Examples of Low Energy Design at Urban Scale in Egypt

Prof. Dr. Suzette Michel and Eng. Hend Elsayed

Housing and Building National Research Centre, Giza, Egypt

ABSTRACT: This paper is extracted from work done by the authors in a project to develop an "Energy Efficiency Code for Residential Buildings in Egypt" and the evaluation of energy performance for the different design concepts through the use of a computer simulation programs (Doe-2, Visual Doe) and CTTC method.
This paper tackles strategies for environmental control on building design and shows that it is essential to take into consideration thermal performance efficiency and the compatibility of the building with the environment through optimizing the design of the building envelope elements such as: optimum thermal resistance of the walls and roofs, window opening size as a ratio of wall area, the glazing type, shading factor, and building materials with a high heat capacity – such as brick, concrete, stone, asphalt which are used for construction. These materials store heat or cold for a long period of time which affects comfort in the indoor and outdoor spaces. In addition, studying the urban characteristics of an area, the geometry, size and shape of buildings, streets and squares which is known to have the largest impact on the urban energy demand.

Keywords: energy, comfort, building survey, simulation programs.

1. INTRODUCTION

In Egypt, buildings in general are responsible for 60.18% of the total electricity consumption in all sectors. Energy demand has reached about 69.2 Billion kWh with an annual increase of 7%, where the industry takes about 43%, Residential and commercial buildings share is 42.6%, Governmental buildings and services consume about 16.7% while Agriculture use only 4%. The two major consumers of electricity are households and industry, followed by Government and public utilities. In order to reduce the energy consumption in buildings, a research has been conducted in the Housing and Building Research Centre in collaboration with UNDP&JEF.

2. PROBLEM DEFINITION

Modernization trends in building designs in Egypt imported a new technology which has led to an increase in energy consumption in buildings and at the urban scale for many reasons:

- At building scale

-Exaggeration in use of metal and glass
- Not using thermal insulation in general practice
- Relying totally on mechanical air conditioning
- No effort done in design to adapt foreign technology to local conditions

- At urban scale

Urban energy demand (at street level) increased for many reasons such as:
- disappear of Natural shading (trees) and artificial shading in streets.
- Not studying the street profile in terms of building heights to street width ratio.
- Air pollution, traffic …

3. OBJECTIVES OF THE STUDY

This study investigates theoretically and experimentally the energy performance of the residential buildings and urban planning in Egypt taking into consideration the climatic conditions in Cairo and Alexandria aiming to:
- reduce the energy consumption in buildings
- improve the comfort of the inhabitants in outdoors in urban areas as well as in indoor spaces.
- enhance the building energy efficiency leading to the quality of architectural and urban environment.

4. METHODOLOGY

The research used the following methodology in two stages:
* **First**: A field survey was conducted in both Cairo and Alexandria regions where construction activities are very high. The survey aim was to evaluate design, construction, and energy use in typical new residential buildings with a view to improving current building practices and introducing new energy - efficient features through comprehensive building code.

In order to have a sample representative of new construction, building selection was carried out according to predefined sampling scheme based on primary and secondary variables. The sample was designed to cover:

- Different zones in Cairo (Maadi, Nasr City, New Cairo …) and Alex (Agami, borg El Arab City...).
Types of building heights (tall: higher than 6 floors, middle: 5-6 floors, low rise: villas of 2 floors).
- Income level (high income, middle income and low income level).
- A number of 140 buildings were surveyed, analyzed and classified into two main Patterns:

A - Introvert looking into internal courts attached and semi detached as shown in table 1.

B- Extrovert with different shapes totally detached with low density arrangements in sites as shown in table 2.

Table 1:

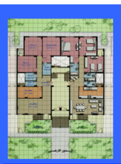
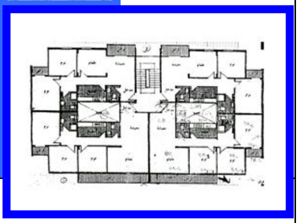
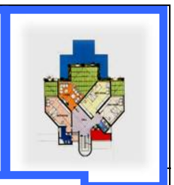
Pattern A	-Semi attached) attached from one side) - Square shape	 
	- Rectangular - Two units per floor - One closed light-well	 
	- Rectangular - 4 units per floor - 2 closed light-wells - Buildings are attached from the sides	**The Base Case Plan**

Table 2:

Pattern B	- Detached and surrounded by a garden - Irregular shape	 
	- Buildings are detached. - T shape. - Units have 3 : 4 external facades	
	- buildings are detached -Swastika shape - units have 4 external facades	

* Second: Energy simulation for performance analysis was conducted using DOE2, Visual Doe and Life cycle cost (LCC).

