Developing Country Studies
ISSN 2224-607X (Paper) ISSN 2225-0565 (Online)
Vol.3, No.14, 2013

Green Architecture Assessment System in Egypt with an Application on *Zeinab Khatoun* House

Waleed Hussein Ali[1] Nermine Abdel Gelil Mohamed[2]*

1. Department of Architecture, Faculty of Engineering, Fayoum University, Fayoum City, Egypt

2. Department of Architecture, Faculty of Engineering, October University for Modern Sciences and Arts (MSA University), 6th of October City, Egypt

(* E-mail of the corresponding author: nonnatt@hotmail.com)

Abstract

This paper aims at introducing the green architecture assessment system and criteria in Egypt as well as exploring some elements and features of traditional Islamic architecture while assessing the application of the green architecture principles on a traditional Cairene house. First, it explores the global principles of green architecture such as energy conservation and climate adaptation, planning a sustainable building site, economizing water consumption, efficient use of construction materials, indoor environment quality, recycling solid waste, design and innovation and respect of users. Second, discusses the most common green architecture assessment systems and their criteria. The paper then explores the green architecture assessment systems in Egypt through introducing the Egyptian Green Building Council, the Green Pyramid Rating System (GPRS) and its assessment criteria. These are sustainable sites development, energy efficiency and environment, water saving, materials selection and construction system, indoor environmental quality, innovation and design process and recycling of solid waste. At the end, it attempts to apply the GPRS on a traditional Cairene residence, *Zeinab Khatoun* House, in order to investigate whether the green architecture principles were applied or not. It was found out that In the *Zeinab Khatoun* House, the use of Islamic architecture elements and features led to an average application rate of Green Pyramid Standards equals to 65%. The house may therefore be considered a historical building with green architecture attributes.

Keywords: Green architecture assessment systems, Egypt, Traditional Cairene, *Zeinab Khatoun* house, Green Pyramid Rating System, GPRS.

1. Introduction

Green architecture calls for the erection of buildings whose design, construction and conservation management system guarantee the health and safety of users, while minimizing any associated environmental risks. The objective of green architecture principles and conditions are therefore to overcome drawbacks and to establish the basis for architectural design. This paper aims at introducing the green architecture assessment system and criteria in Egypt as well as exploring some elements and features of traditional Islamic architecture while assessing the application of the green architecture principles on a traditional Cairene house. The paper first explores the principles of green architecture such as energy conservation and climate adaptation, planning a sustainable building site, economizing water consumption, efficient use of construction materials, indoor environment quality, recycling solid waste, design and innovation and respect of users. Second, discusses some internationally recognized green architecture assessment systems and their criteria. It explores then the green architecture assessment system in Egypt through introducing the Egyptian Green Building Council, the Green Pyramid Rating System (GPRS) and its assessment criteria. These are sustainable sites development, energy efficiency and environment, water saving, materials selection and construction system, indoor environmental quality, innovation and design process and recycling of solid waste. Traditional societies understood these principles and successfully applied them in the overall design of their buildings as well as in all parts of the city to the extent that we can make use of their ideas today. Therefore at the end of the paper, a detailed description of a well-known traditional residence, *Zeinab Khatoun* House, is provided and, in order to investigate whether the green architecture principles were applied or not, the GPRS was used to assess them.

2. Principles of Green Architecture

Green architecture calls for the erection of buildings whose design, construction and conservation management system guarantee the health and safety of users, while minimizing any associated environmental risks. The objective of green architecture principles and conditions are therefore to overcome drawbacks and to establish the basis for architectural design.

2.1 Energy Conservation and Climate Adaptation

This includes minimal use of energy through reducing the amount of electricity, fuel, water and materials consumed, and using (and recycling) energy in the most advantageous manner. It also includes making use of natural energy sources (harnessing the effect of climatic elements to enhance 'thermal comfort' inside the buildings). Some define the concept of thermal comfort as a feeling of complete physiological (bodily) and mental comfort. Climatic architectural design has two principal objectives (Waziri 2007). First: In the winter, architectural designs aim at realizing optimum heat (sunrays) absorption and minimal heat dispersal from building interiors. Second: In the summer, buildings need to be cooled; therefore designs aim at avoiding direct sunshine and minimizing heat absorption, while encouraging heat dispersion from building interiors and using various architectural strategies to cool internal spaces.

Traditional societies understood these principles. The attention paid to shade in the overall design as well as in all parts of the city is an important energy conservation principle of traditional cities that we can make use of today. Shade is a principal factor that contributes up to 30% (Mostafa 2010) to energy conservation. The shading of buildings is therefore a main factor affecting the quality of climate responsive design.

The use of light colors to deflect sunlight and of environmentally friendly materials with a low degree of heat absorption to minimize heat gain serves to reduce the energy consumed for cooling by thermal isolation. This should be combined with the appropriate direction of buildings and openings; in hot climates, the widest side of a building should face north, to avoid absorbing heat (Reffat 2010).

Electricity consumption may be reduced by using photovoltaic cells, which produce electricity directly from the sunlight that falls upon them, through a clean process that does not pollute the environment. Photovoltaic cells are made of silicon (sand), a material that is widely available and which can be used with no negative impact on the environment. Their manufacture however, is costly and photovoltaic cell specifications differ according to the intended use.

It is possible for a building that is confronted with climatic problems to make use of all available climatic and natural resources to ensure the comfort of its human occupants. Such 'climatically balanced' buildings comprise two main factors: protection against the external climate, and internal structural conditions that guarantee human comfort. Thus, in any climate, traditional homes are usually the products of accumulated experiences that result in a combination of environmentally ideal designs and styles and quality architecture.

Traditional environmental solutions include (see figures 1, 2 & 3):

- Inner courtyard (see figure 2): in hot climates, it stores cold air at night to alleviate hot temperatures during the daytime.
- '*Malqaf*' or ventilation trap (see figure 3): located on the tops of building, it has an opening facing the direction from which the wind normally blows. The opening entraps the cooler air passing over building tops and propels it into building interiors.
- '*Salsabeel*': a rippled marble slab inserted in an opening in the wall facing the '*iwan*', or living area. It allows water in the air to condensate on its surface, facilitating the evaporation process and making the climate in that area cooler and more refreshing.
- Skylight or '*shoukhshekha*': covering the main rooms of a building, they provide ventilation and indirect lighting. Skylights also serve, along with ventilation traps (*malqafs*), to draw out the highest layers of hot air (Waziri).
- '*Mashrabiyya*': minutely designed and decorative rounded (equidistant) openings made of wood latticework. They regulate ventilation and natural lighting while providing privacy.
- Rooftops: domed rooftops (in the form of half globes or half tubes), they are always shaded, except at midday. Their shape increases the speed of air flowing over them, thereby reducing rooftop temperatures (Waziri).

The architectural components cited above are the result of interacting - without affecting it negatively - with the surrounding environment to produce a building that provides both interior comfort and protection against external elements.

2.2 Planning a Sustainable Building Site

This involves the selection of appropriate project sites, the provision, on site, of transportation facilities and flexible services, as well as the establishment of maintenance and rainwater management plans. Designing empty spaces with an eye on the health benefits of green spaces is also part of planning sustainable building sites. In addition to improving the local climate in hot regions, green spaces help to purify the air of dust, vapor and the many other pollutants it carries (Waziri).

2.3 Economizing Water Consumption

Through minimizing water consumption: used water technologies devised to keep the water in the buildings i.e. the re-use of grey water (water that has been used for bathing, showering and in the kitchen) are very effective in reducing water consumption in buildings. Grey water is collected in ground tanks, where it is treated and purified using sand, pebbles and biological filters, then used to irrigate the gardens. The collection of rainwater, which can be used for bathing and to irrigate gardens, is another important operation that contributes to water conservation (Waziri) (see figure 4).

