by simple and wonderful techniques.

### *4.1. Ancient Egyptian architecture:*



Mud model of Egyptian house (Egyptian Museum).

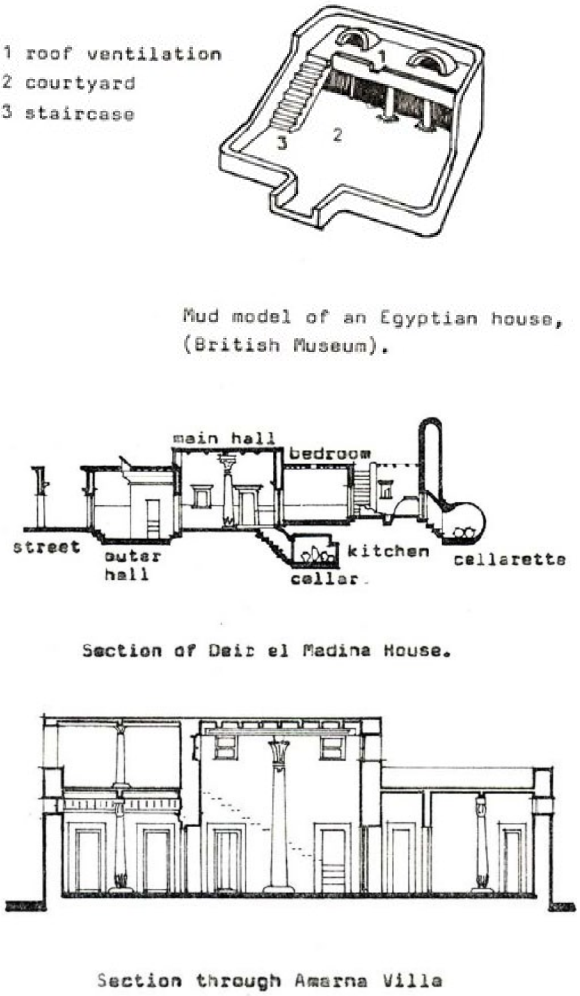



*Fig.6. Egyptian mud model for Egyptian house (British museum), Great incent Egyptian civilization have the first antecedence in sustainable and environmental buildings which documented this antecedence in all existing temples, models and manuscripts (9)*

In previous models (Fig.6.), we have many strategies and techniques like cross ventilation, high thermal mass to avoid radiation, using roof levels for lightings, wind catchers, courtyards, roof ventilation and vaults all those with environmental construction techniques.

### *4.2. Islamic architecture solutions:*

In Islamic architecture Fig (7), there was a big enhancement in sustainable, ecological, environmental, and green design. Islamic buildings around the world until today have a good building performance all over architectural history. Efficiency is the key word for sustainable design, which all-modern environmental strategies, passive and active techniques are seeking. Islamic architecture achieved efficiency with high rates.

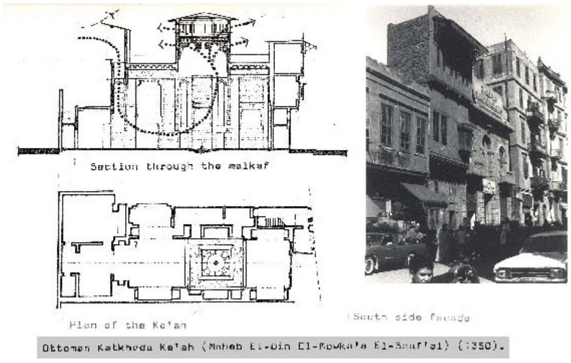



*Fig.7. Egyptian Islamic Sabile ottman katkhoda(9)*

Islamic architecture proved that it had the knowledge about thermal trade off, air movement science and resources managements. They made the healthiest building formed to treat and utilize with all climatic and environmental conditions.

### *4.3. Modern movements:*

Nowadays, we have many tries to face the aggression on the environment and natural resources. We all over the world are trying to think in sustainable way to create and construct buildings, which are saving the planet resources.

Later on, many organizations made rating systems for their countries to be sure about applying green principals and providing facilities to save energy, water, and natural resources. First, one was BREAM in UK and moved to all over the world like Estedama, Qsas, Green Pyramid, and most popular one is LEED, which is for the US.