5. ENERGY PERFORMANCE OF BUILDINGS

To study the impact of the different factors on energy performance of buildings, a simulation analysis was conducted using:

- DOE2 program: a standard program for energy simulation in the USA. It was developed by Lawrence Berkeley National Laboratory (LBL).
- Visual Doe program: a window application that enables architects, engineers, to quickly evaluate the energy savings of building design options.
- LCC analysis: The life cycle cost analysis is the most commonly used rigorous method to determine the economic feasibility of energy efficiency projects, several parameters are needed to perform LCC analysis such as investment costs (including initial costs, replacement costs, and residual costs), annual energy costs (including electricity costs and fuel costs), non – annual operating costs (such as maintenance costs) and interest rates.

The base case is a housing unit in an apartment building in the top floor. The total area of the unit is 125 m2 and the floor has 4 units (see Base case in table 1, pattern A). Each unit has two 0.25 m thick external walls on different orientation built in cement bricks. Windows are of single glazing, transparent and 3mm thick.
The results of the simulation can be summarized in table 3 and are shown in figures 1 to 10.

Table 3: The results of the simulation

	Parameter	Complied	Improvement%	
			Cairo	Alex.
Roof	Insulation	50 mm poly.	39.5	37.16
		150 siliton	37.3	34.28
	Absorbance	Light color & solar absorbance= 0.3	31.64	33.7
	Insulation	25 mm Poly.+ Absorbance 0.3	48.9	42.47
	shading	Optional	20.67	26.76
	insulation +Shading	25 mm Poly.+ Shade	42.9	41.4
Wall	Construction	Hclay_25 mm	8.8	7.81
		Silt_brick_25mm	8.1	7.02
	Insulation	poly 25 mm _Mid	10.5	8.09
	Absorbance	Light color 0.3	13.3	17.09
	Absorbance + Insulation	Light color 0.3 + poly 25 mm _Mid	14.31	16.05
Window	Window type	SHGF_29	9.94	8.25
	WWR	WWR_15	3.16	3.58
	PF+ WWR	WWR_15+PF0.75	5.31	5.3
	WWR +Wind. Type	WWR_15+SHGC0.29	6.75	9.95

Figure 1: Impact of roof insulation on energy consumption

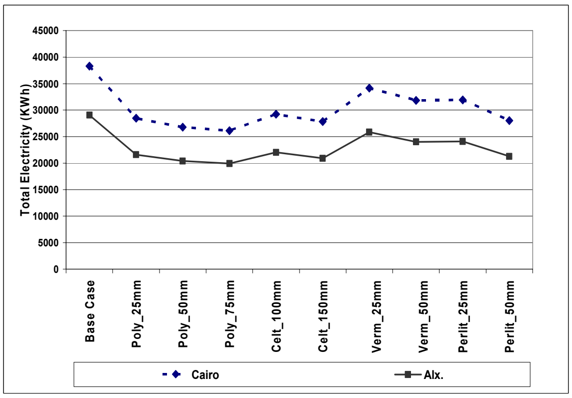
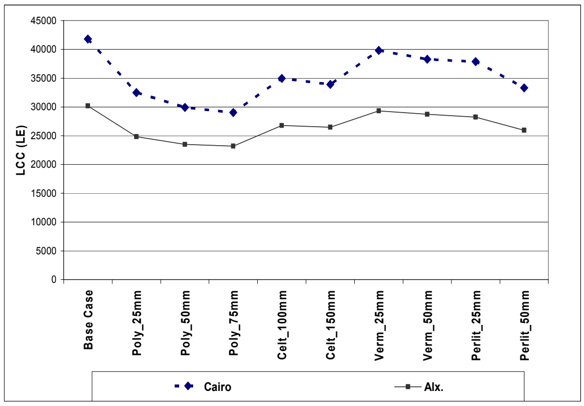


Figure 2: Impact of roof insulation on life cycle cost (LCC)



Studying LCC and the impact of roof insulation on energy consumption shows that the optimum roof insulation is 50 mm polystyrene or 150 mm siliton

