Recently, world has become more conscious about the environment, changes occurring in climate and in earth in general. It started to pay more attention to the impact of the technological and industrial revolution on the ecology and human health, which resulted in directing all the new researches towards renewable energies and recycling materials. In brief, it directed architects to start using Eco-friendly building materials, construction systems, natural ventilation and lighting …etc. This book is concerned with the existing residential buildings which have the most environmental problems in Egypt. Therefore, it aims at providing the architectural design elements to turn the existing residential buildings into ecological buildings that are one of the ways to preserve the earth for next generations.

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Abdel-Aziz was born at Alexandria, Egypt in Dec. 1969, graduated at Architectural Department, Faculty of Engineering, Alexandria University in June 1992. M.Sc. of Architectural Engineering & Environmental Design at AAST, Alexandria in 2011. Studied PHD at Alexandria University at present. Worked as Project Manager at Architectural Consulting Firm.

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An Ecological Residential Buildings Management

An Existing Egyptian House Case Study

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List of Abbreviations

A	Initial cost
a	Area of exposed building roof in m^2
BCC	The batteries charge controller
CDD	Cooling degree day for a base of 25C CDD = $\sum_m \sum_h$ (Tao-25), Tao: outdoor air temperature, m: month, h: hours
d	The market discount rate
DOD	The allowable depth of discharge for the batteries
ΔE	Energy savings in watt
E_L	The average daily load energy for a house (kWh/day)
EGP	Egyptian pounds
F	The future amount of money
g	9.81 m/s^2
G.S.	The governmental subsidization
H	Average solar energy input /day (kWh/m^2/day)
H_O	Occupancy period where AC function
h	Total head (m)
i	The annual inflation rate
i’	The annual interest rate
MOTE	Million Oil Tons Equivalent
n	Number of years
N_C	Number of continuous cloudy days
P e	Electrical power (W)
PBP	Payback Period
PSI	Peak solar intensity at the earth surface (1000 W/m^2)
PV	Photovoltaic panel
P W	Present worth of the total expenses

Q	Water discharge (m^3/h)
TCF	Temperature correction factor
P	Water density (kg/m^3)
φ	Latitude angle
η_b	Battery efficiency
η_{inv}	Inverter efficiency
η_m	Motor efficiency
η_p	Pump efficiency
η_{pv}	Photovoltaic module efficiency
η_{out}	The battery efficiency × Inverter efficiency = $\eta_b \times \eta_{inv}$
RH	Relative Humidity
R si	Thermal resistance of inside surface
R so	Thermal resistance of outside surface
SGR	Shaded glass ratio
SHGC	Solar heat gain coefficient
U- Factor	Thermal Transmittance
Ub	Roof thermal transmittance before adding insulation
Up	Roof thermal transmittance after adding the insulation
USD($)	United states dollar
WWR	Window wall ratio

Chapter 1: Introduction

1-1 General Background

Ecology has become a wide-ranging term that can be applied to almost every facet of life on earth, from local to a global scale and over various times. Attention to living eco friendly requires us to actively be aware of the environmental, social and economic needs of our present generation. Ways of living more ecology can take many forms re-organizing living conditions (ecological cities), reappraising economic sectors (green buildings), and using science to develop new technologies (renewable energy) to adjustment in individual lifestyles that conserve natural resources (El-Ghonaimy, 2010).

Buildings are the single most damaging polluters on the planet. However, if buildings are not constructed thoughtfully, they will waste precious natural and financial resources, harm the environment, and endanger the health of those who use them. (LEED, 2009)

The concept of ecological building incorporates and integrates a variety of strategies during the design, construction and operation of building projects. The ecological building should be a comfortable, beloved and long lasting building. A large amount of energy and resources for the construction of new buildings can be saved if existing buildings are technically and functionally adaptable to change of needs through time. Air-conditioning systems represent the greatest source of climate change gases of any single technology (figure 1.1).

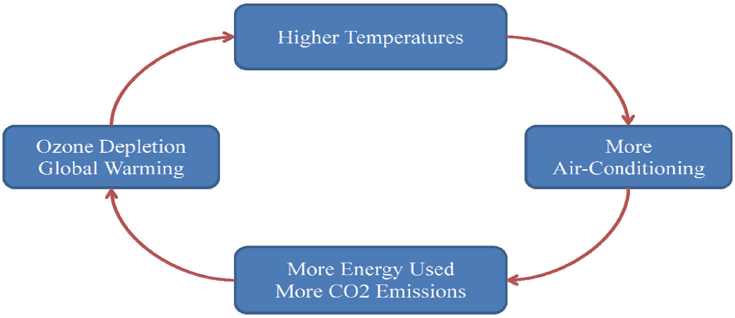


Figure (1.1) Climate change problem (Roaf, 2001)

The world needs a new profession of eco-tects, or archi-neers or engi-tects, who can design passive buildings that use minimal energy and what energy they do use comes from renewable sources if possible.(Roaf, 2001)

1-2 Problem Statement

Recently, most housing projects in Egypt were designed disregarding ecological principles. Therefore, incompatible designs usually create problems to the environment and human health. Egyptian buildings have traditionally been built as green and eco-friendly, until the western techniques in construction, ventilation and lighting … etc. were imported without adapting to our climate and available building materials. Other factors also affect the environment such as energy consumption, water management and materials selection. The cost of the ecological components is still too high to encourage its implementation on a large scale. Therefore, studies and methods to balance costs with ecological and environmental benefits are urgently needed.

1-3 Aims & Objectives

This research aims at introducing the specific architectural design elements of the existing residential buildings according to the surrounding environmental elements while balancing costs with ecological benefits.

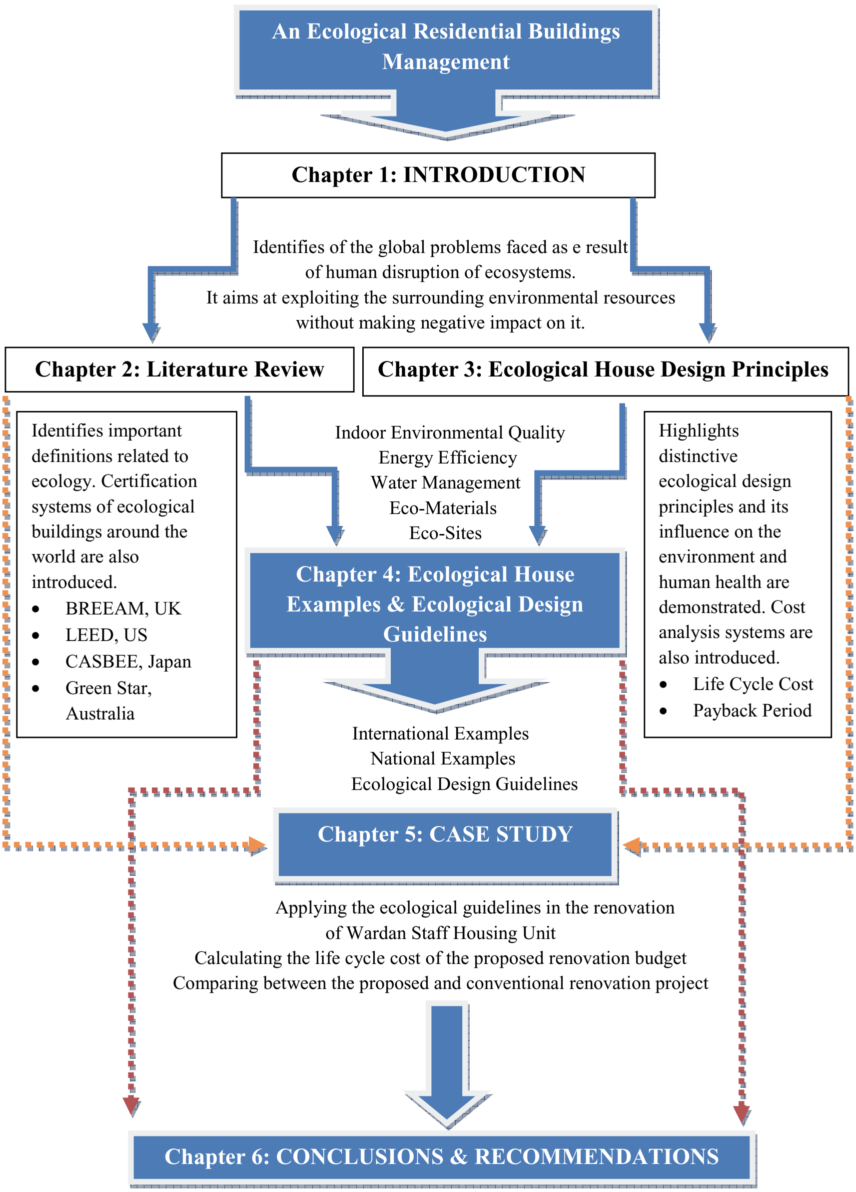
To achieve this aim the following research objectives were developed:
- Study the contemporary eco design models and guiding principles, as well as researching the challenges of eco-houses in Egypt.
- Present guidelines, which could help the architects, designers and the decision makers to turn their buildings towards the eco-friendly.
- Apply those guidelines to a family house in Egypt that depends mainly on solar energy.
- Encourage owners and operators of existing buildings to implement sustainable practices and reduce the environmental impacts of their buildings over their functional life cycles.

1-4 Research Methodology

The methodology of this thesis adapted the following methods to reach its aims and objectives:

- Define the eco system throughout the architectural vision.
- Review the different experience in environmental practices of buildings through the certification systems around the world and compare among them.
- Evaluate these different approaches in terms of their impact on indoor and outdoor environment according to the eco-house design principles and adapt these approaches with the local conditions.
- Study the economics of eco-houses.
- Present guidelines for designers, contractors and owners to turn their existing residential building to become more eco-friendly building.
- Apply these guidelines in a case study in Egypt & analyse the costs of the introduced ecological components using life cycle costing of the proposed alternatives, particularly, energy efficiency components.

1-5 Thesis Structure



Chapter 2: Literature Review

- **Eco-System Definition**

In the Longman dictionary, the ecosystem is defined as the way that plants, animals, and people affect their environment and how the environment can be kept healthy.

Ecology is defined as the study of the interactions of organisms and their physical and biological environment (Roaf, 2001).

In architecture field the eco-design is how to exploit the existing energy improving, the integration between environment and human being needs and how they should tie together to achieve the ideal performance for building, environment and human welfare.

2-1 Ecological Design Criteria

Eco- building design is a matter of involving design from the following (figure 2.1):

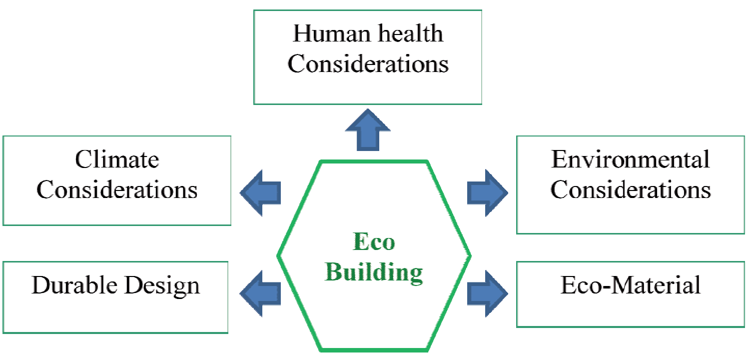


Figure (2.1) Showing the eco building considerations (made by the researcher)

- **Passive and Active Solar Design**

Submissions shall demonstrate as full a range as practical, of passive or active design principles, aimed at the designed structure providing a comfortable internal living environment without mechanical supplement.

- **Energy Efficiency**

Submissions shall demonstrate strategies, which have been adopted to reduce energy demand for air and water heating, cooling, and lighting. Consider primary energy sources and recycled sources.

- **Water Management**

Submissions shall demonstrate design strategies aimed at reducing potable water demand, as against a common methods. All wastewater generated by the home and its user should be considered.

- **Eco-Materials**

Submissions shall demonstrate application of low embodied energy materials, low on-going maintenance levels, and potentially recyclable selections.

- **Climate Appropriate**

Submissions shall demonstrate knowledge of climate appropriate material and design making sure that likely climate change hazards and daily conditions are accounted for to create a resource efficient building.

- **Aesthetics and Affordability**

Construction cost must be within the allowed budget to demonstrate a wide public affordability (budget)

- **Compliance**

All submitted designs must comply with Residential Planning Codes, local and statutory authority regulations, and provide for the constructed house plans to comply with the building code of the region.

2-1-1 Ecological House Definition

An ecological house modelled on the energy and material flows of natural ecosystems, and thus enhances rather than corrupts the environment.

An ecological house conserves resource (energy, water, food and materials). It also produces resources or gathers and stores more of them than it uses. In an ideal ecological house, there is no waste because the resource flow is circular (Roaf, 2001).

As shown in figure (2.2) the house is part of a complex interaction between people, building themselves, the climate and environment. Consideration of (daylight, thermal insulation and the use of machinery can be calculated but it should not be the only concern).