2.4 Efficient Use of Construction Materials

This involves constructing buildings with a low rate of harmful gas emissions by using materials and tools that minimize the consumption of resources and help to preserve the environment. It also includes recycling (using building debris for fill-up work), using materials produced through sustainable processes (such as woods from places that have been reforested), using mainly local building materials and moderating the use of manufactured materials. Environmentally friendly construction materials comprise two basic conditions (Khaled). The first condition is that the materials should not have a high rate of energy consumption (during their manufacture, during their use in construction and even for their maintenance). The second condition is that the materials not pollute building interiors; in other words, building and finishing materials should belong to the 'safe' category, which includes mostly natural construction materials.

2.5 Indoor Environment Quality

The problem of pollution inside buildings was compounded by the increased use of synthetic construction materials and finishing products and various construction chemicals, all of which contribute to the concentration of pollutants in the air, creating an unhealthy internal environment. Good ventilation is an essential factor for combating pollution in building interiors. This is why it is important, in each region, to ensure that building openings face the direction of the wind, while making sure that each room has more than one opening, to create an appropriate air current. Where rooms do not face the direction from which the wind blows, ventilation traps (*malqafs*) or porous materials may be used. To regulate humidity levels within buildings effectively, porous materials should never be covered with paint that fills up the natural pores. Natural brick and stone or wood that is not coated with finishing materials that fill up its pores are examples of porous construction materials (Waziri).

For the efficient use of natural light and appropriate orientation of openings to the outdoors, a good architectural design must allow for the following (see figure 5):

- To avoid glare, each room should have two windows, on different walls
- The distribution and placement of windows should allow for letting in a maximum amount of natural, particularly reflected, light (direct natural light should be avoided).
- Site plans should take into consideration building heights and the distances between buildings, to ensure that no building will block natural light from another that faces, or is adjacent, to it. This explains the importance of studying the angle at which sunrays strike the earth all year round.
- Providing uncovered spaces within buildings to allow people to benefit from ultraviolet rays

- The use of artificial lighting in building interiors, when natural light is insufficient: it is important to select lamps and artificial lighting units that provide light that resembles natural light as much as possible. Energy-saving lighting units should be used (Waziri).

Moreover, exterior wall colors affect the degree to which walls and rooftops absorb sunrays; light colors deflect sunrays. Studies have also proven that West and East-facing walls are more affected by sunrays than are North-facing ones (Waziri).

In addition, efficient sound design and the reduction of noise levels depend on building wall blocs to prevent the transmission of sound and noise. The role of floors in minimizing noise transmission depends on the degree to which flooring surfaces absorb noise. The planting of trees facing the direction from which noise originates (streets, for example), and of 'vegetation belts', at a distance of 6 to 15 meters from the buildings, will effectively reduce the level of noise reaching the buildings (see figure 6) (Waziri).

2.6 Recycling Solid Waste

This is done by collecting and re-using recyclable waste and construction materials, re-using and renewing resources, and by using buildings for more than one purpose in a manner that befits the building's function and how it affects and is affected by its location.

2.7 Design and Innovation

Certain principal elements are needed to complete an architectural work. Interaction among these elements varies according to the specificities of each project. These elements are functional, environmental, economic, social and decorative (see figure 7).

a. Functionality. This is realized through:

- Preserving proper basic functional relationships by avoiding design errors and keeping designs simple

- Applying growth and flexibility functions, functions concerning the relation among empty spaces and between these spaces and their users (of different habits and activities), and keeping wasted space at a minimum.

- Developing an architectural structure and controlling the area of surfaces exposed to sunlight while allowing for wind movement (less width = less sunlight) (appropriate orientation = better natural ventilation)

- The building design should provide security against natural disasters. Many factors must be considered to ensure that a building is secure from fire hazards, such as using fireproof walls and construction elements, ensuring that the number of fire escape stairwells is appropriate to the number of building occupants, and trying to find alternatives for highly flammable construction materials (Ibrahim 1999).

b. Environmental and economic factors. The environment is the main regulating factor of the design process, and this entails respecting the site's physical and ecological characteristics. Green architecture aims at creating a highly efficient internal climate that functions successfully and at reducing different kinds of pollutants and waste materials (by destroying or recycling them). It also underlines efficient energy use (depending on natural and renewable energy sources). Buildings should be supplied with equipment that transforms natural energy into electricity and heat, and it is important to economize on the use of resources. Since water is the most important of these, used (grey) water should be treated and re-used. Other important environmental and economic factors include minimizing waste, and studying the mechanical, environmental and economic properties of the various construction materials in order to use the most appropriate (Ibrahim).

c. Social and decorative factors (architectural style). One of the most important characteristics of an environmentally friendly building, regardless of the function it fulfills, is that its architectural style fits into its social and historical environment. Architectural style is affected by the natural environment that determines the character of a given location (which is constant), and by cultural features, including religious, social, political and economic features, in addition to philosophic, scientific and artistic ideas (which are variable) (Waziri).

2.8 Respect of Users

Implementation methods selected must be ones that minimize hazardous operations and unsafe working conditions, and the materials used for construction and finishing works must not negatively affect construction workers or building users. As for respecting building users (the target group of the design), it is environmentally important to take into account the human element, the suitability of buildings for their intended functions and different individual needs (see figure 8), including the need for privacy, while ensuring a high quality construction to withstand environmental disasters, such as hurricanes and earthquakes. The application of disaster-resistant construction principles is imperative to ensure building resistance to earthquakes and fires (Waziri).

3. Green Architecture Assessment Systems

Numerous green architecture assessment systems and environmental design tools exist. They present techniques for designing buildings that depend on their occupants' needs. Among the most important architecture assessment systems are: 1) BREEAM 2) CASBEE 3) GBTooL, 4) Green Globes™ US, and 5) LEED.

3.1 BREEAM

BREEAM stands for Building Research Establishment's Environmental Assessment Method, a research institute's building assessment method (www.breeam.org). Launched in the U.K. in 1990, it covers a wide range of building types (offices – homes – industrial units – partitioned units – schools). Other building types may be accessed through a detailed application of the system. During building assessment, points are awarded for each criterion; and based on the total number of points they receive, buildings are rated ('Good', 'Very Good', and 'Excellent'). These criteria are:

1. Management (cost / recycling of waste / minimization of pollution / conservation of resources used)
2. Health (ventilation quality / cooling / illumination / thermal comfort)
3. Energy (measurement systems / efficiency / no carbon dioxide traces)
4. Transport (emissions / alternative transport facilities)
5. Water (reduced consumption / measurement / locating leakage and waste)
6. Materials (minimal asbestos traces / recycling equipment / re-use of buildings and materials / use of sustainable wood)
7. Land exploitation (previously used land / treatment of polluted land)
8. Environmental science (land of low ecological value / minimal value changes and preservation of the terrain's main ecological systems / minimal disturbance of biological diversity)
9. Pollution (systems for discovery of leakages and onsite treatment / use of local renewable resources / avoiding the use of materials that contribute to ozone depletion and global warming

3.2 CASBEE

CASBEE stands for Comprehensive Assessment System for Building Environmental Efficiency (Institute for Building Environment and Energy Conservation, www.ibec.or.jp/CASBEE/english). Launched in Japan in 2001, the system's assessment tools depend on the building's life cycle: pre-design stage, new constructions, and old constructions. CASBEE is a new assessment concept linked to the quality of a building's performance (the best building has the least impact on the environment and the highest performance level). Assessment levels are from 1 to 5 and the criteria are as follows:

1. Indoor environment (Sound and noise, thermal comfort, illumination and type of ventilation)
2. Quality of services (functionality and ease of use / comfort facilities, sturdiness, flexibility and adaptability)
3. External onsite environment (preserving and creating biological environment / site layout / natural views / external comfort facilities)
4. Energy (convection / use of natural energy / system and operational efficiency)

3.3 GBTooL

Developed as part of the international Green Building Challenge process, in which more than 25 countries have participated since 1998. Through the participants, GBTooL was designed to adapt to and reflect local conditions (International Initiative for a Sustainable Built Environment IISBE, www.iisbe.org). The system covers criteria such as project site, plan selection, environmental parameters, energy, materials, consumption, indoor environmental quality, functionality, long-term performance, and social and economic issues. All parameters and benchmarks were set by the system's managing organization to accommodate different national, regional and local conditions and priorities. GBTooL has developed over the years and has been tested by participating countries; results have been presented in a series of international conferences. Its assessment criteria are:

1. Energy consumption assesses the use of non-renewable electric energy, the highest demand for electrical operations, cost, and the use of renewable energy.