### *4.4. Green concept:*

All rating systems are based on green design principals, which can define in Figure (8) as:

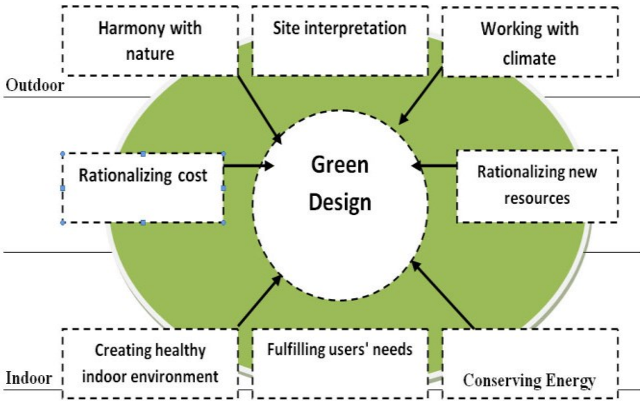



*Fig (8): The main principles guiding our green design are:*
1. *Harmony with nature.*
2. *Site interpretation.*
3. *Working with climate.*
4. *Rationalizing new resources.*
5. *Creating healthy indoor environment.*
6. *Conserving Energy.*
7. *Fulfilling users' needs.*
8. *Rationalizing cost.*

Architect must apply these principals in all design processes and improve building performance by using environmental strategies and techniques.

## 5. Energy modeling:

When the architect wants to check the building performance and test strategies to figure out the CO2 emissions, water & energy consumption, air movement , aerodynamics, acoustics response , lighting levels, he must using simulation tool. This tool simulates all above consumption and figure out results which can help the architect to enhance the building performance. This tool creates an energy modeling.

### *5.1. Definition:*

Energy modeling, or simulation, is the practice of using computer-based programs to model the energy performance of an entire building or the systems within a building. This whole-building modeling provides valuable information about the building and system energy use as well as operating costs and human comfort.

### *5.2. Concept:*

Whole-building simulation is typically performed for an entire year using typical meteorological year weather data, material response and interacting with all physical parameters. An important aspect of whole-building modeling is that it accounts for the interaction between different elements of the building, such as the impact of lighting on space conditioning loads or the impact of day lighting on electrical lighting loads, people activity in each space, number of equipments. The impact of different building uses and occupancy patterns is also accounted for.

### *5.3. Benefits:*

Energy modeling can and should be used throughout the design process to optimize the building design for energy performance and reduced carbon emissions. Energy modeling has been applied to building design for decades, but with the advancement and spreading of computers. The increased emphasis on building operating costs, the use of modeling is more common and often required. It is a valuable tool to assist architects in assessing the impact of various design decisions.

The size, complexity, and potential types of mechanical systems will affect which of the many modeling tools is most appropriate for the project, and the tool may change from one design phase to the next. Thus, it is beneficial to have someone in-house or as a consultant who is familiar with the alternative simulation tools and knows their capabilities in terms of such variables as the number of floors, the number of zones, the ability to define schedules, and the mechanical equipment options

## *5.4. Tools:*

Using a tool that can handle large complex buildings for a simple building can give a result in a waste of time and expense. Tools have been developed, such as DOE2 ,Ecotect, Green studio, E quest, Energy-10, design builder, Vasari, specifically to model all types of buildings.

There is a cost associated with energy modeling, and it varies with the complexity of the building. A speculative developer may find it difficult to bear costs that will accrue savings to the future building owner in the form of reduced utility bills. However, this should be presented as a feature of the building and worthy of a price premium. The building will also be more comfortable and perform more reliably.

## *5.5. Design process:*

Energy modeling can be applied to various degrees in each phase of the design process.

## *5.6. Conceptual design phase:*

During conceptual design, a very simplified model that uses basic assumptions for many of the inputs can be used to examine large-scale impacts such as building configuration and orientation.

For example in Erbil competition for Syriac Culture Center Fig (9) designed by Dr Wael Abo Neama at Engineering Consultants Group (ECG).


*Fig (9): Perspective for Syriac culture center proposed by ECG & designed by Dr. Wael Abo Neama*

### *5.6.1. Climatic analyses*

They started with climatic and location studies Fig (10) to know what the parameter control the design like temperature, relative humidity, wind directions', wind speeds, wind frequencies, average precipitation, radiation, natural lighting. Next step in this stage according to previous studies is Psychometric Chart.