Figure 3: Impact of wall insulation on energy consumption

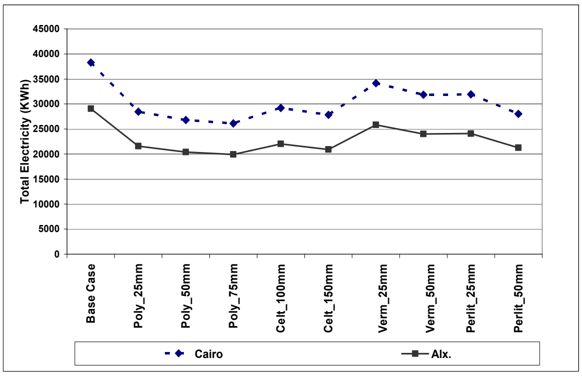
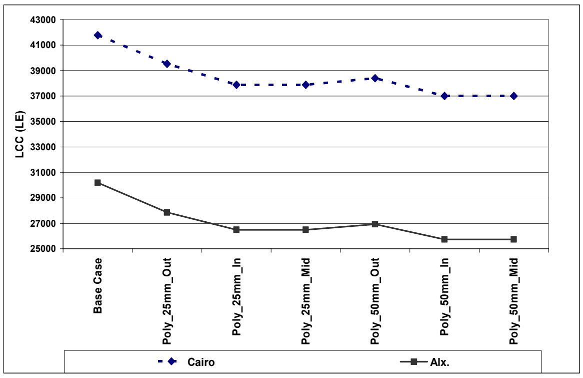


Figure 4: Impact of wall insulation on life cycle cost (LCC)



Studying LCC and the impact of wall insulation on energy consumption shows that the optimum wall insulation is 25 mm polystyrene mid

Figure 5: Impact of projection factor and SHGC on energy consumption in Cairo

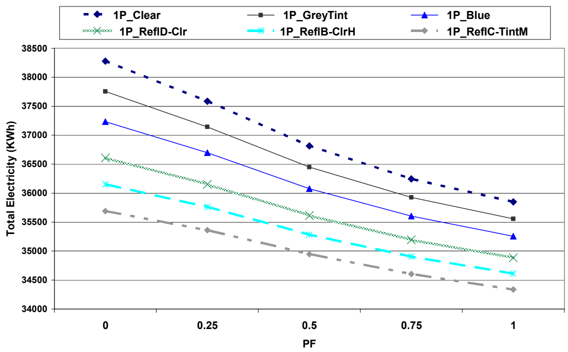
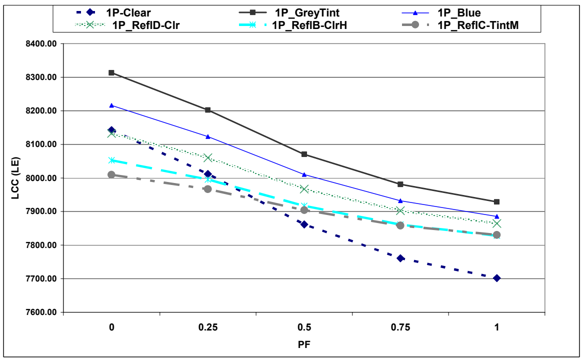
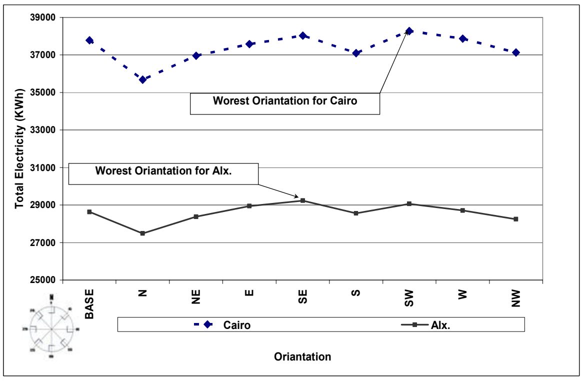


Figure 6: Impact of projection factor and SHGC on life cycle cost (LCC) in Cairo



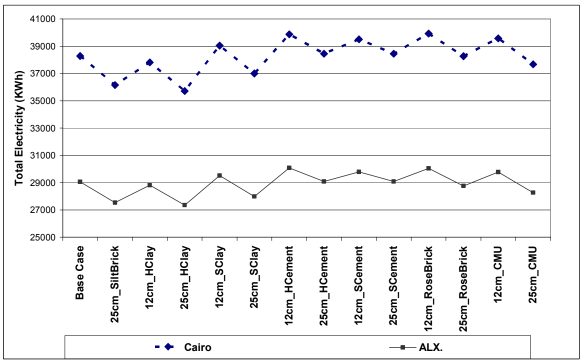
Studying LCC and the impact of projection factor and SHGC on energy consumption in Cairo shows That the optimum PF is 0.5m with 1P ref B-clr H or 1P ref C-Tint M