2. Assessment of materials considers the use of recyclable materials, materials that are manufactured using sustainable methods, locally produced materials designed to be recyclable, system building and using water for irrigation purposes.

3. Environmental factors include greenhouse gas emissions, and other atmospheric emissions, solid waste, rainwater, wastewater, onsite impact, and other local and regional effects.

4. Assessment of indoor environment quality concerns ventilation of enclosed spaces, temperature measurements and quality, relative humidity, natural illumination, noise and sound levels.

5. Additional criteria include suitable site choice (land exploitation, proximity of transportation and availability of utilities), project planning, the design of urban areas (density, various uses, local vegetation, etc)

6. Establishment of rules, flexibility to adapt, performance maintenance, and a small number of social and economic criteria

3.4 Green Globes™ US

Developed in line with the Canadian Green Globes system in 2004, Green Globes™ US is funded by the Green Building Initiative (Green Building Initiative, www.thegbi.org). It is an online tool designed for use by architects and builders for building projects of any size. For commercial buildings, system users can assess impact of their designs according to the score points provided. Third party verification is possible by submitting online data and obtaining a score of 35% of available points. Projects are rated from 1 to 5 and assessed according to the following criteria:

1. Project management (design integration / environmental depletion costs / planning for emergencies and avoiding hazards)

2. Project site (site development / minimizing environmental impacts / enhancing water collection benefits / improving site environment)

3. Energy (energy consumption / reducing energy needs / use of energy efficient resources / use of renewable energy systems / efficient energy transfer)

4. Water (hot water connections and fixtures / water conservation / water reduction off site / treatment)

5. Indoor environment (efficient ventilation systems and control of indoor pollution sources / integrated lighting design / thermal and noise comfort)

6. Resources, construction materials and solid waste (materials with a low environmental impact / minimal use and waste of nonrenewable resources / re-use of existing buildings / sturdy construction / adaptability and possibility of dismantling / reduction and recycling of waste)

3.5 LEED

LEED stands for Leadership in Energy and Environmental Design. Developed by the U.S. Green Building Council, it is a building classification program (U.S. Green Building Council, www.usgbc.org/leed). The program was first implemented in the year 2000, and today LEED certification is granted to construction projects in the U.S. that fulfill the prerequisites of sustainable green architecture, and it has also become a requirement for assessing building sustainability in many other countries. Assessment criteria are:

1. Sustainable project sites (prevention of polluting construction / site development / alternative transportation / rainwater management / reducing the phenomenon of heat islands)

2. Efficient onsite water use (water conservation / minimizing water content in tanks / grey water use strategies)

3. Energy (enhancing energy performance and measuring energy consumption for the entire building / cooling systems / renewable energy use)

4. Materials and resources (gathering recycling sites together / re-use of buildings and waste management / use of local, renewable and recycled materials / using wood products produced from sustainable forests)

5. Indoor environmental quality (surveying indoor emissions / increasing amount and type of ventilation in enclosed spaces within buildings / using materials with low emission levels / thermal and illumintion system controls / selecting sources of materials used)

6. Innovation and design (a professional and innovative process that applies sustainable design strategies)

4. Green Architecture Assessment Systems in Egypt

To promote and encourage the concept of green architecture, many organizations and bodies have agreed to establish building assessment standards and specifications. Today, many countries use green architecture assessment systems that were already developed by several countries (see figure 9). Some of the expected benefits of implementing assessment standards and specifications are:

The move towards applying green building assessment systems in Egypt is a result of dealing with climate related issues. Inefficient energy use and natural resources management and ineffective management of liquid, gaseous, solid and agricultural wastes, as well as sanitary and irrigation water wastes, have a very serious negative impact on the environment that affects all sectors of the State. This necessitated the development of a national Egyptian Green Building Rating System to ensure the realization of our development objectives: to fulfill the needs of the present generation without jeopardizing those of the coming generations, to reduce energy consumption and minimizing costs in the construction sector, in addition to implementing different techniques and methodologies (Mahrous 2010).

4.1 The Egyptian Green Building Council

Established in January 2009, the Egyptian Green Building Council developed the Egyptian Green Building Rating System. The Council's membership includes both government and non-government personalities. One of the objectives of this Council is to provide a mechanism to encourage investors to adopt existing codes that meet the goals of energy efficiency and environmental conservation. As a professional organization, the Council educates and persuades engineers, builders, contractors and owners about the individual and communal benefits of green building. Green construction will thus become the desired objective for all new construction projects. The Council's vision is based on improving the lives of Egyptian citizens, contributing to the global movement towards a cleaner environment, and the provision of renewable energy through the implementation of green building processes (Egypt Green Building Council, Egypt-GBC).

4.2 The Green Pyramid Rating System (GPRS)

As an immediate action to activate the role of the council was developing a national Green Building Rating System called the Green Pyramid Rating System (GPRS), the council has commissioned to define the framework of a rating system and a national committee has been formed to review and approve the Green Pyramid Rating System. Recognizing the unique ecological, industrial and social challenges of the region, the rating system helps to define what constitutes an "Egyptian Green Building". To accomplish that goal, the rating system integrates proven methodologies and techniques used in successful programs from the United States, Europe, Asia, South America and the Middle East, while focusing on the Egyptian BEECs (Building Energy Efficiency Certificates) and factors that are relevant to buildings in Egypt (Mahrous). The GPRS has three rating levels (see figure 10):

1. Silver Pyramid (the lowest level of green building certification; 600 points)

2. Golden Pyramid (the medium level of green building certification; 800 points)

3. Green Pyramid (the highest level of green building certification; 1000 points)

4.3 Assessment Criteria of the GPRS

The following criteria are obtained from the GPRS project by the Housing and Building National Research Center in conjunction with Egypt-GBC (2011)

4.3.1 Sustainable Sites Development (200 points):

- Presentation of project design & planning
- Selection of site location
- Implementing project design & exploitation of project terrain

4.3.2 Energy Efficiency and Environment (325 points):

- Reducing the phenomenon of 'heat islands' and realizing best heat control methods
- Energy efficiency in heat control equipment (cooling towers)
- Energy efficiency in electric water heaters
- Designing gas or liquid fuel heating systems
- Facility of operation and control
- Efficient use of space and necessary openings for mechanical equipment
- Efficient management of annual operation and maintenance costs – Distribution of cooling loads
- Allowing for climate conditions
- Realizing highest airflow speed
- Airflow distribution and canalization
- Energy consumption accounts
- Renewable energy use
- Designing heating, ventilation and cooling systems
- Supplying energy for electric heat pumps
- Enhancing efficiency of electricity supply
- Adapting air conditioning design to technical and economic needs
- Calculating amount of outside air required for artificial ventilation
- Using central air conditioning units rather than numerous small units
- Selecting pollution control methods
- Adhering to heat emission degrees (individuals and equipment)
- Water treatment
- Using energy saving lighting
- Lowest possible negative environmental impacts

4.3.3 Water Saving (efficient use and conservation; 90 points):

- Lowest water consumption rate
- Hot water supply
- Quality rainwater disposal systems
- Use of sanitary fixtures and equipment in building
- Water disposal and ventilation in building
- Re-use of grey water
- Selecting appropriate water tanks