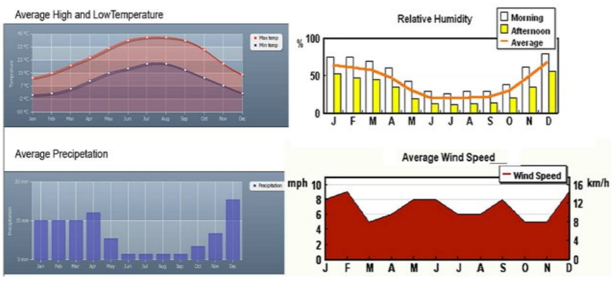



*Fig (10): climatic analyses*

### *5.6.2. Psychometric chart*

Used to show the load of air-conditioning and passive system needs. It shows a high thermal mass, internal heat gain, and wind protection Fig (11).

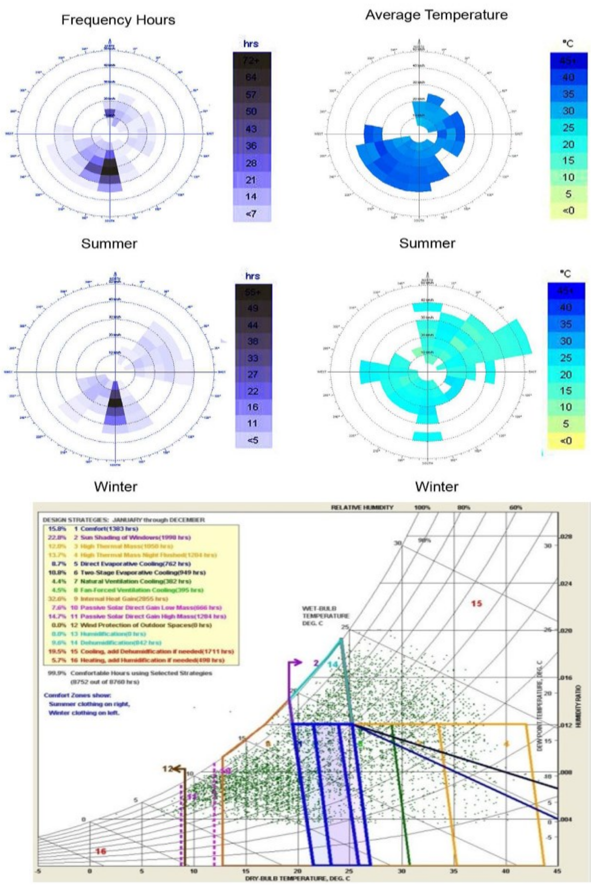



*Fig (11): climatic analyses for Syriac culture center.*

### 5.6.3. *Orientation*

After shaping building form, some studies like sun paths, "shading, and shadows" Fig (12) can support decision for building orientation to reduce thermal loads, heat island effect, make larger area from shadows and using natural light.

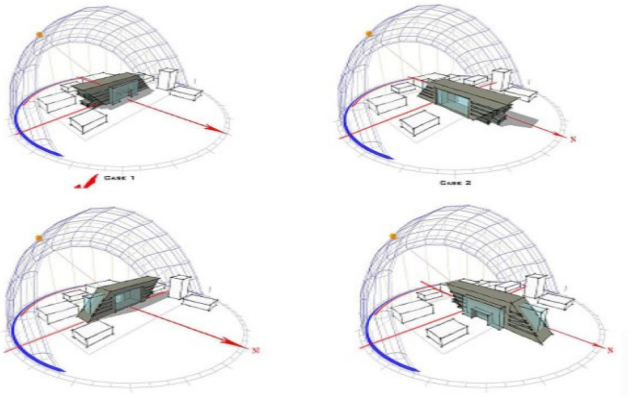
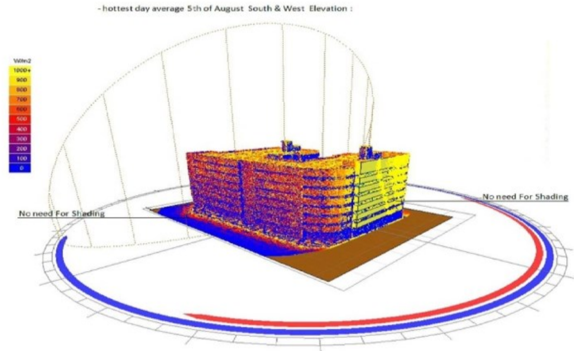


*Fig (12): Sun path and orientation studies for Syriac Cultural Center.*

### 5.6.4. *Thermal loads and treatments*

By using energy simulation, we can find thermal loads on the building and identify places, which need shading treatment using and shading devices. See Fig (13). This action can help the architect of selecting building materials, and external cladding types. A composition of different materials with various low-E parameters could be used to achieve the best building performance.