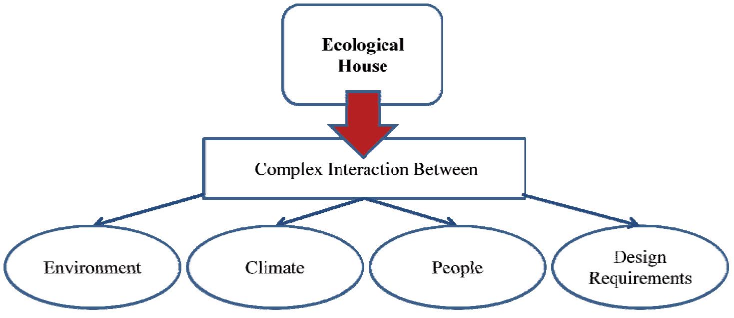


Figure (2.2) Defining the ecological house (made by the researcher)

People have three shelters to survive the first one is skin, the second is clothes and the third is the building. So buildings should protect from the outdoor elements such as climate condition. (Roaf, 2001)

2-1-1-1 The Form of Eco house adapting with climate

- **Heat Exchange**

The surface area of the building has to lose or gain heat from; the compact form of building reduces the efficiency of the building as a heat exchanger.
Before refrigerator invention, people used to store ice in icehouses and take it out in hot summer months to cool rooms. Those icehouses had a minimum surface area in order to keep ice so long.
The form of those houses is both long and thin and has a courtyard or light well, in the centre of the house.
In the very hot climate areas, the courtyards can be replaced with light wells to provide cross ventilation and light penetration as well, and should be shaded against sun overhead.

- **The Yurt Form**

The effectiveness of the insulated envelope depends on:
-The area of the envelope -
The heating requirements of the occupants in it -
The available internal heat sources

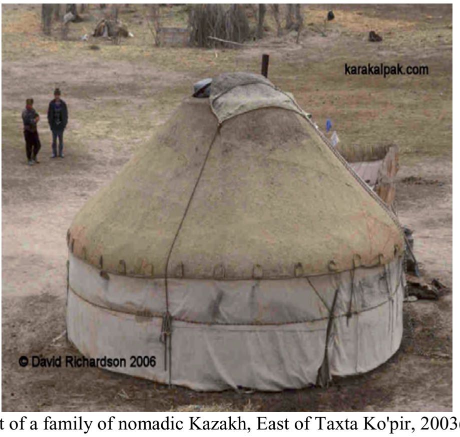


Figure (2.3) The yurt of a family of nomadic Kazakh, East of Taxta Ko'pir, 2003(Karakalpak, 2006)

- **The Nomadic Tent Form**

The nomadic tent can be packed up and moved to another place according to the climate changes.

Note: the steep conical roof Kazakh yurts were traditionally dome-shaped (figure 2.3).

People used to move towards the sun in autumn and away from it in summer.
Not only are they physically moved from place to another but also the actual form of the tent itself can be changed over the year.

Figure (2.4) Tents design in Iran (Raof, 2001)

- **The Igloo**

The concept of (hot air rises – cold air sinks) which provides shelter in the extreme climates. The occupants of the igloo live on a high shelf in order to take advantage of the warmest air in space. While the cold air sinks down in the entrance area (figures 2.5, 2.6).

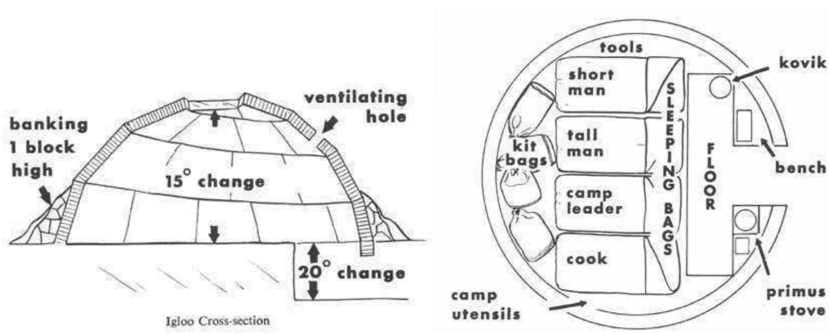


Figure (2.5) Igloo cross section & plan (Roaf, 2001)

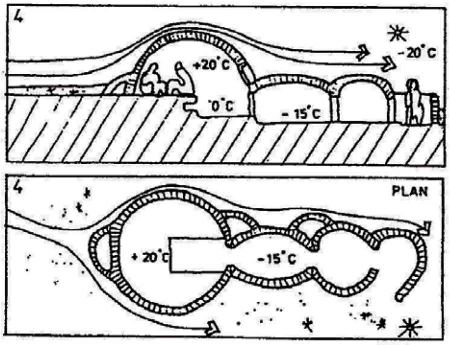


Figure (2.6) Showing the thermal stratification above the raised platform on which people live (Roaf, 2001)

- **The Building as a Roman Bath House**

In Roman bath houses the floors were warmed by an under-floor heating system called a hypocaust. There is a fire under the basin to heat water. This idea uses a convective heat transfer medium, air or water, to a radiator that is part of the building (figure 2.7).

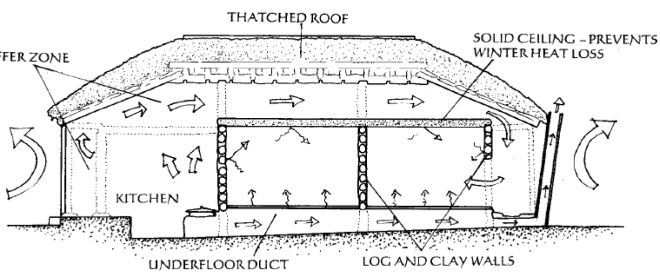


Figure (2.7) Eco house on the remote Korean island of Ullungdo with a horizontal hypocaust under the floor)of the central room (Roaf, 2001)

2- 2 International Assessment and Certification Systems for Ecological Building

There are several assessment methods to measure the ecology of the building's design (new and existing buildings) around the world (figure 2.8) such as:

- **BREEAM, UK**
- **LEED, US**
- **CASBEE, Japan**
- **GREEN STAR, Australia "NABERS"**

Figure (2.8) International Certification Systems for ecological buildings (EGBC, 2010)

Table (2.1): International ecological building rating systems

International System	Country	Introduced Date
BREEAM	UK	1990
LEED	USA	1998
CASBEE	Japan	2001
Green Star	Australia	2003

Source: EGBC, 2010

Table (2.2): National ecological building rating systems

National System	Country	National System	Country
GREEN GLOBES	Canada	HKBEEM	Hong Kong
GBAS	China	IGBC TOOLS	India
GREEN PYRAMID	Egypt	PROTOCOLLO ITACA	Italy
PROMIS E	Finland	LIDER A	Portugal
HQE	France	GREEN MARK	Singapore
DGNB	Germany	VERDE	Spain

Source: EGBC, 2010

2-2-1 BREEAM, UK , 1990

(The Building Research Establishment for Environmental Assessment Method)

2-2-1-1 What is BREEAM?

BREEAM is the leading and most widely used environmental assessment method for buildings. It sets the standard for best practice in sustainable design and has become the de facto measure used to describe a building's environmental performance.

BREEAM is used all around the world and can be used to assess a single development or a portfolio of developments both within and across national boundaries.

Specific versions of BREEAM are available for the UK, the Gulf and Europe.

2-2-1-2 The Scope of BREEAM

BREEAM covers a number of building types:

- Education, Offices, Healthcare, Courts, Prisons, Industrial
- The UK government's code for sustainable homes (CSH) replaced Eco-Homes for the assessment of new housing in and outside England in April 2007.

2-2-1-3 How BREEAM works?

BREEAM rewards performance above regulation, which delivers environmental, higher comfort or health benefits. BREEAM awards points into the sections below: Energy, Management, Health and Wellbeing, Transport, Water, Materials & Waste, Land Use, Pollution and Ecology.

Section scores are then added together to produce a single overall score. Once the overall score for the building is known this is translated into a rating on scale of:

Pass – Good – Very Good – Excellent – Outstanding. (BREEAM, 2008)

2-2-1-4 BREEAM Gulf

- BREEAM- Gulf, (Arab Emirates, Oman, Kuwait, Qatar)
- Types of buildings which can be assessed under the BREEAM Gulf Scheme: Whole new building, Major refurbishments of existing buildings, New build extensions to existing buildings, A combination of new build and existing building refurbishment New build or refurbishments which are part of a larger mixed use development and Existing building fit out. (BREEAM, 2008)

Table (2.3): Comparison between BREEAM UK weightings versus BREEAM Gulf weightings

BREEAM Section	UK, 2008 Weightings%	Gulf Weighting %
Management	12	8
Health & Wellbeing	15	15
Energy	19	14

Transport	8	5
Water	6	30
Materials	12.5	9
Waste	7.5	7
Land Use & Ecology	10	5
Pollution	10	7
Total	100	100

Source: BREEAM UK & Gulf, 2008

2-2-2 LEED, US, 1998

(Leadership of Energy and Environmental Design)

2-2-2-1 What is LEED?

LEED is a US standard and an internationally recognized green building certification system. Developed by the US Green Building Council (USGBC), LEED provides building owners and operators a concise framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions and measured 14000 projects in 50 US States and 30 countries...(LEED, 2006)

2-2-2-2 LEED Environmental Categories

Sustainable Sites, Water efficiency, Energy & Atmosphere, Materials & Resources
Indoor Environmental, and Innovation in Operations
The measurement system is designed for rating and certifying new and existing commercial, institutional, and residential buildings.

2-2-2-3 LEED for Existing Buildings Operations and Maintenance, 2009

The intent is to promote high-performance, healthful, durable, affordable, and environmentally sound practices in existing buildings.

- **LEED 2009 Minimum Program Requirements for Existing Buildings (O&M)**
  - Must Comply with Environmental Law
  - Must be a Complete, Permanent Building or Space
  - Must Use a Reasonable Site Boundary

Table (2.4): LEED 2009 minimum program requirements for existing buildings

LEED 2009 Minimum Program	**Requirements**
Minimum Floor Area	93m2
Minimum Occupancy Rate	12 continuous months
Building energy and water usage data	A period of at least 5 years
Minimum Building Area to Site Area Ratio	No less than 2% of the gross land area

Source: LEED, 2009

2-2-2-4 LEED for Homes 2009

LEED for Homes is an initiative designed to promote the transformation of the mainstream homebuilding industry toward more sustainable practices. LEED for Homes is a collaborative initiative that actively works all sectors of the homebuilding industry.

LEED for Homes Rating System is a part of the comprehensive suite of LEED assessment tools to promote sustainable design, construction, and operations practices in buildings nationwide. (LEED for Homes, 2009)

- **LEED for Homes Score Systems**

Four performance tiers indicate the level of performance:

Certified, Silver, Gold, and Platinum

- **LEED Home Cost**

Table (2.5): Comparison between LEED home and Code home cost

Comparison Criteria	Code Home	LEED Home	Difference ($ Month)	Savings ($ Day)
Sticker Price	$ 300,000	$ 308,500	-	-
Mortgage Payment	$ 1,890	$ 1,945	+ $ 55	+ $ 1.80
Energy Bill	$ 150	$ 105	- $ 45	- $ 1.50
Water Bill	$ 30	$ 20	- $ 10	- $ 0.30
Net Cost of Ownership	$ 2,070	$ 2,070	$ 0	$ 0

Source: LEED for Homes, 2009

2-2-3 CASBEE, Japan, 2001

(The Comprehensive Assessment System for Building Environmental Efficiency)

In Japan, a joint industrial / government / academic project was initiated with the support of the Housing Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT), In April 2001, which led to the establishment of a new organization, the Japan green building council (JAGBC)/ Japan sustainable building consortium which developed the (CASBEE, 2010).

2-2-3-1 CASBEE Tools

Since JPGBC/JSBC started the development of CASBEE in 2001, they have compiled the following tools:

- New Construction, Existing Construction, and Renovation

- Heat Island, Urban Development, and Urban Area & Buildings

- Home (Detached House).

2-2-3-2 CASBEE Categories
CASBEE covers the following four assessment fields:
Energy Efficiency, Resource Efficiency, Local Environment, Indoor Environment.
These four fields are largely the same as the target fields for the existing assessment tools described above in Japan and abroad, but they do not necessarily represent the same concepts, so it is difficult to deal with them on the same basis. (CASBEE, 2010)

2-2-3-3 CASBEE Rating System
Poor (C), Fairly Poor (B-), Good (B+), Very Good (A), Excellent (S)

2-2-4 Green Stars, Australia (NABERS), 2003
(The National Australian Built Environmental Rating System)

The Green Building Council of Australia (GBCA) is committed to providing world-class rating tools to measure the environmental performance of buildings across a range of building types. GBCA has created a suite of Green Star

2-2-4-1 Green Stars Categories
Management, Indoor Environment Quality, Energy, Transport, Water, Materials, Land Use & Ecology, and Emissions & Innovation

2-2-4-2 Green Stars Tools
Office, Office Interiors, Office Existing Building, Shopping Centre Design, Healthcare Education, Multi Unit Residential and Mixed Use

2-2-4-3 Green Stars Rating System
- Four Star "Best Practice" 45-59
- Five Star "Australian Excellence" 60-74
- Six Star "World Leader" 75+ (Green Star, 2009)

2-2-5 GPRS, Egypt, 2009
(Green Pyramid Rating System)

2-2-5-1 Establishment of Egyptian Green Building Council
In January 2009, a major step was taken by establishing the Egyptian green building council (EGBC). Membership in the EGBC consists of both national and international personalities including government ministers from cabinet level agencies, officers from respected LEED, prominent executives, seasoned labour leaders, and major contractors. (EGBC, 2010)

2-2-5-2 Egyptian Green Building Objectives
One of the objectives for establishing this council is to provide a mechanism to encourage building investors to adopt BEECs as well as other sections of existing codes that satisfy both energy efficiency and environmental conservation. By focusing on new construction, the EGBC could use its advantage as a professional organization to educate and convince engineers, builders, contractors and owners about the benefits of green construction to the individual, to the community, to the nation and most significantly to the bottom line. (EGBC, 2010)

2-2-5-3 EGBC Rating System

As an immediate action to activate the role of this council was the approval of developing, a national Green Building Rating System called the Green Pyramid Rating System (GPRS). The Green Pyramid Rating System, which is expected to be completed and take place by the end of the 2011. Recognizing the unique ecological, industrial and social challenges of the region, the rating system will help to define what constitutes an "Egyptian Green Building". To accomplish that goal, the rating system will build upon the Egyptian BEECs and integrate proven methodologies and techniques used in the international and Middle East programs. (EGBC, 2010) Egyptian rating system as the following:

Silver Pyramid – Golden Pyramid – Green Pyramid

2-2-5-4 EGBC Categories

Sustainable Development, Water Saving, Energy Efficiency, Materials Selection and Indoor Environmental Quality.