4.3.4 Materials Selection and Construction System (65 points):

- Using efficient materials
- Using materials that are erosion resistant and require minimal maintenance
- Efficient energy use

- Finishing materials
- Life cycle pricing of materials
- Using environmentally friendly humidity and water resistant materials
- Using surplus wood for wood fixtures
- Using prefabricated units
- Bacteria resistant materials

4.3.5 Indoor environmental quality (quality of ventilation, lighting and noise control; 150 points):

- Ventilation quality
- Reduction of required air amounts
- Natural lighting quality
- Quality of cooling buildings during hottest hours
- Noise level control through architectural vacuum
- Use of environmentally friendly painting materials adapted to sustainable development
- Allowing for topographical aspects
- Allowing for the visual dimension
- Climate control
- Humidity level control
- Evaluation of thermal comfort level
- Designing openings for best ventilation
- Avoiding negative effects of noise
- Quality of flooring and floor coverings
- Attention to vegetation and landscaping
- Consideration of social dimension
- Consideration of sound studies of the surrounding environment

4.3.6 Innovation and Design Process (creativity, renovation and flexibility of development and maintenance operations; 90 points):

- Creativity and innovation
- Implementation of patents in design and execution
- Applying successful management methods to the project
- Environmentally unique design
- Application of standards for the convenience of the disabled

4.3.7 Recycling of Solid Waste (140 points)

- Handling and storage at the waste producer
- Collection and transportation
- Sorting, processing and disposal

As shown above, the highest value is accorded to Energy Efficiency and Environment. Energy conservation is the most important element in the construction process; it affects a building's impact on the surrounding environment, emissions, building operation, the use of equipment and the means for achieving thermal comfort for occupants.

5. Assessment of the Green Pyramid Rating System (GPRS) Criteria in a Traditional Cairene Residence: *Zeinab Khatoun* House

5.1 Description of Zeinab Khatoun House

The construction of the house dates back to 1468 and it is located in Al Azhari Alley, branching off Al Dawadari Alley (Mohamed Abdo Street) in the district of Al Azhar. It consists of two blocs, a two-storey building and a three-storey building. It features a number of architectural elements, including (See figures 11 to 15 and Garcin, et al. 1982, Mohamed 2003, Aga Khan Trust for Culture, Abdel Reda 2011):

1. The entrance (figure 12): A small, square lobby (‘*durka’a*’’) with a stone tile floor and a wood beam ceiling. To the right is a small passage with three doors. The first door, in the southwest wall of the passage, leads to a rectangular room with stone tile flooring and a wooden ceiling, and the second (on the southeast wall of the passage) leads into an uncovered rectangular courtyard with a stone tile floor. The windows and ‘*mashrabiyyas*’ of the house’s inner rooms overlook this courtyard, and the doors of the ‘*mandara*’ and ground floor rooms open unto it as well. A staircase leading up to the ‘*maq’ad*’ is also located in this courtyard.

2. The ‘*mandara*’ is accessed through a door in the southeast wall of the courtyard. It is a rectangular room with stone tile flooring and a ceiling of wood beams. There is a window on its northwest side, and a square door on its southwest side leads to the vestibule off the side entrance; a rectangular corridor parts of which are covered with intersected vaults and others with single vaults. Ventilation openings are located between the two types of ceilings.

3. The main courtyard (figure 13) functions as a passage from the outside to the main hall and ensures privacy. It also serves to regulate temperatures and as a source of lighting and ventilation for most indoor spaces that overlook it. Additionally, it works with the small covered inner courtyard to create a steady airflow inside the house. Surrounded by a number of doors and by the four sides of the house, the main courtyard leans at a 17-degree angle in a northeasterly direction. Calculations show that during the day of June 21 (Abdel Reda), over 82% of the main courtyard’s floor area and 77% of its wall area are shaded. The main courtyard is square, with each side measuring 905 meters and in its center is a water fountain of great value (Hossam El Din 2005).

4. The ‘*maq’ad*’: Located on the first floor, this is a rectangular (4m x 6.5m) space, with stone-tile flooring and an undecorated wood beam ceiling. Two semi-circular arches overlook the courtyard. The ‘*maq’ad*’ is designed to face north for ventilation purposes (see figure 11).

5. The large hall (figure 14) is located on the first floor and comprises a square, marble-floored ‘*durqa’a*’ with a wood ceiling at the center of which is a ‘*shoukhshekha*’. The ‘*durqa’a*’ is flanked on either side by two ‘*iwans*’ of similar design. One is a deep recess in the southwest wall of the ‘*durqa’a*’, whose floor is slightly higher than that of the ‘*durqa’a*’ and whose wood beam ceiling is lower. The northwest wall of this ‘*iwan*’ features a ‘*mashrabiyya*’ that looks out unto the ‘*durqa’a*’. The second ‘*iwan*’ faces northeast and has a raised, stone tile floor and a wood beam ceiling.

6. The bath is located on the first floor and is accessed through a door from the main hall. It consists of three rectangular rooms of varying size (Abdel Reda). A vaulted ceiling with light holes covers the space (figure 15).

7. The small hall on the first floor consists of a rectangular, stone-tile floor ‘*durqa’a*’. It has a wood ceiling with a ‘*shoukhshekha*’ at the center featuring a turned wood cover. There is an ‘*iwan*’ on the northwest side of the ‘*durqa’a*’ with a stone-tiled floor and wood beam ceiling. A ‘*mashrabiyya*’ on the southwest wall of the ‘*durqa’a*’ overlooks the courtyard. The ‘*shoukhshekha*’ in both the large and small halls serves to draw out the hot air that rises up inside indoor spaces and to provide indirect natural lighting. ‘*Salsabeels*’ are also used to moderate hot temperatures.

8. The second floor consists of a staircase leading up from the small inner courtyard to a passage with two doors, each opening unto a small room, and the roof where the ‘*malqafs*’ serving the two halls are located. The ‘*malqafs*’ are ventilation traps that capture the cool breeze and direct it into the halls.

9. Façade features (figure 12): The house has two façades. The main façade, facing southwest, overlooks the Al Azhari Alley and has two rows (a lower and an upper row) of windows separated by a wood ‘*mashrabiyya*’. On the west end of the façade, several stone steps lead up to the main entrance, surmounted by a wooden cantilever, that supports the upper ceiling of the ‘*maq’ad*’. There is also a simple side entrance leading to the building’s annexes. The second façade faces northwest. This small, less important façade adjoins the southeast corner of Al-Azhar Mosque and has no ornamental or architectural features.

10. Openings: The windows overlooking the inner courtyard have ‘*mashrabiyya*’ covers and are surmounted by ‘*kamareyas*’, which serve to minimize the intense sunlight and increase ventilation (Abdel Reda). Upper openings are used in many parts of the house to allow hot air to escape and to let in the cool breeze, and to provide natural lighting to the deepest possible recesses of indoor spaces (Abdel Reda).

11. Construction materials used: Stone was used to build the ground floors and brick for the upper floors, and most construction materials are derived from the local environment.

5.2 Assessment of the GPRS Criteria

In the following, each criterion is assessed and given points (see table 1).

The first standard (Site Sustainability) was applied through:

1. The building design pattern was determined according to an inwards-oriented view that is dependant on the role of the inner courtyard

2. The suitable orientation of openings (the ‘*maq’ad*’ faces north, for instance)

3. Minimization of, and protection against, the sun’s rays and controlling areas exposed to the sun by limiting the number of openings facing south and placing them at elevated levels, in addition to the overhangs above ‘*mashrabiyyas*’

4. The use of locally available natural construction materials, such as wood and stone

5. Orientation of buildings to the northwest (direction facing the wind)

No plants or site planning elements were used for shading purposes.
70 % or 140 out of 200 was given to this criterion.