*Fig (13): Above,Perspective for QIB proposed by ECG, & Designed by Dr.Wael Abo Neama, Below, on the other side Thermal loads study*




### 5.6.5. Shading and shadows

Also, we can use energy modeling in sketsh design to be sure about efficiency of courtyards and atriums to reforming building. Orange Jordan telecom headquarter Fig (14) & (Fig (15) reshaped the building to make shaded court inside the building by rising western side of the building to prevent direct radiation and make shading court.

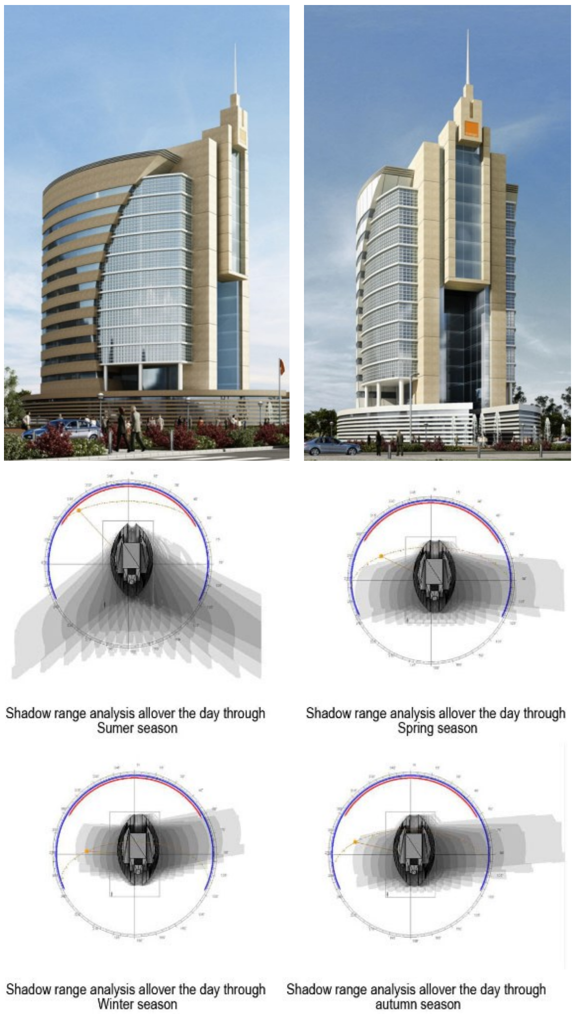



*Fig (14): Above, Perspective for Orange Telecom headquarter, proposed by ECG, & Designed by Dr.Wael Abo Neama, Below shadow study*