2-3 Comparison between International & National Ecological Building Rating Systems

Table (2.6): Comparison between international & national ecological building rating systems

Scheme	**International**			**National**	
	BREEAM UK	**LEED US**	**CASBEE**	**NABERS**	**GPRS**
Country	**United Kingdom**	**United States of America**	**Japan**	**Australia**	**Egypt**
Definition	The Building Research Establishment Environmental Assessment Method	leadership in Energy and Environmental Design	Comprehensive Assessment System for Building Environmental Efficiency	The National Australian Built Environment Rating System	Green Pyramid Rating System
Introduced Date	1990	1998	2001	2003	2009
Updated	2008	2009	2007	-	-
Developed By	Building Research Establishment, UK (BRE, UK)	US, Green Building Council (USGBC)	Japan Green Building Council (JAGBC)	Green Building Council of Australia (GBCA)	Egyptian Green Building Council (EGBC)

Scope	Offices Retail Industrial Education Eco homes Healthcare Multi Residential Courts Prisons	New constructions Existing buildings Commercial Interiors Schools Retail Healthcare Homes	New construction Existing construction Urban Area & Buildings Heat Island Homes	Office Interiors, Office Existing Building, Shopping Centre Design, Healthcare Education, Multi Unit Residential and Mixed Use	Residential Offices Sustainable Cities
Category	Management Health & wellbeing Energy Transports Water Materials Waste Land use & Ecology Pollution	Sustainable sites Energy & Atmosphere Water management Materials& Resources Indoor air Quality Innovation in Operation	Energy efficiency Resource efficiency Local environment Indoor environment	Management Indoor Environment Quality Energy Transport Water Materials Land Use & Ecology Emissions & Innovation	Sustainable Development Water Saving Energy Efficiency Materials selection Indoor Environmental Quality
Score **30-45%** **45-60%** **60-75%** **+75%** **+80%**	- Pass - Good - Very Good - Excellent - Outstanding	- Certified - Silver - Gold - Platinum	- Poor - Fairly Poor - Good - Very Good - Excellent	- Four Star - Five Star - Six Star	- Silver - Golden - Green Pyramid

Source: Made by the researcher

According to those comparisons, the international & national ecological building assessment schemes are participated in the following categories:

Indoor Environmental Quality, Energy Efficiency, Water Management, Materials & Waste, and Ecological Sites

2-3-1 Comparison between (BREEAM verses LEED)

The competition between the two schemes BREEAM and LEED has promoted innovation, both in the schemes and in delivered buildings.

Table (2.7): Comparison between BREEAM versus LEED

Scheme	BREEAM, UK	LEED, US
Strengths	- Allows comparison and benchmarking of different buildings - Independently audited - Can assess any building with the Bespoke version - Quantitative thresholds - Pedestrian and cyclist safety	- Strong marketing gets the message through - Lots of information is available. - No need for an assessor and training - Percentage thresholds - LEED office is on-line - Occupant comfort, internal pollution - Water and acoustics
Weaknesses	- Very exact requirements - Complex weightings system - Market profile - Cost of compliance - Responsibility is delayed (App. 3 weeks)	- Based on US systems - Intense documentation required - No independent audit of the assessment - Mixing building function and form is difficult to assess
Cost	Approx. 2-7% added of construction costs	Approx. 3-8% added of construction costs

Source: Inbuilt, 2010 (modified by the researcher)

2-3-2 LEED Eco House Existing Building Example

2-3-2-1 USEA Home, Westwego, U.S (LEED, 2009)

"Extreme Makeover" volunteers help family rebuild after Hurricane Katrina.

(From tragedy to platinum in 106 hours)

Lead Builder, Designer, Structural Engineer: Deltec Homes

Project Size: 3.860 square feet, with 6 bedrooms

Deltec Homes has been building energy-efficient homes across the United States for 40 years. It uses 100% renewable energy to produce the structural components of its homes and ships them directly to the job site, where they are assembled and finished by local labour.

Figure (2.9) USEA home, Westwego, U.S. (LEED, 2009)

- **Project Background**

For the USEA family in Westwego, disaster struck twice: First, Hurricane Katrina destroyed the home in August 2005, forcing the family to move to Brad's home. Then a tornado hit Brad's home, destroying the backyard trailer where Chris lived and damaging the main house. However, the tragedy became an opportunity when ABC's "Extreme Makeover: Home Edition" asked Deltec Homes to lead a team of builders to rebuild the Usea home. TV crews documented the process for audiences of the popular show, which dedicates each episode to rebuilding a house in less than seven days. The crew working on the Useas' home did it all in 106 hours stretched over five days, and in the end, they had Louisiana's first LEED-certified home, as well as the first green-certified "Extreme Makeover" home.

- **The Challenges of going green on TV**

One design challenge was lighting; The TV production crews needed a certain amount of light to be able to properly film the home, and even though the team worked to reach a compromise with the crew on the number of lights, the amount of light far exceeded what a typical home requires. The energy-efficiency solution was threefold: All lights were fluorescent, the home was built with a conditioned attic to prevent light heat loss, and additional switches were installed to give the homeowner greater control over down lighting.

Waste management was difficult because the show's staging area took over a couple of blocks in the neighbourhood, with hundreds of people needing to be bunked and fed onsite. The extra waste was offset by Deltec's prefabrication process, which produces 78% less waste than the construction of a conventional home's shell. The tight time schedule meant some low-flow water fixtures were not available in time for the production deadlines, and the show's producers did not want to sacrifice aesthetics for more readily available water-wise products from another manufacturer. Therefore, to make up for the opportunities lost by tough plumbing choices, the crew pushed harder in other areas, such as rainwater collection and irrigation.

- **Strategies and Results**

The home maintains a sustainable site by being completely devoid of conventional, water-guzzling turf. Some 85% of the lot is permeable, allowing rainwater to filter into the ground rather than polluting the aquifer as runoff. The home's Home Energy Rating System (HERS) rating predicts energy use reduction of 37% over International Energy Conservation Code. Cooling efficiency is 45% better than a conventional new home, a major coup in muggy Louisiana. Three separate water-heating systems serve three zones of the house to minimize travel distance for hot water. The house is stocked with energy star, rated windows and appliances.

- **LEED Assessment**

Extreme Makeover: Home Edition, Westwego Louisiana, and LEED for Homes.
Certification awarded April 23, 2008. (Platinum, 88.5 points)

Conclusion

- An ecological house conserves resource energy, water, food and materials.

-The ecological building management categories according to the different international certification systems:

1- Indoor Environmental Quality

2- Energy Efficiency

3- Water Management

4- Eco-Materials & Waste Management

5- Ecological Sites

- These categories can be used as a ecological design principles when turning the existing building into ecological ones and the next chapter will demonstrate these principles in details.

- When choosing an environmental rating for a building outside the UK or US, it is generally preferable to use the local system.

- BREEAM and LEED are a measurement tool and not a design tool.

- LEED has clearly encouraged innovation than BREEAM.

- In BREEAM's favour is a more of the social aspects of sustainability.

- BREEAM has licensed assessors who assess the evidence against the credit criteria and report it to the BRE.

- For LEED evidence is collated by the design team then submitted to the US-GBC, which does the assessment and issues the certificate

- BREEAM is funded from the license fees for the assessor organizations and the project license fees.

- LEED is funded in part by the license fees (which tend to be higher than BREEAM) but also through USGBC memberships.

- BREEAM and LEED are constrained, especially when calculating carbon and energy savings, by the methodologies, which they use to award credits.

- While BREEAM is generally more relevant in the UK as it uses UK policies, LEED can sit alongside as part of a global corporate policy.

- Both systems continue to learn from each other's mistakes and as time go on convergence on some matters is inevitable.

Chapter 3: Ecological House Design Principles

Eco-House Design Principles according to the previous chapter conclusion as the following:

1- **Indoor Environmental Quality**
2- **Energy Efficiency**
3- **Water Management**
4- **Eco Materials**
5- **Ecological Sites**

3-1 Indoor Environmental Quality

3-1-1 Providing Healthy Living Conditions

Increasing attention to indoor air quality has contributed to the awareness of poor health associated with a poor indoor environment.

Two types of illnesses related to poor indoor air quality have been identified:

- Sick building syndrome (SBS)

- Building related illness (BRI)

Definition of sick building syndrome:

It is a situation in which occupants of an experience acute health effects that seem to be linked to time spent in a building. Symptoms of SBS include irritation of sensory organs (eyes, nose, throat, ears and skin). (Zhang, 2005)

Definition of sick building related illness:

A specific**,** recognized disease entity caused by some known agents that can be identified clinically. Symptoms of BRI include hypersensitivity pneumonia, humidifier fever, ashram, and legion Ella. The distinction between SBS and BRI is whether the causes of the sickness can be diagnosed clinically. The Environmental Protection Agency (EPA) considers indoor air pollution among the top five environmental risks to public health, it has estimated that it costs $2 billion in medical costs and lost productivity every year. (Zhang, 2005)

The source of pollutants that affect indoor air quality (IAQ) can be classified into two main categories:

Indoor materials & **Inhabitant's activities and life styles**

3-1-1-1 Indoor Materials

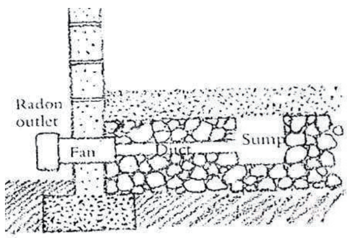
There are many different health risks in the home. Indoor materials are the significant factors that influence on human health. Many of them can be quite simply designed out, once they have been recognized as a problem.

Table (3.1): Indoor house materials and its influence on human health

Materials		Description
Asbestos		- Asbestos causes lung cancer and rare tumours Lungs, chest abdomen. - Avoid this material completely
Asbestos Forms	**White**	- In board or sheeting products, surface treatment or as thermal and acoustic insulation
	Brown	- In laminated boards and pipe lagging
	Blue	- In fire insulation on steel frames or thermal insulation to heating systems
Lead		- Lead is a poison. - Lead paint is most dangerous when it is broken and flaking - Lead can damage the brain and the nerve tissues. (Pearson, 1991, pp. 51) - Remove all lead pipes from the home.
Legionella		- Legionella is a bacterium found in all natural fresh water where it poses little threat to health. (Roaf, 2001, pp 136) -It grows into high concentrations and can be dangerous when inhaled in droplets of water from sprays, as found in showers, hot & cold taps and air-conditioning systems. - A type of pneumonia that typically causes death in one in ten of those who contract it - Legionella grows best in stagnant water at temperature between “20-50 C”

Materials		Description
To Avoid Legionella by:		- Thermostats in water tanks should be set to 55 C or be regularly flushed with water above this temperature(Roaf, 2001, pp 136)
Moulds		- For moulds to grow, it needs moisture, warm temperature, low air movement, and a food source. (Zhang, 2005, pp. 29) - Mould feeds on the organic materials of a building such as carpets, wood and wallpaper and eats into wallboard & brickwork
Moulds Kinds	**Moulds that cause illness**	- Moulds can be very toxic, leading to allergies; "sick building syndrome" and even death
	Moulds that cure illness	- Penicillin
To Avoid Moulds by:		- Eliminate cold bridges in the external and internal walls - Remove moisture from the home with good zoning of wet activities, range of good opening windows & vents, and repair any cracks in the structure - Have moisture-absorbing walls such as a plaster finish with a eco-paint finish (Roaf, 2001, pp. 137)
Paints		- Paints can be toxic - Paints can exacerbate humidity problems in a room - Traditional paints with a lime base allow the wall to breathe - Avoid any paints with chromium in them; it can cause dermatitis, ulceration and cancer. - Some of the new water based eco-paints

Materials	Description
	also perform very well(Roaf, 2001, pp. 139)
Plants	- Studies have found that plants can indeed not only reduce the CO_2 and the relative humidity of a room but also they can lower the temperature of the room. - It is rather nice to think of putting a living machine in the form of plants into buildings to clean up the internal air quality.
Plaster	- Sand and lime plaster may also be used, possibly with a final coat of gypsum. - Mud plaster is also excellent and can be made waterproof by mixing well-fired wood ash or rammed earth into the wet mix before kneading.
Polyvinyl Chloride (PVC)	- The main concern is for the householder exposed to high levels of newly installed PVC in an airtight home for a long period. - A number of toxic substances are also combined with the PVC in the manufacture stage. - Use timber windows if possible rather than PVC ones and avoid PVC furniture. (Roaf, 2001, pp. 141) - PVCs can cause birth defects, cancer, chronic bronchitis, and skin disease. (Pearson, 1991, pp. 49)
Radon **Radon Sources:** - Groundwater pumped into wells - Construction materials such as blocks that emit radon - Gas that emanates up from the soil and	- Radon is naturally occurring radioactive gas that is tasteless, odourless and colourless. - When inhaled, decay products rest in the respiratory tract, and present a risk of lung cancer.