The second standard (Energy Conservation) was applied through:

1. Limitation of ‘heat islands’ through use of the inner courtyard to regulate temperatures and to provide protection against external elements

2. Creation of a constant airflow between the shaded courtyard and the uncovered courtyard

3. The use of ‘*malqafs*’ to capture the breeze and to conserve energy consumed by heat repelling equipment

4. The use of construction materials with low thermal conductivity properties, derived from the local environment (brick and stone)

5. Limiting the number of openings in south-facing façades, and placing them at a high level

6. Increasing the shade ratio in the courtyard, which helps to lower temperatures

7. The use of ‘*shoukhshekhas*’, ‘*malqafs*’ and ‘*mashrabiyyas*’ to ventilate the halls and to create a constant current of air

8. Using water in ‘*sansabeels*’ to reduce humidity levels and to lower temperatures

9. Raising the level of ‘*maq’ad*’ floors and orienting them northward to face the direction from which the wind blows, although ventilation is less effective in the absence of a ‘*takhtaboosh*’

10. Insulating indoor spaces and using other spaces (such as ‘*iwans*’) to provide protection from external elements

11. Designing a ventilation and cooling system based on the different pressure zones in the small shaded courtyard and the larger uncovered courtyard, and using ‘*shoukhshekhas*’ to expel the hot air that rises upwards and ‘*malqafs*’ to capture cool breezes to replace it, in addition to the cool air stored in the courtyard during the night

12. Using natural energy sources facilitates building operation and control. Thermal comfort, ventilation and natural lighting all depend on natural energy sources, and it is easy to control the use made of the natural construction materials of which the house is built

13. Controlling the horizontal arrangement of rooms and the distance between them and the sources of heat and noise (both the small and large halls are located at a distance from the main sources of noise)

14. Integrating technical and economic functional design elements by adopting environmental house designs (using natural energy sources, low-cost environmental solutions and locally available natural construction materials)

15. Minimizing annual operation and maintenance costs by using local materials, such as stone, and by depending on natural energy sources for ventilation, lighting and thermal comfort

16. The house-cooling task was divided among several systems (‘*maqafs*’, ‘*shoukhshekhas*’, inner courtyards and (‘*mashrabiyyas*’), in addition to water vapor cooling (‘*sansabeels*’) and using stone to reduce thermal conductivity.

17. Various environmental solutions were adopted to deal with climatic conditions (inner courtyards, ‘*malqafs*’, and the use of natural, non-polluting construction materials with low thermal conductivity, such as stone).

18. Increasing the speed of airflow by incorporating levels of varying height and ‘*malqafs*’ to distribute airflow inside buildings

Energy conservation is dependant on natural and renewable energy sources, the use of natural materials and resources, and the adoption of natural lighting and ventilation systems to provide thermal comfort, all without negatively affecting the environment.

70 % or 228 out of 325 was given to this criterion.

<u>The third standard (Water, Efficient Use and Conservation) was applied through:</u>

Sanitary fixtures were used in the house. The bath is composed of three rooms and water is heated prior to being used. As mentioned earlier, a vaulted ceiling with light holes covers it. No water recycling solutions were used.

50 % or 45 out of 90 was given to this criterion.

<u>The fourth standard (Resources and Construction Materials) was applied through:</u>

1. The use of efficient materials; natural construction materials with low thermal conductivity (stone) were used to build the ground floor and to combat water and humidity brick, an environmentally friendly material, was used for the upper floors,

2. The use of erosion resistant materials that require minimal maintenance (stone, wood) and that are easy to control and operate

3. Efficient energy use through the use of locally available natural building materials

4. Life cycle pricing of materials in the process of materials selection (the use of locally available materials reduces transport, operation and maintenance costs)

5. Use of ‘*mashrabiyyas*’ in suitable sizes and shapes for lighting and ventilation

70 % or 46 out of 65 was given to this criterion.

The fifth standard (Indoor Environment Quality) was applied through:

1. Ventilation quality was realized by the use of natural lighting and by exploiting the different air pressure zones created in the shaded courtyard and the uncovered courtyard to control airflow, as well as the use of ventilation features (‘*malqafs*’, ‘*shoukhshekhas*’, ‘*mashrabiyyas*’ and upper openings).

2. Regulation of air humidity levels through vapor from ‘*sansabeels*’

3. Ensuring appropriate ventilation of indoor spaces by orienting these spaces in suitable directions and by using the inner courtyard as the principal source of indoor space ventilation, as well as the use of ‘*malqafs*’ and ‘*shoukhshekhas*’.

4. Reducing indoor temperatures to realize thermal comfort, using construction materials with low thermal conductivity and utilizing the inner courtyard to regulate indoor temperatures

5. Cooling the house during the hottest hours by means of the high ratio of shade in the larger courtyard, through the natural ventilation provided by ‘*malqafs*’, ‘*shoukhshekhas*’ and ‘*mashrabiyyas*’, in addition to using stone (a material with low thermal conductivity) to minimize the passage of external heat into the house interior

6. The use of ‘*malqafs*’: orienting their openings northwards and covering them with ‘*mashrabiyyas*’; quality of incoming air was ensured by the shape and details of ‘*mashrabiyya*’ openings

7. The quality indoor lighting: using the courtyard to distribute lighting among indoor units, using architectural features such as ‘*kamareyas*’, ‘*mashrabiyyas*’ and light wells to keep out direct sunshine and let in light, as well as using the difference in height between ‘*durqa’as*’ and ‘*iwans*’, and the upper openings, for lighting purposes

8. Noise level control: avoiding the negative effects of noise by arranging the placement of indoor spaces (large and small halls) away from the street, by adopting an inward-oriented design and by using thick stone walls to reduce noise transmission levels

9. Use of environmentally friendly stone tile and marble flooring and environmentally friendly natural construction materials

10. Furniture is made of environmentally friendly wood and stone and renewable natural energy sources are used.

11. Consideration of social dimension: ensuring privacy through the use of ‘bent’ or ‘broken’ entrances, by separating reception and private units, through the use of ‘*mashrabiyyas*’ and an inward-oriented building design, as well as by the limited number of openings on external facades and their elevated placement

12. Allowing for the visual dimension: natural lighting, controlling the degree of sunlight penetration through ‘*mashrabiyyas*’, and using the courtyard to provide lighting to indoor units without exposing them to direct sunlight

13. Consideration of sound studies of the surrounding environment: the halls are placed at a distance from the street, the use of ‘bent’ or ‘broken’ entrances as transitional spaces between the outside and the inside and the use of stone for construction to minimize noise levels

14. Allowing for the climatic dimension and climate control through adoption of an inward-oriented building design, the use of natural ventilation and lighting, realizing thermal comfort through the use of environmentally friendly features and solutions (‘*malqafs*’, ‘*shoukhshekhas*’, ‘*mashrabiyyas*’ and courtyard), by using natural and locally available construction materials, ‘*sansabeels*’ to increase humidity levels, in addition to the orientation of spaces (north-facing ‘*maq’ad*’, for instance)

80 % or 120 out of 150 was given to this criterion.

<u>The sixth standard Innovation (Creativity, Renovation and Flexibility of Development and Maintenance Operations) was applied through:</u>

1. The processes of design, implementation and operation realizes functional, social, economic and environmental dimensions

2. Project management applies economic and environmentally friendly methods: use of natural and renewable energy sources and locally available construction material and implementation of climatic solutions suitable to the local climate.

40 % or 36 out of 90 was given to this criterion.

<u>The seventh standard (Pollution Control and Waste Recycling) was applied in the house through:</u>

1. The use of natural construction materials that do not adversely affect the environment (stone, brick, wood)

2. The use of ‘*kamareyas*’ to let in light and afford protection against external elements

3. The use of an inward-oriented building design to provide protection against external pollution, noise and heat

50 % or 70 out of 140 was given to this criterion.

In the *Zeinab Khatoun* House, the use of Islamic architecture elements and features led to an average application rate of Green Pyramid Standards equals to 65%. The house may therefore be considered a historical building with green architecture attributes.