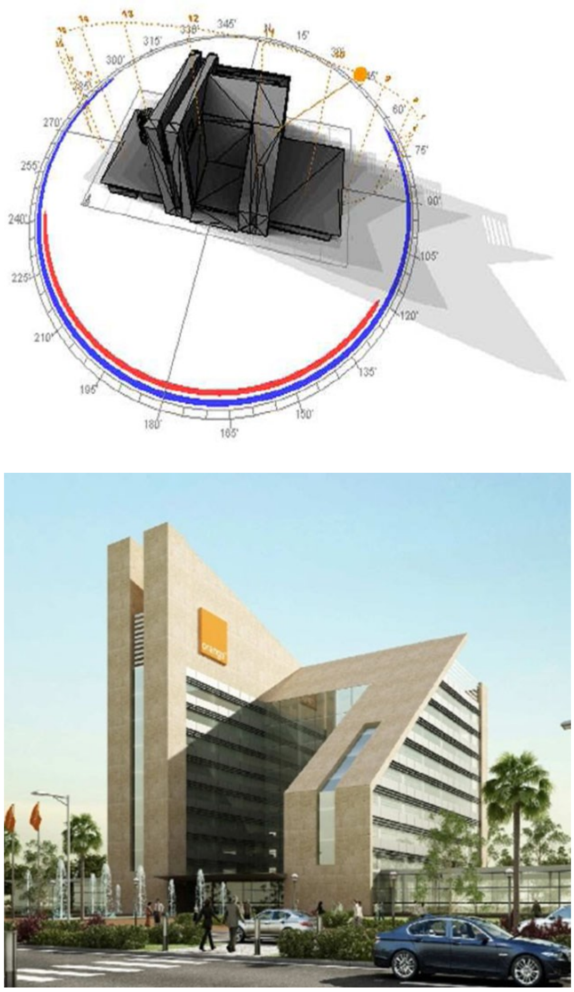


*Fig (15): Above, shadow study, below Perspective for Orange Telecom headquarters, proposed by ECG, & Designed by Eng.Nabil Shafiq*

*5.6.6. Outdoor impact:*

Energy modeling can be used in sketch design phase to measure the impact of the building on surrounding environment. It can help landscape designer to treat with outdoor spaces and select soft-scape or hard-scape elements according to the temperature of outdoor spaces and its radiation directions. The target is to reduce heat island effect. The Egyptian Media Production City (EMPC) Fig (16) mall competition challenge is the radiant temperature for outdoor spaces. The solution was focused on the external cladding material and the building function. The architect located all service corridors in the building parameter facades to reduce this heat. In addition, it affected the selection of plants in building' surrounding.

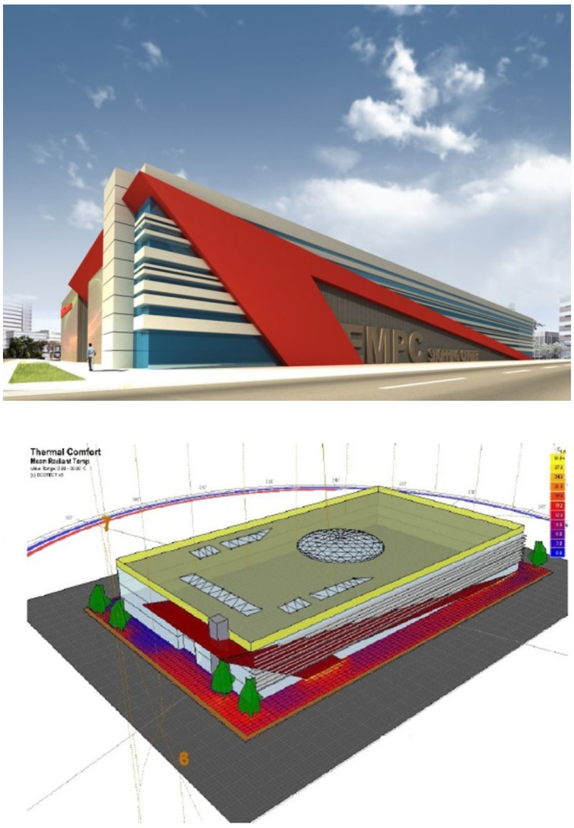



*Fig (16): Radiant temperature study for Egyptian Media Production City in 6 October. Proposed by ECG & Designed by Dr. Wael Abo Neama*

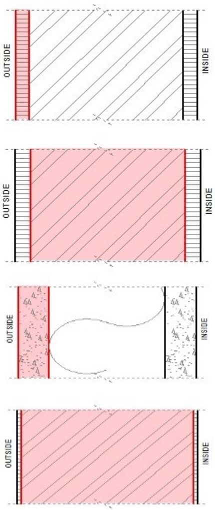
### *5.7. Sustainable input in Schematic design phase:*

At schematic design, a more detailed energy model is useful for identifying the primary energy factors. Understanding the energy loads for (space heating, cooling, lighting, water heating, etc.) are dominant providers and guidance on what aspects of the building design should be targeted for energy savings. The greater the energy use, the greater the opportunity for cost-effective energy savings. For instance, the designer could test alternative percentages of façade glass area on the principal orientations for energy and aesthetic implications.

*5.7.1. Envelope design:*

In case study from low-income housing competition designed by ECG, due to competition characteristics, they try to choose building envelope, which serve cheapest, and most efficiency concept. The envelope must save thermal comfort without using mechanical solutions. They depend on energy modeling to achieve the best performance for building envelop.