Materials	Description
rocks into basements and lower floors. **To Avoid Radon by:**  Figure (3.1) Radon collects in an underground duct with the radon outlet fan (Pearson, 1991)	- The amount of radon emitted into a home depends on the rocks on which the home is built and how much soil or other material covers the radon-emitting rocks. - Sedimentary rocks, except for black shale and phosphate-rich rocks are generally low in the uranium that emits the radon, and metamorphosis rocks such as gneiss schist are richer in uranium than marble, slate or quartz. (Roaf, 2003) - In risk areas, radon concentrations can be reduced by placing a perforated, impermeable membrane between the concrete lower floor slab and the ground, or a well-ventilated crawl space beneath the floor. - Sealing all cracks and openings into the basement will prevent the entry of radon into the house and the use of exhaust ventilation can remove any that dose. Maximum permissible level (MPL) radon is 2 pci/litre or 75 BQ/m3. (Pearson, 1991) - As a means of prevention, the EPA and the office of the Surgeon General recommend that all homes below the third floor be tested for radon. - Because radon is invisible and odourless, a simple test is the only way to determine whether a home has high radon levels.
Volatile Organic Compounds (VOCs) and Organic Solvents	- VOCs are found in many everyday materials in the home, including carpets, under layers, adhesives, caulks, sealants, thermal insulation materials, paints, coatings, varnishes, viny1 flooring, plywood, wallpaper, bituminous emulsions and waterproof membranes.

Materials	Description
Wallpapers	- Choose wallpaper that is made of paper and not synthetic materials such as vinyl. Painting over it should be an eco-paint
Wood Preservatives	- Many different chemicals are used to protect wood from insect or fungal decay and many are potentially very harmful. - They should be handled with care and contact with skin should be avoided. - Any product for protecting buildings from woodworm should be applied only by an expert. Avoid their use in enclosed spaces and do not use rooms where a smell of the chemical product lingers. - Avoid storing these chemicals in the house. (Roaf, 2003, pp. 170-171)

Made by the researcher, 2011

3-1-1-2 Inhabitant's Activities and Lifestyles

Some of the indoor pollutants results from inhabitants activities and can be very harmful. Among these pollutants are the following:

- **Carbon Dioxide**

Carbon dioxide is not toxic except at high concentrations. It results from combustion of fuel. If CO2 concentration increases 1% increase in the depth of breathing is noticed, it reaches the double at concentration of 3% of CO2. At concentrations of 3-5%, increased respiratory effects become uncomfortable and severe headaches may develop.

A 30 minutes exposure to 5% CO2 is reported to produce signs of intoxication and of mental depression. A CO2 concentration of 0.5% is normally taken as the upper limit when designing the ventilation of occupied space. The Environmental Protection Agency (EPA) recommends a maximum level of 1000 ppm (1.8 gm/m3) for continuous CO2 exposure. Opening a window or door is the most effective way of purging the room of CO2 in a short time. (Mc Intyre, 1980)

- **Tobacco Smoke**

Major effects of passive smoking are odour and eye irritation. Suitable ventilation rate has to be applied to reduce smoking effect.

Ventilation rate in Britain is 7 litre/s per smoker while in U.S.A. it is 14 litre/s per smoker. (Mc Intyre, 1980, pp. 276)

- **Odours**

Odour intensity depended strongly on the amount of space/person as well as the ventilation rate. A rule of thumb sometimes used by engineers is that body odours become objectionable when expiration raises the CO_2 level above 0.15% for sedentary people, with a CO_2 output level of $5*(10)^{-3}$ litre/s per person, this would indicate a ventilation rate of about 3.5 litre/s per person.(Mc Intyre, 1980, pp. 275-276).

3-1-2 Thermal Comfort

Defining the thermal comfort according to ASHRAE 1989:
That condition of mind in which satisfaction is expressed with the thermal environment.
Maintenance of thermal comfort is a problem of heat balance between the body and its surroundings.
The body exchanges heat with its environment through four processes (figure 3.2):

- Conduction (contact)
- Conduction- convection (air movement)
- Evaporation- convection of skin moisture
- Radiation (solar and thermal) (Watson, 1983)

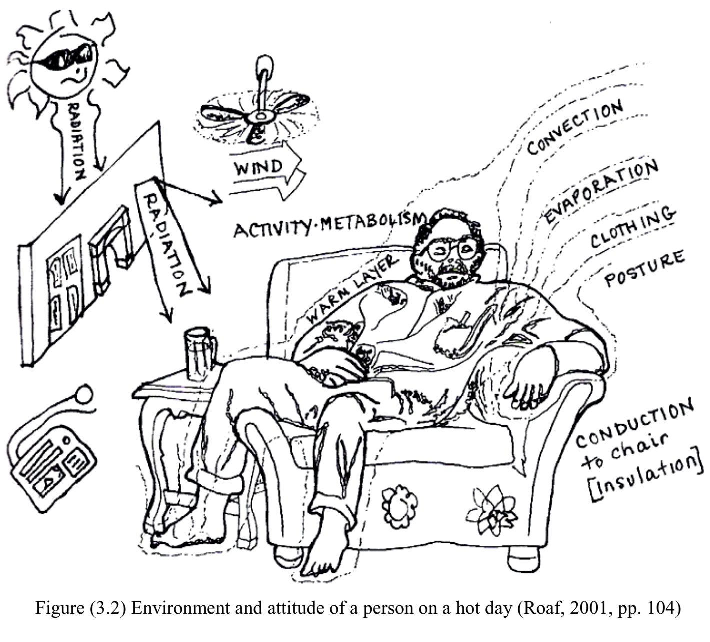


Figure (3.2) Environment and attitude of a person on a hot day (Roaf, 2001, pp. 104)

Table (3.2): Heat transferred methods

Heat Transferred by	Is Primarily dependent on
Conduction	Surface Temperature
Convection	Air temperature, air motion, humidity
Radiation	Surface temperature
Evaporation	Humidity, air motion, air temperature

Source: Watson, 1983

From this comparison, it is evident that humidity is of relatively low importance in cold conditions, where heat loss by conduction, convection, and radiation is dominant. However, humidity is of primary importance in hot condition, dominated by evaporative heat loss. This is further evident in comfort studies, which show that skin temperature is an important factor in cold conditions while skin wittedness (percent covered by water) is of most important in hot conditions. Designers of building can aim for specific comfort goals, especially where the measurable environmental factors are concerned. (Stein, Reynolds and Mc Guinness, 1986, pp. 34-36)

Table (3.3): Identification of hypothetical and practicable strategies of climate control

<table>
<tr><th colspan="3"></th><th>Conduction</th><th>Convection</th><th>Radiation</th><th>Evaporation</th></tr>
<tr><td rowspan="6">Control Strategies</td><td rowspan="2">Winter</td><td>Promote Gain</td><td>-</td><td>-</td><td>-</td><td>Promote Solar Gain</td></tr>
<tr><td>Resist Loss</td><td>Minimize Conductive Heat Flow</td><td>Minimize External Air Flow & Infiltration</td><td>-</td><td>-</td></tr>
<tr><td rowspan="2">Summer</td><td>Resist Gain</td><td>Minimize Conductive Heat Flow</td><td>Minimize Infiltration</td><td>Minimize Solar Gain</td><td>-</td></tr>
<tr><td>Promote Loss</td><td>Promote Earth Cooling</td><td>Promote Ventilation</td><td>Promote Radiant Cooling</td><td>Promote Evaporative Cooling</td></tr>
<tr><td colspan="2">Heat Sources</td><td>-</td><td>Atmosphere</td><td>Sun</td><td>-</td></tr>
<tr><td colspan="2">Heat Skins</td><td>Earth</td><td>Atmosphere</td><td>Sky</td><td>Atmosphere</td></tr>
</table>

Source: Watson and Kenneth Labs,1983

- **Bioclimatic Chart**

The bioclimatic chart was developed by Milne and Givoni (1979) to relate climate and design strategies. The average monthly data can be plotted here thus revealing some appropriate strategies.

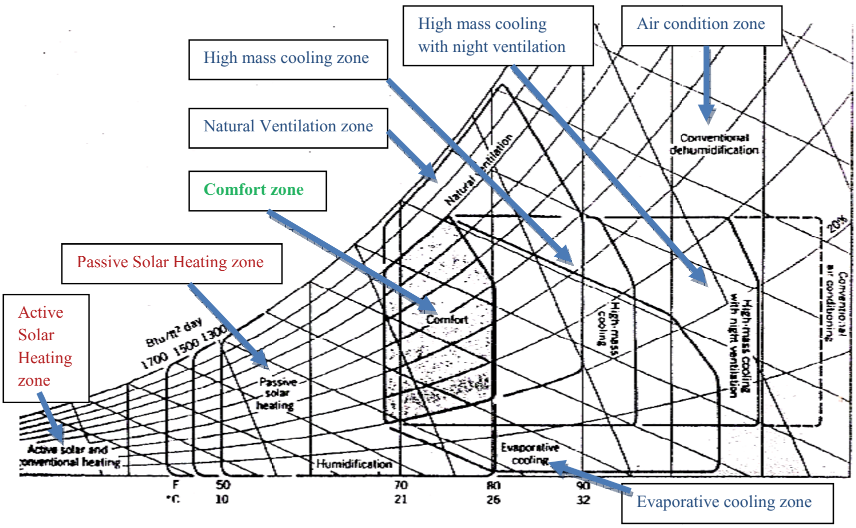


Figure (3.3) The bioclimatic chart, Givoni chart, (Stein, 1986)

Buildings usually contain sources of heat. The more heat occurs within the building, the more an artificially warmer climate is created. Thus, after plotting outdoor climate data on this chart, consider how shifting these plots would affect our choice of design strategy

The more solar gains allowed inside, electric lights, business machines, etc.

The more the plots move horizontally to the right.

The more: people, cooking, bathing, other heat-plus-moisture sources

The more the plots move up and to the right, following the rh curves. The design strategies shown in figure (3.3) include the following:

3-1-2-1 Cooling Strategies & Natural Ventilation

- **High Mass Cooling**

This is an especially useful strategy in warm, dry climates, where the extremes of hot days are tempered by the still-cool thermal mass of the building. Cool nights slowly drain away the heat that such mass accumulates during the day. The thermal mass can be on floors, walls or roofs; the roof has the advantage of radiating to the cold night sky, but should like all other thermal mass in these conditions, be protected from the sun by day. As in all these cooling strategies, day lighting is usually designed to occur without direct sun, since solar space heating is unneeded in these conditions.

- **High Mass Cooling with Night Ventilation**

This hot dry climate design strategy must use the air at comfortable night-time temperatures to flush away the heat stored in daytime. The building switches from a closed condition by day (to exclude sun and hot air) to an open one at night (to allow ventilation to cool the mass). Night-time outdoor temperatures should be cooler than the comfort zone, if this strategy is to be effective.

- **Natural Ventilation Cooling**

This is the most obvious strategy by the comfort charts present earlier, where higher air temperatures were offset by increased air motion. It is most appropriate in more humid, hot climates where temperatures are only slightly lower by night than by day. Buildings should be open to breezes while simultaneously closed to direct sun. They should be thermally lightweight as well, since night air is not cool enough to remove stored daytime heat.

- **Evaporative Cooling**

This design strategy relies on the principle that when moisture is to air, the air increases in relative humidity while decreasing in dry-bulb air temperature. In conditions that are more uncomfortably dry then uncomfortably hot, higher humidity is gladly exchanged for lower air temperature. However, large quantities of both water and outdoor air are needed; fan-driven evaporative coolers are the most common way to provide this kind of cooling.

- **Air Conditioning**

These are familiar air conditioning methods, which rely on machinery and can cool on demand. Buildings utilizing such equipment should be much closed to both wind and direct sun. Thus, conventional air conditioners can be used as backup to passive systems, which imply closed buildings, such as high mass with night ventilation. Where evaporative coolers are used, conventional air conditioners can also be used to back up their cooling. (Stein, 1986)

3-2 Energy Efficiency

Energy efficiency as well as healthy living conditions could only be achieved through the application of climatic design, which is concerned with three main parts:

- Renewable Energy Resources
- Shelter Design
-Building Envelope

3-2-1 Renewable Energy Resources

There are renewable energy resources as the following**:**

Solar energy - Wind energy - Biomass – Biogas – Nuclear energy

3-2-1-1 Solar Energy

Solar energy is the one of the most promising new and renewable energy sources in 21st century; it is expected to play a very important role in meeting energy demands in the near future. Since it is clean type of energy with a diversity of applications, decentralized nature and availability, solar energy will represent a suitable solution for energy requirements especially in rural areas. Solar energy will protect these areas from pollution and avoid large amounts of CO_2 emissions. (Wouters, 1997)

Photovoltaic solar panels are the common system to generate the energy power from the sun.