Conclusion

This paper aimed at introducing the green architecture assessment system and criteria in Egypt as well as exploring some elements and features of traditional Islamic architecture while assessing the application of the green architecture principles on a traditional Cairene house. After exploring the global principles of green architecture and discussing some internationally known green architecture assessment system, the paper introduced and discussed the green architecture assessment system in Egypt which is the Green Pyramid Rating System (GPRS). At the end of the paper, a detailed description of a well-known traditional residence, *Zeinab Khatoun* House, is provided and the GPRS was used to assess them in order to investigate whether the green architecture principles were applied or not. In the *Zeinab Khatoun* House, the use of Islamic architecture elements and features led to an average application rate of Green Pyramid Standards equals to 65%. The house may therefore be considered a historical building with green architecture attributes.

References

Abdel Reda, Sh. (2011). *Tatbeeq ossos al3mara al khadra’a letarsheed estehlak al taqa lel mabani al sakaneya*. Master’s Dissertation, Faculty of Engineering, Cairo University, Cairo.

Aga Khan Trust for Culture Image Library. [Online] Available: www. archnet.org
BREEAM official website. Available: http://www.breeam.org/

Egyptian Green Building Council Database. [Online] Available: http://www.egypt-gbc.gov.eg

El Essawy, M. A. 2007. *The Economics of Environmental Architecture*. PhD. Dissertation, Faculty of Engineering, Cairo University, Cairo.

Fathy, H. (1986). *Vernacular Architecture: Principles and Examples with Reference to Hot Arid Climates*. Chicago: the University of Chicago Press.

Garcin, J. C., Maury, B., Revault, J., and Zakarya, M. (1982). Palais et Maisons du Caire, vol. 1, Epoque Mamelouke (XIII e–XVIe siècles). Paris: Institut français d'archéologie orientale du Caire.

Green Building Initiative official website. Available: http://www.thegbi.org/green-globes/

Hossam El Din, M. 2005. *Derassa ta7leeleya makan lelthawabet wa almotaghayerat fe al 3emara al phar3ouneya wa al 3emara al islameya be misr*. PhD Dissertation, Faculty of Engineering, Ain Shams University, Cairo.

Ibrahim, Abdelbaki M. (ed.) (1999). *Al 3emara al khadra'a bayn al mafhoom wa al tatbeeq*: Green Architecture Competition. *3alam al bena'a* Magazine, (214).

Institute for Building Environment and Energy Conservation official website. Available: http://www.ibec.or.jp/CASBEE/english/

International Initiative for a Sustainable Built Environment IISBE official website. Available: http://www.iisbe.org/iisbe/gbc2k5/gbc2k5-start.htm

Mahrous, H. (2010). *Nozom al taqyeem al akhdar ka madkhal le ta7seen al'ada'a al bee'ee be masr*. Master's Dissertation, Faculty of Engineering, Cairo University, Cairo.

Mohamed, A. (2003). *Atlas al 3emara al islameya wa al qebteya bel qahera*, Vol. 10. Cairo: Madbouly Library.

Mostafa, Kh. (2010). *Al3mara al khadra'a wa al tasmeem bel taqa al hayaweya totabaq 3alla nemouzad wekalat kharoob wa villa 21 be Al Maadi*. Master's Dissertation, Faculty of Engineering, Cairo University, Cairo.

Reffat, R.M. (2010). *Shaping the future of property development: The green architecture approach*. Paper presented at the 1st Built Environment Development Symposium: Real Estate and Housing Sustainability, King Fahd University of Petroleum and Minerals, Saudi Arabia.

Revault, J. (1988). L'Architecture domestique au Caire a l'époque Ottomane. In: Groupe de recherches et d'études sur le Proche-Orient (Eds.), *L'habitat traditionnel dans les pays musulmans autour de la méditerranée* (Vol. 1, pp. 43-60). Cairo: Institut Francais d'Archeologie Orientale.

The Housing and Building National Research Center and The Egyptian Green Building Council (2011). *The Green Pyramid Rating System (GPRS)*. The Arab Republic of Egypt Ministry of Housing, Utilities and Urban Development. [Online] Available: http://www.hbrc.edu.eg/files/GPRS-%20for%20Public%20Review_June%202011.pdf

US Green Building Council official website. Available: http://www.usgbc.org/leed

Waziri, Y. (2007). *Environmentally-Friendly Architectural Design: Towards Green Architecture*. Cairo: Madbouly Library.

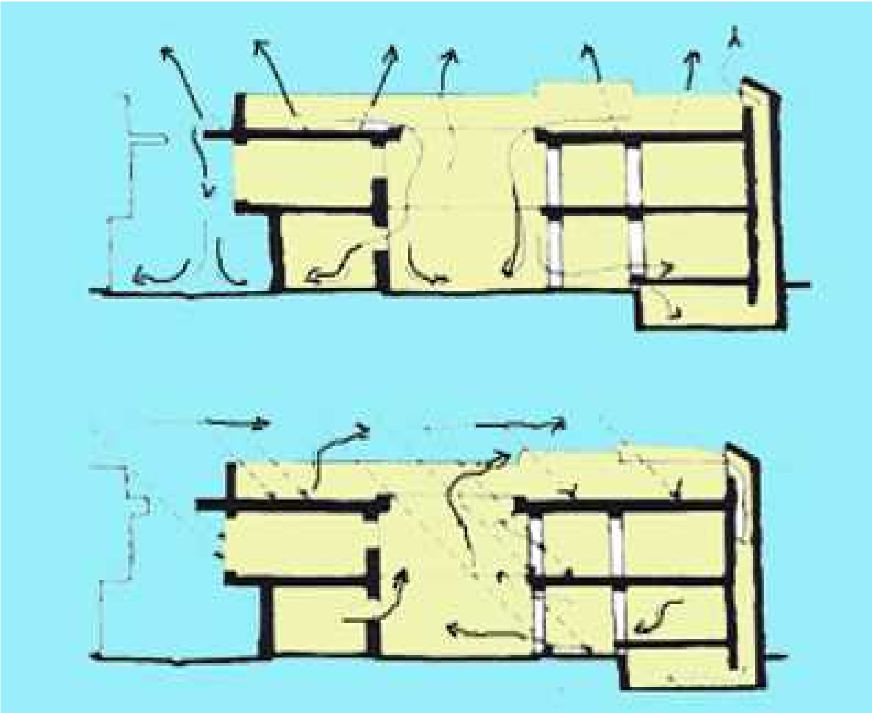

Figure 1: Traditional Home in Hot Climates. Source: www.arabegyfriends.com

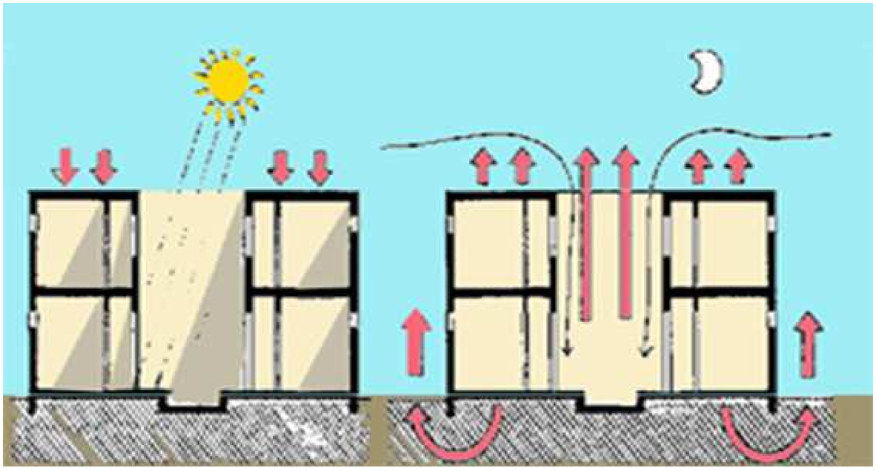

Figure 2: The Inner Courtyard as a Temperature Regulator. Source: www.greenstone.org