After applying all sketch design stage steps and regarding all pervious studied recommendations, a model shall be improved. Energy modeling helps the architect to define the activity and thermal properties to can choose between four alternatives of walls cross sections Fig (17).



| | Layer Name | Width | Density | Sp.Heat | Conduct. | Type |
|---|---|---|---|---|---|---|
| 1. | Plaster Building (Molded Dry | 10.0 | 1250.0 | 1088.000 | 0.431 | 85 |
| 2. | Brick Masonry Medium | 110.0 | 2000.0 | 836.800 | 0.711 | 25 |
| 3. | Plaster Building (Molded Dry | 10.0 | 1250.0 | 1088.000 | 0.431 | 85 |

| | Layer Name | Width | Density | Sp.Heat | Conduct. | Type |
|---|---|---|---|---|---|---|
| 1. | Plaster Building (Molded Dry | 20.0 | 1250.0 | 1088.000 | 0.431 | 85 |
| 2. | Brick Masonry Medium | 200.0 | 650.0 | 800.000 | 0.136 | 25 |
| 3. | Plaster Building (Molded Dry | 20.0 | 1250.0 | 1088.000 | 0.431 | 85 |

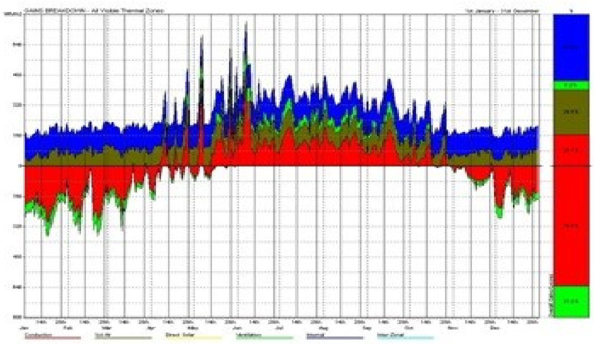
| | Layer Name | Width | Density | Sp.Heat | Conduct. | Type |
|---|---|---|---|---|---|---|
| 1. | fibergalssed conc | 2.0 | 2000.0 | 1088.000 | 0.002 | 35 |
| 2. | insolation | 7.5 | 20.0 | 836.800 | 0.030 | 45 |
| 3. | fibergalssed conc | 2.0 | 2000.0 | 1088.000 | 0.002 | 35 |

| | Layer Name | Width | Density | Sp.Heat | Conduct. | Type |
|---|---|---|---|---|---|---|
| 1. | Plaster Building (Molded Dry | 10.0 | 1250.0 | 1088.000 | 0.431 | 85 |
| 2. | Brick Hard Fired Silica | 400.0 | 1800.0 | 753.100 | 0.400 | 25 |
| 3. | Plaster Building (Molded Dry | 10.0 | 1250.0 | 1088.000 | 0.431 | 85 |

*Fig.17 walls cross sections low-income housing ECG design report.*
*First section brick plaster walls.(traditional section), Second section delta block walls, Third section GRC wall, Forth section bearing walls.*

After finishing the model and assigning the materials, a running model calculation for the same building using different envelope cross section in each time should be performed. The design team compares the following. Fig (18), (19) & (20):

- Heat gains and lose comparing for air-conditioning loads.
- Heat gain.



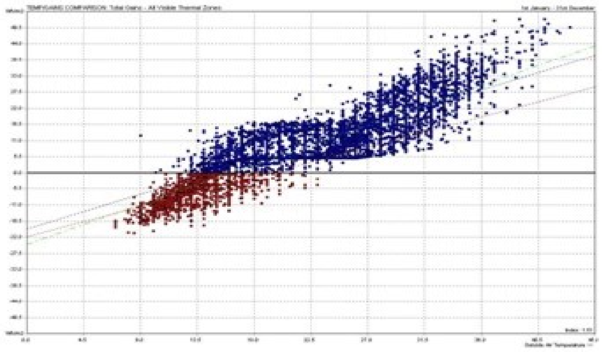


*Fig.18 upper building gains break down and on right total gain and loss around the year, low-income housing ECG design report*