- **What is a Photovoltaic?**

Photovoltaic cells convert sunlight directly into electrical energy.
The electricity they produce is DC (direct current) and can either be used directly as DC power; converted to AC (alternating current) power; or stored for later use. The basic element of a photovoltaic system is the solar cell that is made of a semiconductor material, typically silicon. Because sunlight is universally available, photovoltaic devices have many additional benefits that make them not only usable, but of great value, to people around the world. They are the future and by 2020, when the conventional oil supplies begin to really dry up, they will be everywhere.
Photovoltaic panels have been commercially available since the mid-1970s and were initially used to power some early demonstration buildings, such as those that are still working at the Centre for Alternative Technology in Wales. However, the 1990s saw the first great boom in PV buildings around the world. Germany, USA, Britain and Japan already having over a Million Solar Roof Program in place (Roaf, 2001)

Figure (3.4) Photovoltaic Panels, Syria (Med-Enec, 2010)

- **PV System**

PV cells are typically grouped together in a module for ease of use. PV system consists of one or more PV modules, which convert sunlight directly into electricity, and a range of other system components that may include an AC/DC inverter, back-up source of energy, battery to store the electricity until it is needed, battery charger, control centre, mounting structures and miscellaneous wires and fuses.

- **PV in Buildings**

Even in cloudy, northern latitudes, PV panels can generate sufficient power to meet all, or part of, the electricity demand of a building. PV systems can provide electricity during conventionally produced electricity blackouts resulting from poor supply conditions or bad weather. There are already a range of uses for which a secure energy supply should be essential; these include, water pumping (see figures 3.4, 3.5), electric garage doors and gates, lift safety systems, smoke and fire alarms, emergency lighting and security systems, computer UPS systems and communications systems.

The Oxford Eco house, for example, incorporates 48 PV panels on the roof that generate enough energy to lower the household electricity bills by 70 per cent.

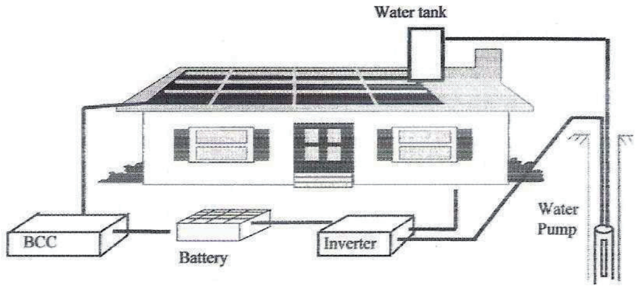


Figure (3.5) Schematic diagram for a photovoltaic-fired house in rural zones (Ahmed, 2002)

- **Environmental Benefits of PV Systems**

The electricity produced by every square meter of PV can effectively displace emissions of more than two tons of CO_2 to the atmosphere over its lifetime. (Roaf, 2001)

Table (3.4): Photovoltaic panels emissions

Energy & Emissions	PV (mono-crystalline silicon)	UK Electricity Generation mix	Total Avoided Emissions(25 year)
Energy (GWhth)	29	47	18
CO_2 (tones)	6	52	46
SO_2 (tones)	0.03	0.32	0.29
NO_x (tones)	0.02	0.16	0.14
Particles (tones)	0.002	0.02	0.02

Source: Roaf, 2001, pp. 168

- **Photovoltaic Cost**

Solar electric PV systems are now an economic and viable technology in many parts of the world. Prices are expected to fall significantly over the next decade as demand grows and the PV industry achieves economies of scale in production. In parts of Germany and the USA (Sacramento municipality), the cost of installing one watt of PV power into a home has already fallen to around £2.75 per watt, which is very low compared with current UK estimates of £9 per watt for an installed system. (Roaf, 2001)

To use PVs properly the building electricity loads should be as low as possible, and only then should the system be designed to meet part or all of those loads to give you a magic building that generates its own energy.

- **The main requirements for a PV system design**
  - Choose the PV system (see figures 3.6, 3.7)

- The site information (environmental data); where the data of solar intensity, ambient temperature, relative humidity and cloudiness must be available.
- The electrical load type, profile and requirements are very important for good design.

- **The PV Systems:**

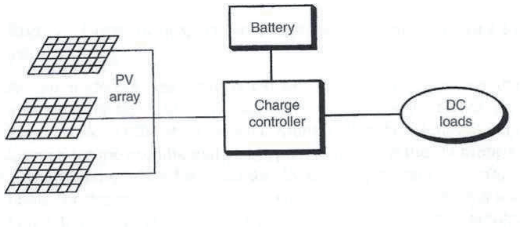


Figure (3.6) PV stand-alone system (Roaf, 2001)

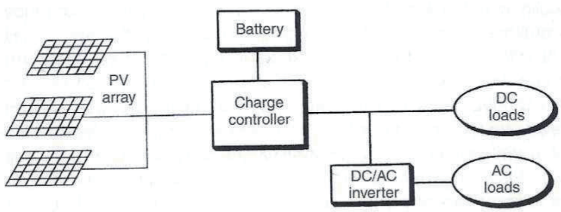


Figure (3.7) PV stand-alone DC/AC system (Roaf, 2001)

- **Photovoltaic Module Type:**

Table (3.5): Photovoltaic module types

Module type	**Appearance**	**Colour**	**Efficiencies %**	**Durability (years)**
Mono crystalline	Module composed of circular polygonal shapes	Blue black	10-16	25-30
Poly crystalline	Sparkling crystal chaotic surface	Blue black	8-12	20-25
Amorphous	Matt dull surface	Red, green, orange, blue black and yellow	4-8	15-20

Source: Sue Roaf, 2001, pp.179

3-2-1-2 Solar Hot Water Systems

Solar hot water systems gather energy from solar radiation and turn it into heat that is distributed in the form of hot air or water to where it is to be used or stored until needed. Active solar water consists of a solar collector, a hot water storage tank, and a pump. In addition, a heat exchanger and expansion tank are required in freezing winter climates and an electrical generation device is needed if regular AC grid-connected power is not available. Piping, insulation, valves and fittings are considered installation materials and are normally available at hardware stores and plumbing centres.

- **Solar Collector**

A solar collector consists of a translucent cover, an absorption plate and a heat transfer system, involving hot water pipes or hot air see figure (3.8).

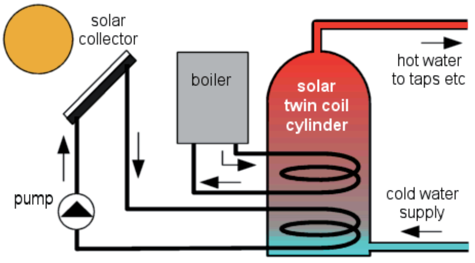


Figure (3.8) Solar hot water system (Norfolk, 2011)

- Copper water tubes and headers in the collector are necessary if any water solution is to be used as the heat transfer liquid. A liquid solar collector under no-flow or stagnation conditions can attain boiling temperatures. Plastics other than silicone are not suitable materials for liquid collectors.
- The absorber plate is made of copper, aluminium or steel and bonded to the waterways. The plate surface is approximately equal to the glazing surface and is painted with black paint or selective coating.

- **Hot Water Store**

Heat storage is a key feature of the solar hot water system. Without it, the hot water would be available only when the sun is actually shining. A storage tank allows the solar system to operate whenever energy is available and to supply the energy when it is needed. The storage tank can be sized either to store enough heat for 24 hours, so that the water heated during the day can be used in the evening, or as an inter seasonal store with the container of a much larger size. A larger container can be gradually heated up over the hot months and will retain that heat through the autumn and winter.

- **Cost**

An example from the UK, a total solar collector area of around 5 m^2 is recommended for a typical domestic water heating installation. A little maths shows us that it is possible to collect 1500 kWh of energy per year. If the original heating method was an electric heater, that would have cost around 120$. Since the 5 $m^2$of solar collector will cost around 1400$, the payback period would be around 11 years. Since the lifespan of solar collectors is around 20 years, one gets 9 years of free hot water. In terms of the modern economy 9 years free hot time, but we must remember that we do not know what the cost of the energy will be in 9 years' time, though it will not be lower than today, that is for sure.(Roaf, 2001)

- **Environmental Benefits of Solar Hot Water**

The domestic hot water systems are responsible for between 6 and 8 percent of the total CO_2 emissions in developed countries such as the UK. If every house had a solar water system that could produce over half of the entire annual hot water requirement using free clean solar electricity then we could save around 3 per cent of all emissions of greenhouse gases from the country simply by adopting a solar hot water policy. (BSICP, 1980)

Table (3.6): CO_2 emissions from a three-bedroom semi-detached house, UK, 1995

Items	Emissions (kg CO2/ year)
Space heating	1506
Hot water	864
Cooking	125
Pumps and fans	96
Lights and appliances	1650
Total	4241

Source: BSICP, 1980

3-2-2 Shelter Design

3-2-2-1 Integrated Cooling Systems

There are different cooling systems such as:

- **Courtyard Conventional House Type**

The courtyard acts as a light well as well as an airshaft bringing both daylight and ventilation to the rooms around it. TALIB 1984 has described how the courtyard functions in 3 phases (figure 3.9):

- During the first phase, the cool night air descends into the courtyard and fills the surrounding rooms. The courtyard loses heat rapidly by radiation to the clear night sky.
- During the second phase, at midday, the sun strikes the courtyard floor directly. Some of the cool air begins to rise and leaks out of the surrounding rooms.
- During the third phase, the courtyard floor and the inside of the house get warmer.

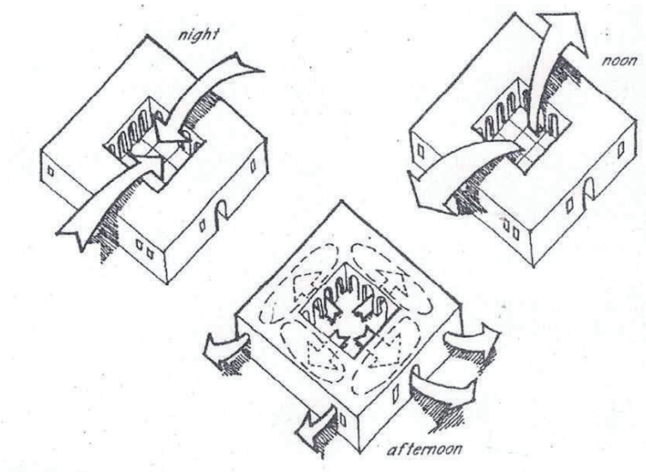


Figure (3.9) Diagrammatic explanation of the three thermal phases of a courtyard (Moore, 1993)

- **Wind roof catcher (the Malqaf)**

In hot arid zones, a difficulty is found in combining the three functions of the ordinary window: light, ventilation and view. If windows are used to provide for air movement indoors, they must be very small, which reduces room lighting. Increasing the size of the windows permits sufficient lighting and an outside view lets in hot air as well as strong annoying glare. Therefore, it is necessary to satisfy the three functions ascribed to the window separately.

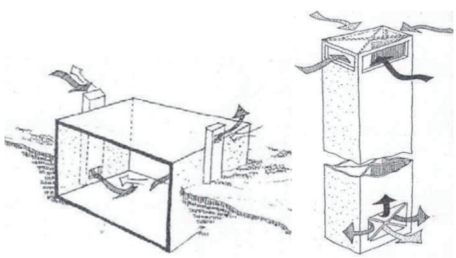


Figure (3.10) An air circulation system which will reverse its flow as prevailing winds shift (Golany, 1983)

To satisfy the need for ventilation alone, the malqaf or wind-catch was invented. This device is a shaft rising high above the building with an opening facing the prevailing wind. It traps the wind from high above the building where it is cooler and stronger, and channels it down into the interior of the building. The malqaf thus dispenses with the need for ordinary windows to ensure ventilation and air movement. The malqaf is also useful in reducing the sand and dust so prevalent in the winds of hot arid regions.

The wind captures above the building contains less solid material than the wind at lower heights, and much of the sand which dose enter is dumped at the bottom of the shaft (figure 3.10).