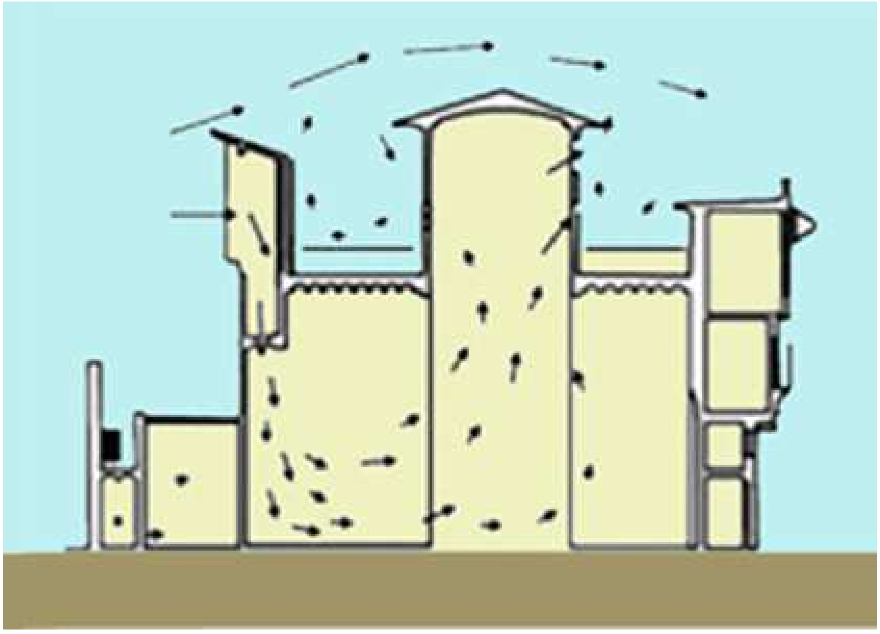

Figure 3: '*Malqaf*' (Ventilation Trap) in Traditional Architecture. Source: www.al-jordan.com

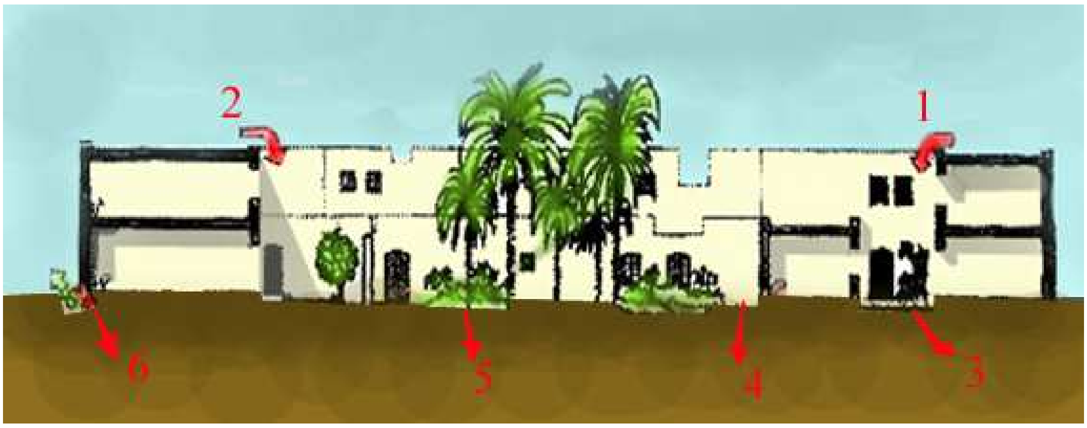

Figure 4: Cross Section Illustrating Methods of Using Rainwater and Wastewater.
Source: Waziri 2007
1. Rainwater
2. Rainwater on rooftops is directed towards inner courtyards
3. Inner courtyards are 400 cm below buildings' ground floor level
4. Sedimentation tanks in public gardens to hold non-polluted wastewater
5. Public gardens are 400 cm below buildings' ground floor level and 600 cm below street level
6. Flood water from inner roads is directed to public gardens

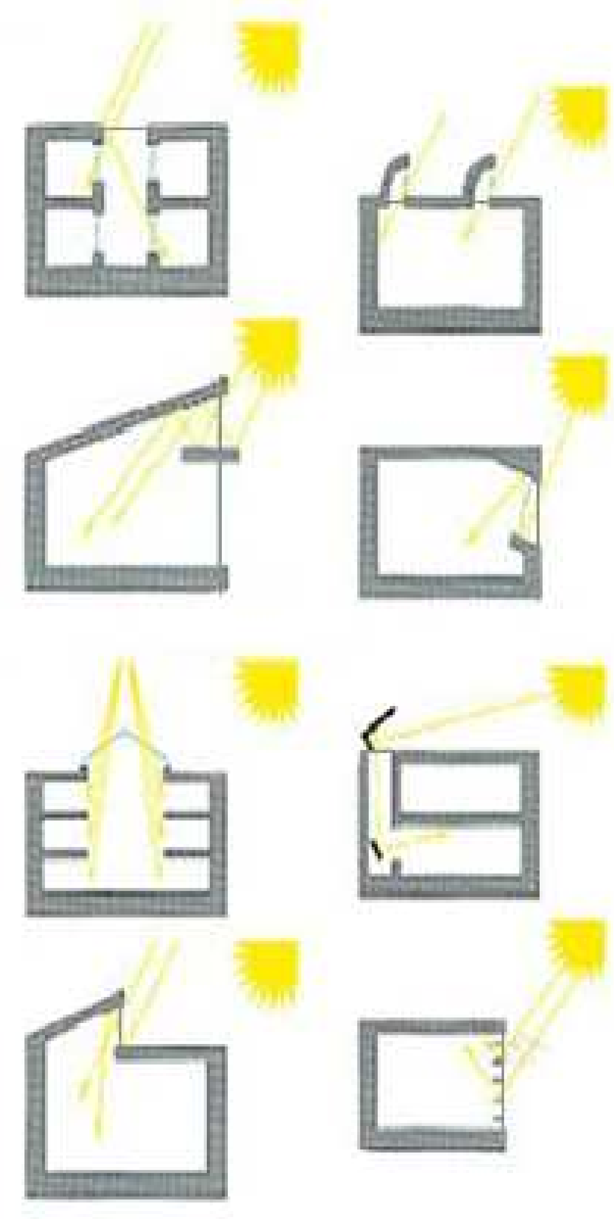

Figure 5: Methods for Using Natural Light
Source: http://ar.wikipedia.org/wiki

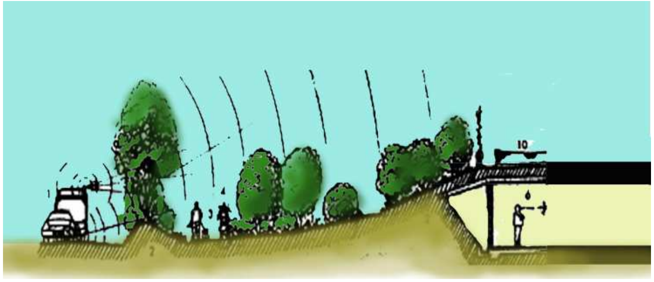

Figure 6: Trees and Vegetation in Front of a Building Reduce Noise Levels. Source: Waziri 2007