Figure 7: Impact of orientation on energy consumption



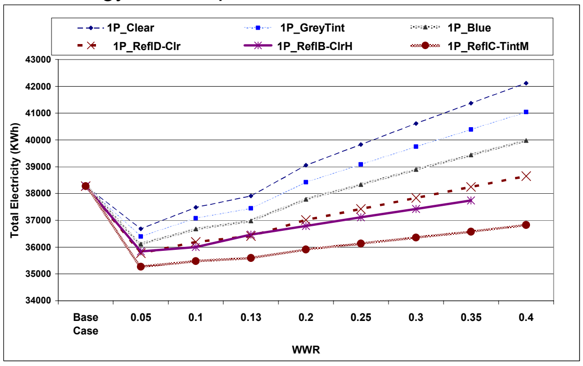
The best orientation for Cairo and Alex is N but the worst orientation for Cairo is SW and for Alex is SE

Figure 8: Impact of wall construction on energy consumption



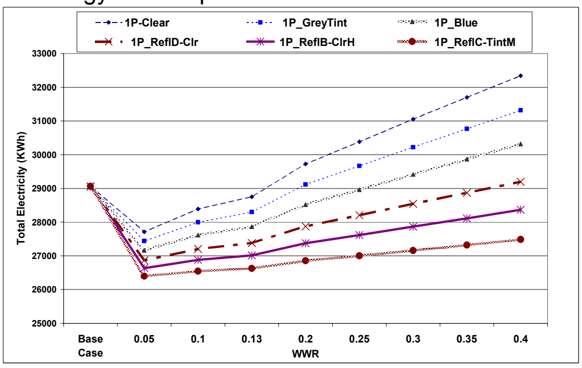
The simulation shows that using 25 cm of wall construction is better than 12 cm and using silt or

Figure 9: Impact of Glass type (SHGC) and WWR on energy consumption in Cairo



The simulation shows the optimum WWR is .15 with 1P ref B-clr H or 1P ref D-clr in Cairo

Figure 10: Impact of Glass type (SHGC) and WWR on energy consumption in Alex



The simulation shows the optimum WWR is .15 with 1P ref B-clr H in Alex.

6. URBAN CLIMATIC DESIGN

- Climate-adapted urban design takes climatic aspects into consideration at an early stage in the city planning.
- The objective of urban climatic design is to improve the comfort of the inhabitants outdoors in urban areas.
- Improving outdoor comfort also means improving the possibilities for the house to create a comfortable indoor climate.
- Improved climatic conditions indoors also means improving the possibilities to reduce the energy demand of buildings for heating in winter and cooling in summer.

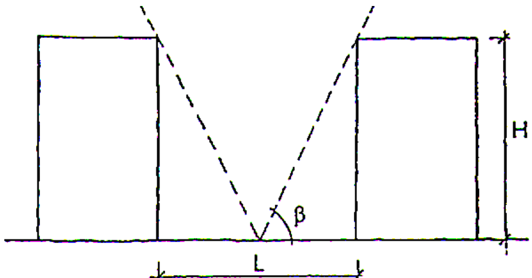
6.1 Factors influencing the energy performance of urban

6.1.1 Geometry of the built environment

The geometry – the size and shape of buildings, streets and squares in an urban area – is known to have the largest impact on the urban energy demand.

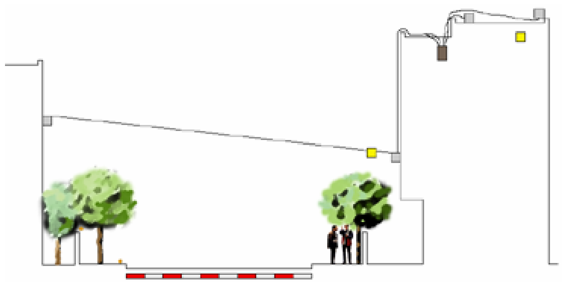
The geometry of the built environment has an impact on several climatic aspects such as: the radiation balance, wind conditions and heat exchange between surfaces and between surfaces and the air. The geometry of an urban area is often very complex and a lot of heat from solar radiation is trapped in the urban fabric.