In Egypt, the malqaf is developed and has been a feature of vernacular architecture. An example of how the malqaf is used is shown in the Qa'a of Othman Katkhuda, in Cairo, which dates from the fourteen century A.D.(figure 3.11)

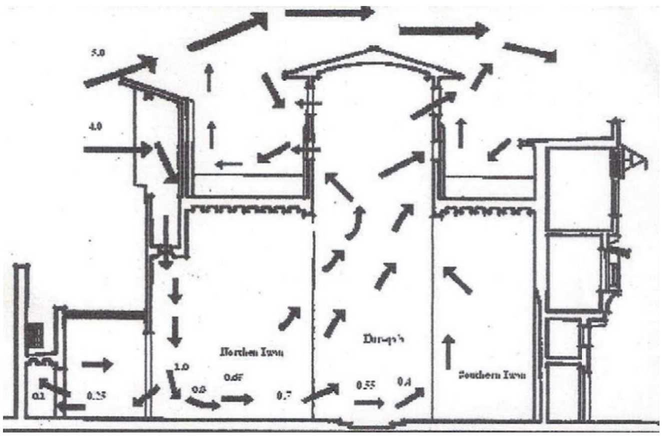


Figure (3.11) Section through the Qa'a of Othman Katkhuda, arrows indicate the direction of airflow, all wind and airspeed are given in meters per second. (Fathy, 1986)

3-2-2-2 Orientation

- Exposures 25 deg. E of S secure balanced orientation, but all exposures are good form S to 35 deg. E of S.
- For bilateral buildings with cross ventilation, 12 deg S of W axes are preferred.
- East & West walls should decrease and North & South walls should increase. (Olgay, 1963, pp. 167)

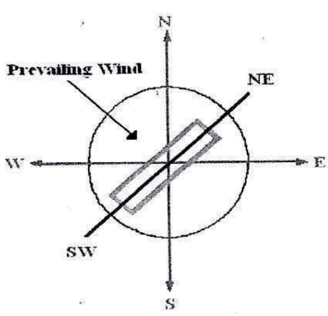


Figure (3.12) Optimum house orientation in Cairo region, Egypt (Azmy, 2007)

3-2-2-3 Colour

- White paint has reflection ratio on sun exposed surfaces.
- Dark absorptive colours are adaptable where reflections toward interior are expected.
- Deep-set surfaces can be dark coloured for winter radiation absorption.
- Bright colour contrasts are in agreement with the general character of the region. (Olgay, 1963, pp. 167)

3-2-2-4 Form & Volume

- High volume to surface ratio and dwelling with double-banked rooms are preferable.
- High ceilings are not significantly comfortable than rooms with ceiling height of 2.7m or even 2.5 m.
- More compact form with courtyard is required to minimize heat gain.
- Closer spacing between dwellings should be adopted.
- Medium rise apartment blocks are suitable meanwhile high-rise isolated apartment blocks are very unsuitable.

Table (3.7): The requirements for building form in relation to climate

Climate	Element and Requirement	Purpose
Hot Arid	Minimise west walls	To reduce heat gain
	Minimise surface area	To reduce heat gain and loss
	Maximise building depth	To increase thermal capacity
	Minimise window wall	To control ventilation heat gain, and light

Source: Evanes, 1980, pp. 74

3-2-3 Building Envelope

3-2-3-1 Roofs and Walls

Roofs and walls with high thermal capacity and adequate resistance will reduce this external diurnal range so that the temperature variation at the internal surface is only about 15 to 20% of the external air temperature range. A time lag should be eight hours up to 14 hours. A time lag of eight hours can be achieved more economically if a roof construction has an insulating layer on the outside of a heavy layer (Evanes,1980, pp. 88).

3-2-3-2 Thermal Insulation Materials

Thermal insulation materials can be classified as follows:

- Loose fill insulation materials
- Semi-rigid insulation materials
- Rigid insulation materials
- Foamed insulation materials
- Reflective insulation materials

But not all those thermal insulating materials are eco friendly and so therefore a rating has been developed to classify the thermal insulating materials in terms of ecological impact.

- Comparison between the thermal insulation materials (natural & synthetic)

Table (3.8): An evaluation of thermal insulation materials from ecological and cost impact perspectives

Insulating Materials	Insulation Value	Toxicity	Waste Disposal	Diffusivity	Hygroscopicity	Draught Proofing	Fire Resistance	Cost	Overall Score
Natural									
Straw & Clay	-1	0	0	+2	+2	+2	+2	+2	+9
Wood-wool	+1	0	+2	+2	+2	0	-1	+2	+8
Foamed lime	+1	0	0	+1	+1	+2	+2	-1	+6
Strawboard	+1	0	+2	+2	+2	+1	-1	-1	+6
Cellulose (recycled paper)	+2	-1	0	+2	+2	0	-1	+2	+6
Cork (baked)	+2	0	+2	+2	+2	+1	-1	-2	+6
Foam glass	+2	0	+1	0	0	+1	+2	-1	+5
Synthetic									
Mineral wool	+2	-2	-2	-2	-2	+1	0	+1	-4
Urea Formaldehyde	+2	-2	-2	-2	-2	0	-2	+1	-7
Polyurethane	+2	-2	-2	-2	-2	0	-2	-1	-9

+2 =Very advantageous use, +1 = Advantageous, 0 = Neutral, -1 = Disadvantageous and -2 = Very disadvantageous use. Source: Sydney, 1996, pp. 173

- **Roof Insulation:**
  - A maximum U value of 0.9 watt/m2 degree C is recommended for roofs.
  - A cheaper but less effective way of shading the roof is with reed matting or timber boards suspended above the roof leaving an air cavity
  - A relatively lower U value is recommended for East and West walls
  - Horizontal roofs receive less sunlight per sq. m (Sydney, 1996)
- **Wall Insulation:**
  - Use construction bricks with insulation materials to increase its thermal resistivity and decrease its thermal capacity especially in East-West walls.
  - Thermal insulation layer in walls should be placed in the direction of heat source.
  - Use several consecutive air voids in walls to decrease "U" value.
  - Reflective thermal insulation should be used on outer layer of the wall.

- Lightweight interior and exterior plaster of low thermal conductivity could be used for wall finishing.
- Eco-paints should be used as an aid to wall thermal insulation.

In general, required thermal resistance could be calculated using the coming equations for walls and roofs respectively according to Givoni:

$R = 0.05 (T\ max - 25) + 0.002 (a \times I\ max)$ for walls.

$R = 0.05 (T\ max - 25) + 0.003 (a \times I\ max)$ for roofs.

Where R: required thermal resistance, T: maximum temperatures in the area,
a: surface colour and I max: quantity of solar energy and differs according to direction

3-2-3-3 Openings

- Use low inlets and high outlets to produce a good pattern of air movement.
- A slot between wall and sunshade is required for airflow that is more direct
-When using wind pressure for cooling, a large inlet and a small outlet is recommended because it results in a lower maximum speed but a better distribution of air over the space double glass windows with low-solar gain are recommended (Olgay, 1963, pp.168)

3-2-3-4 Shading Devices

- Connect shading devices to the building only at necessary points, leaving an open air space in between.
- Horizontal shading devices are recommended for Southern orientation while vertical and egg-crate types work towards East and West orientation.

3-3 Eco Building Materials

The Environmental Impact of Building Materials

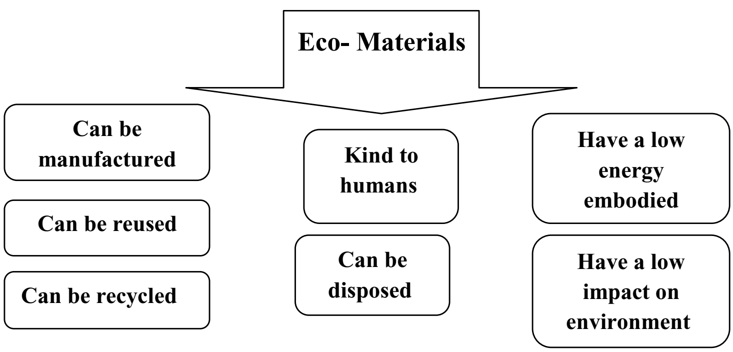


Figure (3.13) Eco-materials requirements

3-3-1 Low Embodied Energy Materials and Minimal Environmental Effect

3-3-1-1 Selecting Low Embodied Energy Materials

In order to select the lowest embodied energy materials, the basic rules for material selection are:

-Use materials that are as natural as possible

-Use materials that are local as possible

Embodied energy of materials are measured through the whole process starting from excavation to processing it from raw materials to finished products to transportation to construction to demolition and recycling of materials.
The embodied energy of the main materials used in construction as follows:

Table (3.9): The energy content of the building materials

Materials	Embodied Energy
Concrete	It has low energy content but reinforced concrete has greater energy content. (Anink, 1996)
Solid stone, manufactured and synthetic stone	The main environmental effect is the damage made to the countryside caused by quarries and related infrastructure and because of their large quantities, transport is an issue too (Anink, 1996). Use the thermal mass of stone to enhance passive solar strategies. Look for local sources and attempt to minimize transportation distances wherever possible (Wilhide, 2003)
Sand lime brick	The energy content of sand lime brick mainly comes from the burning of the lime and the high-pressure compression involved in forming bricks or blocks. Sand lime brick is unsuitable for reuse as reclaimed aggregate in concrete
Ceramics	The energy content of ceramics is a result of the high temperature required for firing the clay and adding the glaze
Loam	The energy content is low as the material is not chemically or thermally processed and provided that no cement is added, loam is well suited for reuse.
Aluminium	The energy content of aluminium comes from extraction and conversion of raw material, bauxite, into a semi-manufactured product. Aluminium is recyclable.
Steel	Compared to other metals the energy content per kg of steel is relatively low. Steel is suitable for reuse though this is less successful than with aluminium.
Zinc	Extraction of zinc involves emission of cadmium, which is

Materials	Embodied Energy
	damaging to the environment. Reduction of theses cadmium emissions can only be achieved practically by limiting the use of zinc.
Lead	Depletion of reserves is expected within decades. Its production causes pollution, but it is recyclable.
Copper	The use of copper in pipes causes pollution but it is recyclable.
Polyethylene PE, Polypropylene PP	Polyethylene PE, Polypropylene PP is recyclable
PVC (Polyvinylchloride)	PVC has low energy content, but its production process causes environmental problems and their extraction causes harmful emissions.
Bitumen	It can be easily reused, though in practice bitumen is not yet recycled because of pollution of the material.
Wood	selecting wood are: - Forestry management - The need for preservatives - Transport distance

Sources (Anink, 1996 and Wilhide, 2003)

The energy is being used in the following:

- The extraction from the earth of raw materials
- The processing of the raw material into finished products
- The transportation to the supplier
- The construction process
- Demolition and recycling of materials

According to this, attempts have been made to put numerical values to energy intensiveness, so that material can be ranked. (Brenda and Val, R., 1996, pp. 41)

3-3-2 Recyclable and Renewable Materials

The basic selection will be added to conclude with and recommend because the basic selection is a practical solution, having low environmental impact and being easy to implement, without giving rise to practical problems. The following selection is according to David Anink selections (Anink, 1996).

Table (3.10) Materials selection for eco house elements

Eco House Elements		Materials Selection
Floor Construction	**Ground Floor**	Hollow concrete elements but the large-scale availability of concrete elements with reclaimed aggregate
	Typical Floor	Concrete with reclaimed aggregate in broad slab. The availability of reclaimed aggregate concrete varies depending on the area
Internal Wall Construction		Sand-Lime-Brick and cellular concrete are preferable to concrete with reclaimed aggregate to reduce threats to the environment
External Wall Construction	• **External Wall Skin**	Brickwork is already used on a large scale and is included in the basic selection Rammed earth concrete is used in the low rise buildings, site soil should be tested before using
	• **Internal Wall Skin** •	Sand-Lime block is included in the basic selection: it is relatively cheap and is common in concrete construction methods. Wall panels made of prefabricated wooden wall filling elements are quite suitable in most cases; these are even less environmentally damaging.
	• **Wall Insulation**	Foam panels are included in the basic selection because of its suitability and current application.
Roof Construction	• **Flat roof construction**	Concrete with reclaimed aggregate is included in the basic selection
	• **Flat roof insulation**	Foam panels and foam are included in the basic selection
External window	• **External window frames**	Softwood treated with solid borate

frames and doors		implants
	• **External doors**	Plywood or softwood, possibly with a solid implant based on borate, is included in the basic selection
Internal window frames and doors	• **Internal window frames**	Softwood internal frames
	• **Internal doors**	Honeycomb door with hardboard skins.
External Wall Cladding		Fibre cement and synthetic resin bonded sheets and rammed earth plastering.
Glazing Type	• **Living areas**	Using LE-glazing
	• **Bedrooms**	Using double-glazing

Source: Anink, 1996 (modified by the researcher).

Rammed Earth:

- Rammed earth construction is the forceful tamping to compact a mixture of earth and cement into a formwork system to create a dense and structurally stable wall.
- The mix is 8 percent water, 3 percent cement, and 89 percent soil (sand, clay without organic materials such as peat or loam)
- Rammed earth walls are a good thermal mass, energy efficient, fire resistant, and environmentally friendly.
- Disadvantages include the risk of not ensuring the correct earth mix, and the labor and cost could be higher than other construction types.(Ballard, 2006)

3-4 Water Management

3-4-1 Water Supply

- **Rainfall**: It is insufficient to sustain planting.
- **Surface water:** It is the main traditional source of water; it is abstracted from rivers, or lakes.
- **Ground water:** It is abstracted from wells using simple suction pumps.
- **Gray water:** Which is reused water particularly treated sewage effluent (TSE).

3-4-2 Irrigation

- **Surface (flood irrigation):**

  It has the lowest water use efficiency because a substantial proportion of the applied water is lost in evaporation, this can cause problems of water logging and salinity build-up if sub soil drainage is poor.

- **Sub-surface irrigation:**
  Underground trickle is extremely efficient in terms of water use. The major drawback of sub-surface systems is that they cannot utilize saline water.
- **Sprinklers:**
  It is more efficient than surface systems. Although evaporation losses are still a major factor, percolation losses are considerably reduced.
- **Trickle irrigation:**
  It is extremely efficient in terms of water use. It has been estimated that a trickle system will use 66% of the amount of water that a sprinkler system will use and only 40% of the water required by a surface irrigation system.