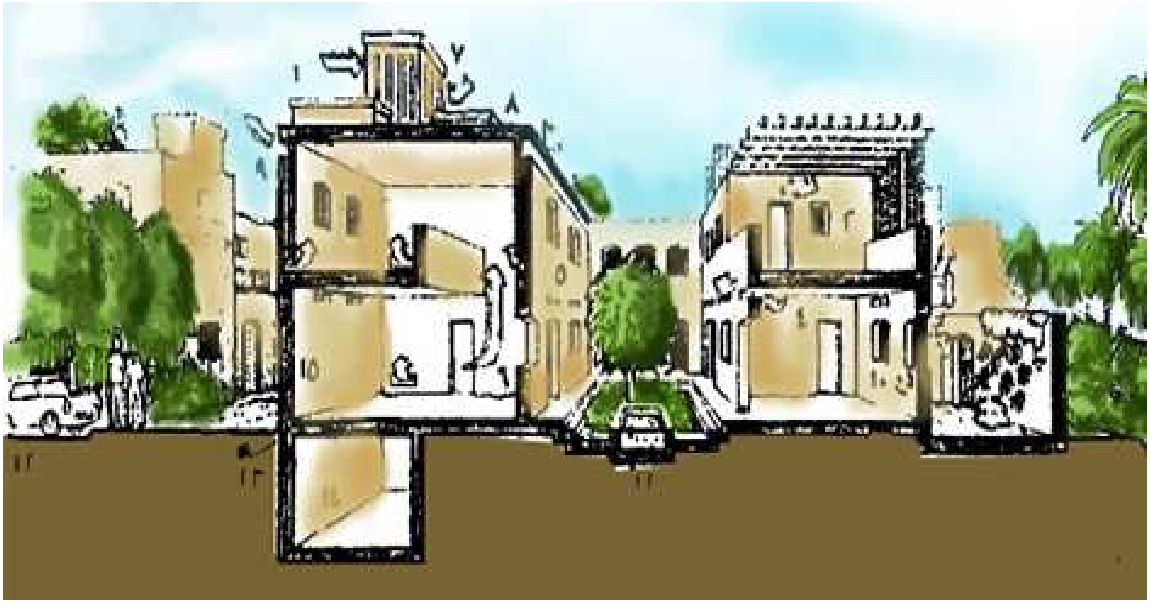

Figure 7: Imaginary Cross Section Illustrating Comprehensive Design and Solutions that can be Applied to 'Green Buildings'. Source: Waziri 2007

1. Solar tank heater system provides hot water
2. Open terraces for hot evenings
3. Narrow, shaded pedestrian paths
4. High openings (below roof level) and thick tiles keep rooftops cool
5. Windows overlooking shaded courtyards minimize hot temperatures and glaring light
6. High ceilings allow air movement
7. Ventilation traps to catch air drafts
8. Water surfaces to cool air entering the ventilation traps
9. In humid climates, air may be made to pass through conduits, installed in the walls, that contain moisture absorption substances
10. *Mashrabiyyas* and lattice work regulate lighting and provide privacy
11. Water and vegetation in private yards and public gardens help to cool the air and purge it of dust
12. To minimize noise and because it interferes with pedestrian traffic, motorized traffic is forbidden in the residential area
13. Waste water canalization is directed to water collection tanks used to irrigate gardens
14. Underground floors benefit from regular temperatures
15. Thick outer walls with a small number of narrow openings reduce heat absorption

Figure 8: Ensuring Protection Inside Buildings.
Source: El Essawy (2007)

Figure 9: Leading International Assessment Tools Today
Source: Egyptian Green Building Council website: www.egypt-gbc.gov.eg

Figure 10: Rating Levels in the Green Building Rating System in Egypt
Source: Source: Egyptian Green Building Council website: www.egypt-gbc.gov.eg

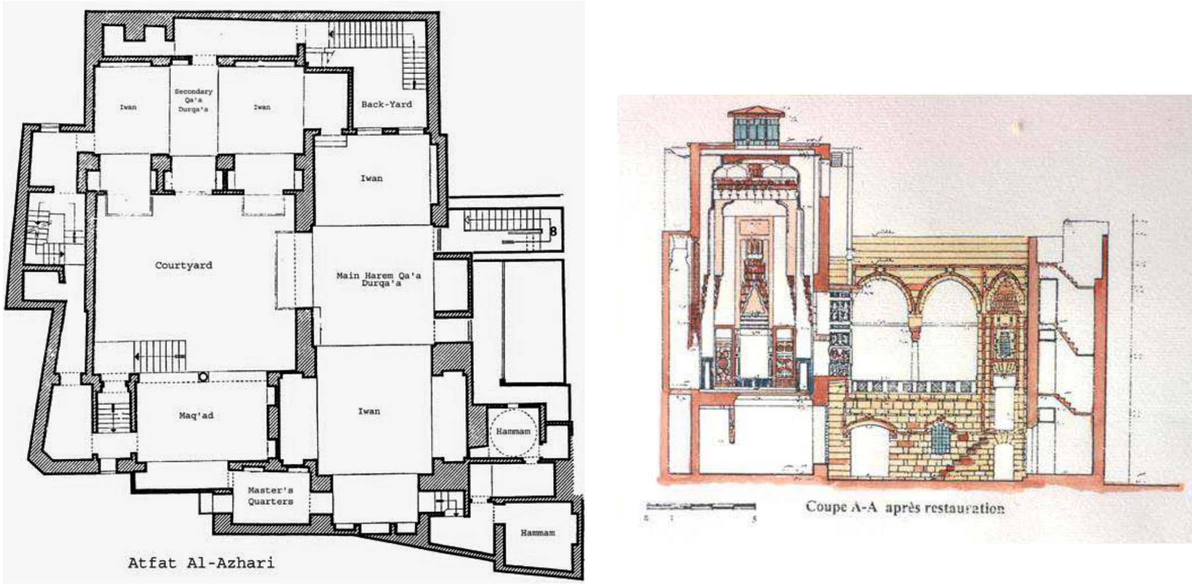

Figure 11: ***Zeinab Khatoun*** **House**. Left, first floor plan. Sourse: Garcin 1982. Right, Cross-section passing through the *qa'a* (reception hall) and *maq'ad*. Source: Aga Khan Trust for Culture, www. archnet.org

Figure 12: Entrance Façade of ***Zeinab Khatoun*** **House**. Left, general view, source: Aga Khan Trust for Culture, www. archnet.org. Middle, Entrance, source: survey by Abdel Gelil Mohamed, Nermine. Right, *mashrabiyya* overlooking the entrance, source: survey by Abdel Gelil Mohamed, Nermine.

Figure 13: Facades of the Inner Courtyard of *Zeinab Khatoun* House. Source: survey by Abdel Gelil Mohamed, Nermine.

Figure 14: Reception Hall "*Qa'a*" of *Zeinab Khatoun* House. Source: survey by Abdel Gelil Mohamed, Nermine.

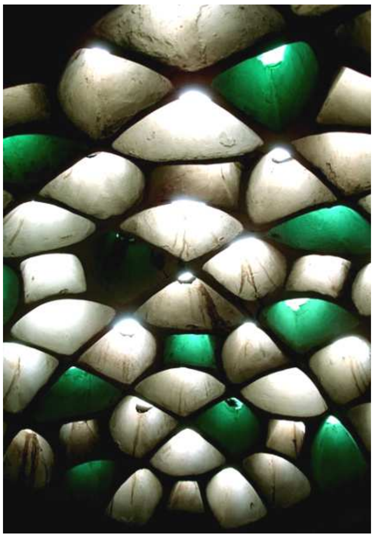

Figure 15: Vaulted Ceiling of the Bathroom of *Zeinab Khatoun* House. Source: Aga Khan Trust for Culture, www. archnet.org

Table 1: Assessment of the Green Pyramid Rating System (GPRS) Criteria in the *Zeinab Khatoun* House

Green Pyramid Criteria	Applied	Points
Sustainable Sites Development 200 points	70%	140
Energy Efficiency and Environment 325 points	70%	228
Water Saving 90 points	50%	45
Materials Selection and Construction System 65 points	70%	46
Indoor environmental quality 150 points	80%	120
Innovation and Design Process 90 points	40%	36
Recycling of Solid Waste 140 ponts	50%	70
Total out of 1060	**64.5%**	**684**