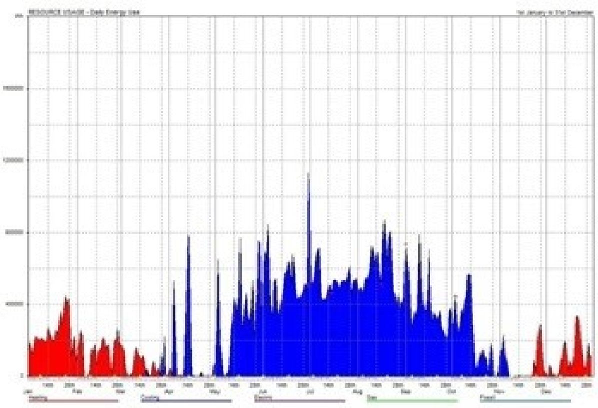


*Fig.19 Hourly Temperature inside zones in hottest peak day and coldest peak day*

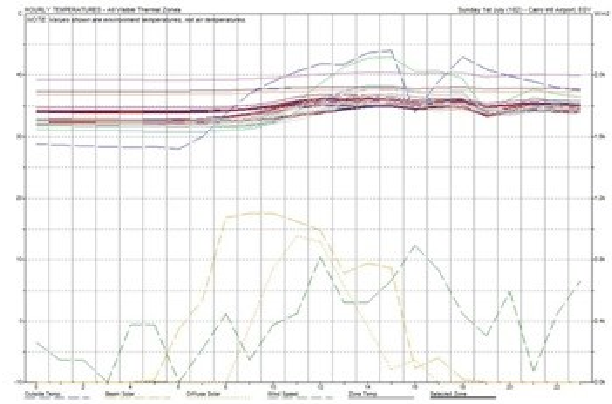


*Fig.20 RESOURCE USAGE - Daily Energy Use study around all year hours, low-income housing ECG design report.*

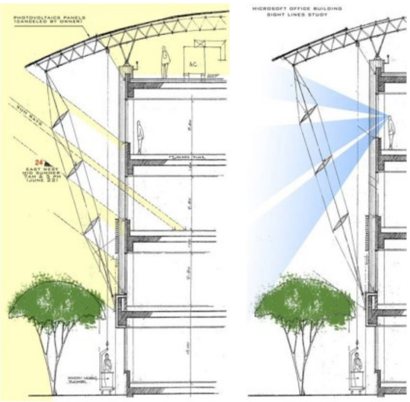
From previous statistics saving in each cross section according to base case (brick plaster wall):

- GRC heating saving: 83.27 %
- GRC cooling saving: 57.70 %.
- Delta Block Heating Saving: 83.1 %.
- Delta Block cooling saving: 57.45 %.
- Bearing walls heating saving: 80.16 %.
- Bearing walls cooling saving: 28.49 %

### *5.7.2. Shading devices*

Other new utility using for simulation tools in this stage, we can design any element like shading device. We can control the efficiency time and check visibility in Microsoft headquarter in Smart Village in Egypt. A study of the sun Paths & building orientation developed a three row of horizontal membranes stretched between steel posts stabilized by a net of vertical, horizontal and bracing cable. Fig (21).

*Fig.21 shading design by ECG, designed by Eng. Nabil Shafiq , for Microsoft building*



### ***5.8. Design Development phase:***

During design development, a detailed energy model should be used to conduct parametric analyses to evaluate alternative specifications and more fully understand of the trade-off between initial cost and life-cycle cost. The accuracy of the model is important at this stage; therefore, providing as much information as possible on the expected use and occupancy schedules of the building is important. The phrase "garbage in, garbage out" is particularly relevant to modeling at this stage It means as mush detailed accuracy you type as much real model you get. For example, using a default 8-to-5 Monday–Friday operating schedule for an office facility that operates 24/7 would significantly underestimate the building's electricity use for lighting and equipment. Using the wrong glazing specifications could significantly affect the heating and cooling load predictions

## 6. Conclusion &results:

Sustainability is not an option and it is an architect and planner responsibility. Knowledge, technology, and computer day by day provide techniques and simulation tools to improve building production, life quality, and human comfort by clear methodology. Therefore, there is no excuse to think green to save future generation rights and resources


## 7. Recommendations:

- Sustainable design starts with the first sketch and in the beginning of the design phase.
- Architects and consultants who start to develop the building towards sustainability in the construction phase will not produce any sustainability value in the building.
- Energy modeling using any tool will help the design teamwork to figure out the building performance and will help them to enhance their design and push it steps forward towards sustainability.
- In Egypt, we have the experience and projects, which proved its location in the sustainability, map.
- The whole design team is responsible of producing sustainable project not only the architect.
- Respecting ecological conditions around the project can save a lot of energy and water using passive design.

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