  Trickle is the most suitable system for use with TSE. (Ali and Brown, 1977)

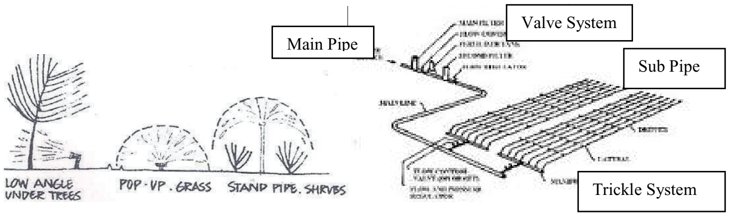


Figure (3.14) Sprinkler and trickle irrigation systems (Ali and Brown, 1977)

3-4-3 Grey Water Systems

Gray water is water that is mildly soiled from washing, bathing or showering, as opposed to "black water", which is water flushed from toilets.

Water from kitchen sinks, dishwashers, and washing machines also counts as black water due to its high level of combination from detergents, grease and organic matter. Gray water cannot be simply collected and reused; it must first be filtered and treated. There will be a risk of disease and plumbing blockages, after treatment, it can be used for garden irrigation or toilets flushing. Systems to recycle gray water have become increasingly prominent in recent years.

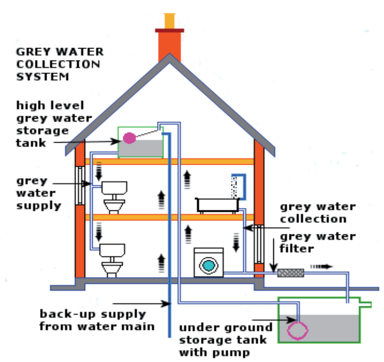


Figure (3.15) Grey water systems (Low-energy house, 2011)

In these, gray water is first coarsely filtered through crushed stone or gravel, then run through reed beds to be biologically purified by microorganisms feeding among the roots of the plants. (Sydney, 1996)

3-4-4 Composting Toilets

One dynamic way of cutting water consumption is to install a composting toilet- a waterless system that breaks down human waste matter into organic compost.

A shaft directly to a large scaled container in a basement or lower level connects the toilet. Air circulates through the container to break down the waste matter and an exhaust vent extracts smell and emits them above the roof. There may also be a shaft for adding organic waste from the kitchen and another opening for adding garden waste. Large containers only need to be emptied every couple of years. (Wilhide, 2003, pp. 40)

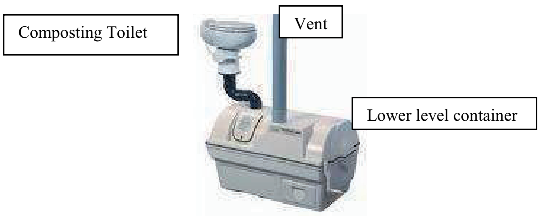


Figure (3.16) Composting toilets (Wilhide, 2003)

3-5 Ecological Sites

3-5-1 Outdoor Pollutants

Dust, fume, humidity and noise are among the main outdoor pollutants that can penetrate into indoor spaces and affect inhabitant health.

3-5-1-1 Dust

Air borne particulate matter is one of the major forms of outdoor air pollution. Dusts are small solid particles formed by the breakdown of material into fine particles. The most important individual disease is silicosis caused by inhalation of silicon dust and asbestosis by the inhalation of asbestos. Some dust can cause the development of cancer in the respiratory tract, notably the fiber of blue asbestos. (Mc Intyre, 1980)

3-5-1-2 Noise

Site noise can reach 90 dB, causing heart stress. As soon as the decibel volume exceeds 80 db the blood pressure starts to rise; the stomach and the intestine operate more slowly, the pupils of the eye become larger and the skin becomes paler. Children in particular can suffer from high blood pressure due to high noise inputs.

- **Methods are used to deflect and absorb noise:**
  - Concrete is used as a mass material to deflect and stop noise penetration.
  - Noise barriers, earth beams and protective belts of trees answers being proposed and erected in many cities and towns.

- Protective belts of trees forming thick forest are not only providing a sustainable product, but also can be irrigated by waste water.

For Example: Jeremy Till Eco House, London, UK, 2004

Jeremy Till and Sarah Wigglesworth eco house in London, the architects used sandbags for noise reduction on the elevated atelier is next to a railway track. On the northeast and northwest, a thick layer of traditional bales of straw insulates the house.

These were layered around a supporting structure of wood and covered with homogeneous multi-layer plastic materials to keep out rain, but to allow air to reach the straw.

Inside, the house is finished with loam and paneled with recycled wood. A tower of bookshelves that serves as a ventilation chimney took shape in the spandrel between the two wings of the building. The home's technology includes solar heating, rainwater use and a composting toilet, among other. The architects won the RIBA Sustainable Award in 2004 for the house. (Linz, B., 2009)

Figure (3.17) Jeremy Till eco house, London, UK (Linz, B., 2009)

3-5-1-3 Humidity and Health

Electrostatic Effects: The risk of electromagnetic shocks increased sharply as the humidity fell below 40 % for nearly all carpets materials. Maintaining humidity over 40 % will reduce the risk of causing shocks. The reason given for the harmful effects of low RH is that it dries out the mucus in the nose the mucus layer in the nose serves to trap foreign matter, including bacteria and viruses and prevent them from reaching the lungs. Many people suffer from allergic rhinitis, where inhalation of the house dust produces symptoms of sneezing and a running nose, which similar to those of a cold.

The concentration of mites depends on strongly on the humidity, and every few are found below a vapour pressure of 11mb (45 % RH at 20 deg C). Thus, sufferers from allergic rhinitis are recommended to reduce the humidity in the bedroom. The main reason for limiting humidity levels in buildings is to limit condensation and mould growth. It is generally held that if the relative humidity in a room exceeds 70 % for long period, (12 hours a day or more) mould growth is possible. (Mc Intyre, 1980 pp. 283-287)

3-5-1-4 Insufficient Lighting

Sunlight is one of the most fundamental ingredients of life and living quality. Sufficient penetration of direct sunlight into interior spaces constitutes one of the most critical aspects of any building particularly the residential ones. Through the penetration of infrared waves into living spaces, the effects of sunlight are set into motion. The repetitive daily cycle of solar radiation and natural light, have a significant influence on our comfort level, our moods and our activities. In recent years, through the development of visible light to hormone levels the body has been recognized. (Habitat, 2000, pp. 270)

Glare can caused tiredness, dry and gritty eyes, headaches, flicker, and lack of contrast. Conventional white fluorescent lighting in particular is likely to cause eyestrain, headaches and should be replaced with non-fluorescent lighting as much daylight as possible. (Habitat, 2000)

3-5-2 Site Selection

In hot dry climates, wind is a liability not an asset. Hot dry winds will increase discomfort, carry dust and sand and so therefore:

- Protected sites where wind speeds are lower are therefore to be preferred.
- Maximum shade and minimize wind.
- In case there is a slope, the site should be chosen at the bottom of the slope for exposure to cold airflow at night and on east orientations for decreased solar exposure in the afternoons.

3-5-2-1 Soil

The qualities of many desert soils give rise to a number of problems as far as plant growth is concerned. There are two basic options for the designer:

- Complete modification of the soil within areas to be planted, traditionally solved by replacing with an important mix of wadi soils, sand and organic material
- For large-scale desert landscape projects, an alternative approach is required. This is to select the species for the site conditions rather than to modify the site to fit the species. This has a sounder ecological basis which will, in time, improve the quality of the soil (and the microclimate as well). (Ali and Brown, 1977)

3-5-2-2 Subdivision Layout

Subdivision layout can plan roads to run east/west, allowing builders to orient towards the road and gain optimum solar exposure. Building lots easily can be arranged on east/west roads to eliminate shade cast from one lot to the next. If roads must predominantly north/south, sitting for proper solar orientation is more difficult. Two simple ways to optimize building orientation in these situations are to combine lots and to use "flag lots." These involve redesigning the shape of the lot to simplify access to the road. Both options must be considered in relation to local zoning restrictions and market response. (Schwolsky and Williams, 1982, pp. 63)

3-5-3 Passive Conditioning of Outdoor Air

Passive conditioning of outdoor air strategies as the following:

- **Wind breaks:**
  - Use shrubs and trees to lessen the impact of strong hot wind and to cool the air.
- **Dust:** To reduce dust:
  - Ensure planting the land on the windward of the site.
  - Avoid exposed land
  - Adopt compact plans for group of houses to avoid formation of dust.
  - Use air that has travelled over water or vegetation.
  - Ensure that ground surfaces adjacent to the house are shaded and absorptive or planted.
  - Well-placed holes in "breeze walls" around the garden can allow pleasant wind in walls facing unpleasant wind should have no holes.
- **Noise:** To avoid noise:
  - Use a substantial garden wall as a sound barrier.

3-6 Ecological Economical House "Eco Eco-House"

If we handled both the ecological and economical aspects and brought them together we should reach what will be a healthy, comfortable, and energy efficient house that will also be environmentally friendly and an affordable house.

3-6-1 Cost Analysis System

Establishing a cost analysis system is urgent need for helping designers reach a trade off between cost and ecological aspects during the different phases of housing development. The designer is constantly making decisions as he goes through the design process. Each decision has a cost impact that should be analyzed and in order to achieve eco-houses. additional costs might be required, a comparison should be done between eco-design cost and regular or traditional design solutions in terms of costs taking into consideration all the advantages from eco-design and the pay back system that may not be instantly felt but on the long run (Azmy, 2007).

3-6-2 Cost Effectiveness Modules for Ecological Measures

Cost analysis modules integrated with the proposed system are needed to help designers decide about cost effectiveness of specific design measures aiming at ecological and environmental improvement and preservation. These modules varies from environmental impact assessment (EIA) to evaluation of energy performance in residential buildings, as well as evaluation of appropriateness of different construction systems and different building materials used in residential buildings regarding their availability and suitability to local natural conditions.

To study the impact of the different factors on energy performance of residential 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, for quickly evaluates the energy savings of building design option.

- Life Cycle Cost analysis: the life cycle cost analysis is the most commonly used method to determine the economic feasibility of energy efficiency projects. Several parameters are needed to perform LCC analysis such as investment costs (initial costs, replacement costs, and residual costs), annual energy costs (electricity costs and fuel costs), non- annual operating costs (such as maintenance costs) and interest rates

$$P = \frac{\mathbf{A}\,(1+i)^{n-1}}{(1+d)^{n}} \qquad \text{(Ahmed, 2002)} \qquad (1)$$

Where: P= Present worth A = Initial costs, n = Number of years, i = Inflation rate, d = Discount rate

3-6-2-1 Evaluation of energy performance in residential buildings taking into consideration life cycle cost

As part of developing the building energy code, the energy performance of residential buildings aiming to:

- Reduce the energy consumption in buildings.
- Improve the comfort of the inhabitants in outdoor urban areas as well as in indoor spaces.
- Enhance the building energy efficiency leading to the quality of architectural and urban environment.

3-6-2-2 Payback analysis for existing building improvements

Payback analysis helps designers, owners and operators decide about accepting or rejecting improvement measures since it relates initial costs needed to improve building performance to save costs and reduce the running costs.

- **Payback analysis for adding thermal insulation layer to the roof**

Example: Assuming an exposed ceiling of 300 m2 area in residential unit at (Cairo, Alexandria and Aswan) composed of a layer of reinforced concrete 12 cm thickness (U= 3.45 watt/m2.C). Adding a layer of thermal insulation 6 cm thickness will decrease thermal transmittance (U= 0.45 watt/m2.C).

$\mathbf{\Delta E = H_O \times a \times (Ub\text{-}Up) \times CDD}$ (Azmy, 2007) (2)

Where:

ΔE: Energy savings in watt

H_O: Occupancy period where AC function

a: Area of exposed roof in m^2

Ub: Roof thermal transmittance before adding insulation

Up: Roof thermal transmittance after adding the insulation
CDD: Cooling degree- day for a base of 25C
CDD = $\sum_m \sum_h$ **(Tao-25)**, **Tao:** outdoor air temperature, m: month, h: hours
Δ E = 15×300 (3.45-0.45) × 2500 = 33750 kWh/year

Payback period = Initial Cost / Annual Savings

PBP = Cost of insulation/ Energy saving (assume the cost of electricity is 0.10 EGP/kWh, assume the cost of m2 insulation is 20 LE)

Payback period = (300×20)/ (33750×0.1) = 1.7 years

It found that payback period is 1.7 years in Alexandria. It decreases to 1.3 years in Cairo and 0.9 year in Aswan. It is obvious that the harsher the climate, the shorter payback period.

- **Payback analysis for increasing glazing thermal resistance by using double glazed panels**

Calculation is made for a building envelope with 200 m^2 glazing. Single glazing have a U value of 5.6 watt/m2.C while double glazing U value decreases to 2 watt/m2.C

Table (3.11) Thermal transmittance of different materials are used in the home example

Items	12 cm Concrete slab	5 cm Thermal insulation	Single glazing	Double glazing
Thermal Transmittance	3.45 watt/m2.C	0.45 watt/m2.C	5.6 watt/m2.C	2 watt/m2.C

Assuming the cost of 1 m2 in double glazing exceeds the cost of m2 of single panel by 200 LE, and the cost of electricity is 0.1 LE/kWh.

For Alexandria: E = 15× 200(5.6-2) × 2500 = 27000 LE/kWh.
Payback = (200×150)/ (27000×0.1) = 14.8 years

Table (3.12) Comparison between payback period of eco house features in Alexandria, Cairo and Aswan, 2010

Items	Alexandria	Cairo	Aswan
Payback Period of Thermal Insulation	**1.7** years	**1.3** years	**0.9** years
Payback Period of Double Glazing	**14.8** years	**11.6** years	**8.8** years

Made by the researcher

The payback period of adding thermal insulation layer is acceptable in Alexandria, Cairo and Aswan but is high for double-glazing for Alexandria, Cairo.