- One way to describe the geometry, or the density, of an urban area or a street canyon is the ratio between the Height of the building and the Width of the street -the H/W-ratio.
- A similar concept is the Sky View Factor, determining to what extent the sky vault can be seen from a point in the middle of the street.

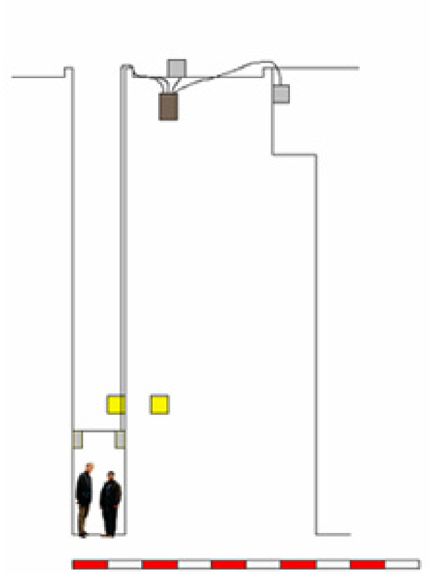


H/W ratio

Sky View Factor (SVF) = cosβ



Wide street, Height of Building 10.5 m
Width of Street 20 m, H/W=0.5



Narrow street, Height of Building 13.5 m
Width of street 1.4 m, H/W=9.5

Figure 11: Examples of street canyons with different H/W-ratios

6.1.2 Thermal properties of materials

In urban areas, building materials with a high heat capacity – such as brick, concrete, stone, asphalt which are used for construction. These materials store heat or cold for a long period of time, compared to the vegetation.

6.1.3 Anthropogenic Heat

Heat is created by the people living in urban areas. Activities such as industrial production, transportation, heating and cooling of buildings all generate heat.

6.1.4 Lack of vegetation

Vegetation is sometimes scarce in urban areas. However, parks and green areas have been found to mitigate the urban heat island effect.

6.1.5 Air pollution

It is considered one of the most important problems which affect badly, Pollutants reduce both the amount of incoming shortwave solar radiation and the net outgoing long wave radiation.

6.2 Results of Urban energy performance

- The urban energy performance may be improved by deliberate design of city structures, for example by orienting and grouping buildings to benefit from increased ventilation.
- The orientation of the street also has an impact on the solar exposure and wind conditions of the buildings situated along the street.
- Facades, roofs and streets should have a colour adapted to climatic conditions: light colours in a hot climate (a high albedo value) to minimise absorption of solar radiation.
- Building elements such as arcades, shading screens and fountains influence climatic conditions.

7. CONCLUSION

This paper has shown how the work of the architect and urban designer should tend to an energy efficient and thus sustainable built environment. The main concern is the design of the building envelope and the immediate surrounding of the building. Building energy performance is a trade off between different design factors to achieve a target level of energy consumption that varies according to the climatic conditions of the city. The impact of the different design elements and measures evaluated for both Cairo and Alexandria climates show variation giving relative importance to the different passive solutions.

ACKNOWLEDGEMENT

This paper is a conclusion of a project to develop an Energy Efficiency Code for Residential Buildings in Egypt and is supported by the UNDP & JEF. The authors wish to acknowledge Housing & Building National Research Center for support.

REFERENCES

[1] Energy Efficiency Residential Building Code, Ministry of Housing, HBRC, Egypt, September (2003).

[2] Energy in Egypt, Organization for Energy Planning, Ministry of Planning, Egypt, (2001/2002).

[3] M.M Razek, G. B. Hanna, E.M. El Salam and N. Farag "Computer Simulation and Thermal Measurements of Passive Heated and Ventilated Buildings", 3rd International PLEA Conference, Mexico City, Mexico 6-11 August PP. 952-959 (1984).

[4] G.B. Hanna and M.H. Khalil, "Thermal Investigation of Shaded and Insulation Roof in Hot Arid Climate", Passive and Low Energy Architecture conference. (1984)

[5] Moncif Kararti, Life cycle cost (LCC) analysis – Doe2 training - HBRC, March2004.

[6] http://www.urbanclimate.net

[7] http://www.stadtklima.de/webklima/start_d.htm

[8] Karin Grundström, The Urban Climate an introduction, Hpusing and Building Development Mangement (HDM), Sweden, (2003)