Conclusion

- **Indoor Environmental Quality**

Table (3.13): Comfort levels recommended by the Chartered Institution of Building Services Engineers

<table>
<tr><th colspan="2">Parameter</th><th>Recommended Level</th></tr>
<tr><td colspan="2">Temperature (dry bulb)</td><td>19-23 degree C</td></tr>
<tr><td colspan="2">Relative Humidity</td><td>40 – 70%
More than 55% RH is needed in carpeted buildings with under floor heating to avoid electrostatic shocks</td></tr>
<tr><td rowspan="3">Ventilation</td><td>Deliver of Fresh Air</td><td>8 litres/sec. per person (minimum)
16 litres/sec. per person where someone smoking
25 litres/sec. per person where heavy smoking</td></tr>
<tr><td>Total Air Supply</td><td>4-6 air changes per hour</td></tr>
<tr><td>Air Speed</td><td>0.1 – 0.3 m/sec
Less than 0.1 m/sec. causes stuffiness.
More than 0.3 m/sec. causes draughts.</td></tr>
<tr><td colspan="2">Sound</td><td>46 DBA is upper limit for general office work.</td></tr>
<tr><td colspan="2">Lighting</td><td>500 lux for general office work</td></tr>
</table>

Source: CIBSE, 1986

- **Energy Efficiency**

Solar energy (photovoltaic panels), natural ventilation (Malqaf), thermal insulation

- **Advantages of photovoltaic system as a domestic source of energy**
  - It is a clean green energy source.
  - It produces minimal CO_2, NO_2 or SO_2 emissions.
  - The silicon PV panels are non-toxic in production.
  - The energy payback is 2–5 years, while the working life of a PV panel can be well over 20 years.
  - Energy is generated on site so there are very few losses in transport, unlike remotely generated supplies relying on long supply lines.
  - It is reliable.
  - Panel warranties are now typically for 20 years.
  - They are low maintenance.
  - PVs are a transportable technology and can be moved between buildings.

- They can provide power during blackouts.

- **Natural Ventilation**

Wind catcher (Air Malqaf)

- **Thermal Insulation**

Natural thermal insulation for roof and walls

- **Water Management features:**

- Gray water is water that is mildly soiled from washing, bathing or showering, as opposed to "black water", which is water flushed from toilets.
- Trickle irrigation is extremely efficient in terms of water use. It has been estimated that a trickle system will use 66% of the amount of water that a sprinkler system will use and only 40% of the water required by a surface irrigation system.

- **Eco- Materials Selection**

Table (3.14) Ranking of material according to energy intensiveness

Low Energy Materials	**Energy Content kWh/Kg**	**Medium Energy Material**	**Energy Content kWh/Kg**	**High Energy Material**	**Energy Content kWh/Kg**
Sand, Gravel	0.01	Plaster Board	1.0	Plastic	10
Wood	0.10	Brick Work	1.2	Steel	10
Concrete	0.20	Lime	1.5	Lead	14
Sand-Lime Brick Work	0.40	Cement	2.2	Zinc	15
Light Weight Concrete	0.50	Mineral Fibre Insulation	3.9	Copper	16
		Glass	6.0	Aluminium	56
		Porcelain	6.1		

Source: Brenda and Val, 1991

- **Ecological Economical Housing Features:**

- The payback period of adding thermal insulation layer is acceptable in Alexandria, Cairo and Aswan.
- The payback period of using double-glazing is high for Alexandria and Cairo.
- The payback period of using double-glazing is acceptable in Aswan.
- The harsher the climate, the shorter the payback period
- Cooling loads will decrease leading to electricity savings.

Chapter 4: Eco House Examples

4-1 International Eco House Examples

4-1-1 Oxford Eco- House, UK, 1995 (Roaf, 2001)

Location: Oxford, London, UK
Latitude/Longitude: 51°N, 1°W, 40 m above sea level
Area: 232 m²; 250 m² including porch and sunspace/3 stories, 6 bedrooms
Completion date: Construction took about 18 months; Completed in1995
Owner: Susan Roaf
Design Team: Sue Roaf and David Woods

Figure (4.1) Oxford eco-house, UK (Roaf, 2001)

4-1-1-1 Eco-house Design Features

12Kwh Photovoltaic per day, 5m^3 solar hot water, high levels of insulation and high thermal mass, triple-glazing windows, orientation, materials, no mechanical ventilation system, wood burning.

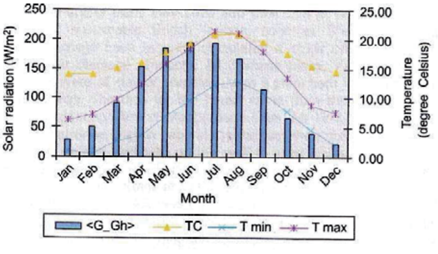


Figure (4.2) Solar radiation and temperature on Oxford region (Roaf, 2001)

4-1-1-2 Design Considerations

The Oxford Eco house is a three-story building built of traditional cavity wall construction. The design concept aims were to have a quiet and healthy house with minimal CO2 emissions, which was achieved with the following:

- Heavy construction -
Natural finishes & no carpets -
Buffer spaces to the front and back of the house

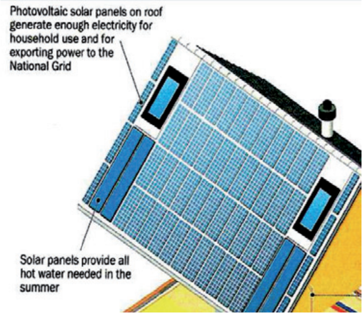


Figure (4.3) Photovoltaic solar panels & solar hot water in the hose roof (Roaf, 2001)

- **Construction and Insulation**

The roof is constructed of concrete tiles on battens on 50mm continuous expanded polystyrene 200mm deep insulation between rafters, with 6mm plies below. The timber attic floor is insulated with 200mm of mineral wool fibre between joists walls have handmade bricks facing to the outside, fill of mineral wool fibre with nylon wall ties behind the brick and concrete block inner leaf with two coats of plaster finish internally. The ground floor is a 150mm floating timber flooring over 150mm concrete slab, on polystyrene floor insulation with U-value of 0.19 W/m^2 C (table 4.1).

Table (4.1): Thermal transmittance in the Oxford eco house features

Materials/Element	U Value (W/m^2)	Description
Walls	0.22	Brick/Block
Floor	0.19	150 mm Insulation
Roof	0.14	250 mm Insulation
Windows	1.30	Triple-Glazed

Source: Roaf, 2001

Oxford only receives about 4.0 peak hours of sun in the summer and 0.6 hours in the winter. During summer months, there are surpluses, predicted to be around 12 kWh per day that are exported to the local electricity station or stored for use at night. Then in the winter, when there is not enough energy, electricity is imported from the power station.

- **Photovoltaic**

There are 48 photovoltaic modules arranged in 4 vertical rows mounted on a built-up aluminium frame screwed on the roof (see figure 4.3).

- **Solar hot water**

On the roof alongside the photovoltaic are 5m² solar hot water panels connected to a 300-litre tank to supplement the energy demand for hot water

- **High levels of insulation and high thermal mass**

These prevent heat gain and loss, therefore reducing the need for outside heating and cooling systems (figure 4.4).

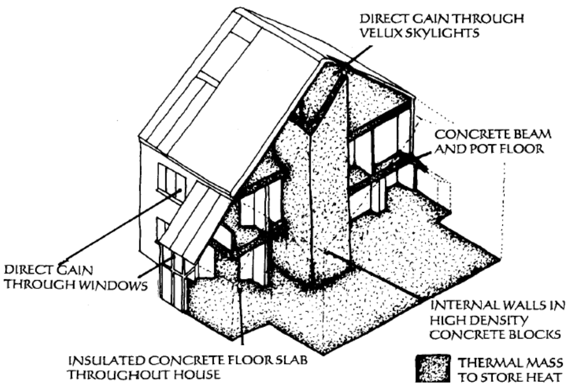


Figure (4.4) Sketch of the Oxford Eco-house showing the wide variety of considerations that have to be taken into account at the outset of a building design, including considerations of a storage of passive solar gain (Roaf, 2001).

- **Windows:**

Triple glazing to prevent thermal transference except in the sunroom, which is only double-glazed.

- **Orientation:**

The house is oriented roughly east west with a south-facing slope which provides good solar access. Heating costs are minimized with passive solar gain.

- **No mechanical ventilation system:**

In the Oxford eco-house, the wall temperature of a building is altered by the use of plants to shade walls to provide natural ventilation through wall temperature.

4-1-1-3 Cost Saving of the Oxford Eco House

Table (4.2): Comparing the Oxford Eco-house with a similar detached house cost

Type	$kWh/m^2/a$	Electric Cost (£)	Gas Cost (£)	Total Cost (£)	CO2 Emissions (kg)	Construction Cost (£) (per m^2)
Oxford Eco-house	26	8	44	52	148	720
Typical House	90	180	476	566	6500	720
Saving	64	172	432	514	6360	0

Source: Roaf, 2001

4-1-2 Berkeley Eco-House, U.S, 2007 (Berkeley, 2007)

Ecology Centre, San Pablo Avenue, Suite H Berkeley, California, US

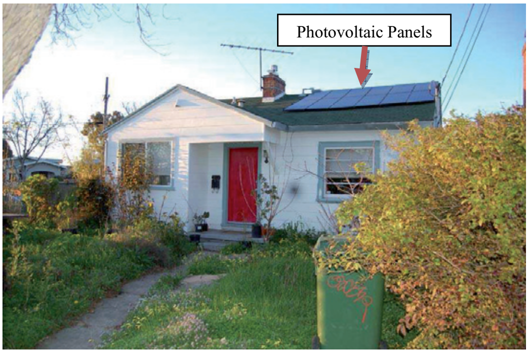


Figure (4.5) Berkeley eco-house, California, US (Berkeley, 2007)

- **Mission**

Berkeley eco house aspires to overcome the barriers to healthy environmental choices, making ecological ways of living accessible and affordable to people of all ages, ethnic/racial backgrounds, and income levels.

Berkeley eco house was founded in April 1999 as a non-profit, community-based educational organization created by a group of diverse, talented, and inspired individuals with a common passion for restoring our ecological systems and building healthy, socially just and stable communities.

Berkeley Eco House grew out of the extraordinary neighbourhood efforts at Hopkins and Peralta Streets that have produced the finest gardens and educational exhibits. EcoHouse founders and team members developed a growing sense of community with neighbours

through personal contact, information exchange, neighbourhood celebrations, and participation in construction and upkeep of the ecological demonstration projects.
In 2006, Berkeley eco house became a program of the Ecology Centre, and has since become a popular demonstration site for the Ecology Centre's many classes and workshops on sustainable living techniques.

- **Steering Committee:**

Berkeley eco house Steering Committee consists of community leaders, architects, perm culture educators, landscape architects, gardeners, energy specialists, and community members. Many of the original people involved in the founding of EcoHouse are still active members of the steering committee.

4-1-2-1 Eco House Features

Berkeley eco house has solar panels, an on-demand water heater, water-saving fixtures, natural and recycled building materials, natural linoleum floors, salvaged kitchen cabinets, bamboo kitchen countertops, a gray water and wetland system, a rainwater cistern (figure 4.6), a straw bale and rammed earth shed, a living roof vegetable garden, an organic perm culture garden, native drought tolerant plants, and mushrooms.

Figure (4.6) Berkeley, garden house and grey water tank (Berkeley, 2007)

Berkeley eco house structure is a modest home in an urban neighbourhood that exhibits simple environmental approaches of global importance. The house displays features that can be readily applied to any residence.

The Berkeley house incorporates ecologically friendly materials and methods that reduce resource use, come from renewable resources, have minimal impacts in their manufacture, avoid toxic chemicals, do not off-gas harmful compounds, and can be reused or reclaimed at the end of their useful life. It contains such environmentally preferable products as natural linoleum floors, wood floors from a demolished house, salvaged cabinets, and bamboo for the kitchen countertops and wood from sustainable forests.

Of primary importance is reducing our need for non-renewable energy sources. We completely insulated the house with cellulose, replaced lighting fixtures with low energy yet attractive fluorescents, installed high efficiency appliances, and replaced the hot water heater with a “flash” or instantaneous water heater that only heats water as it is being used. A solar water heater on the roof pre-heats water so the flash heater has to use less gas to get the water to the desired temperature.

Figure (4.7) Photovoltaic roof shingles and rammed earth wall (Berkeley, 2007)

The Berkeley home’s photovoltaic installation provides all of the home’s electricity, and is especially appreciated on the sunniest, hottest days, when it supplies energy back into the grid. Eco House water-efficient appliances sink and shower aerators, and a low-flow toilet. Wastewater from the shower, sink, and washing machine is piped to the grey water system outside and reused in the garden.

When building the garden shed, including straw bale, rammed earth wall for passive heating, and salvaged lumber insulated with light clay-straw. The garden shed houses equipment for the photovoltaic system (figure 4.7), while its living roof and natural building materials blend beautifully with the perm culture gardens. The water captured from the roof drains into a salvaged tub that serves as the ducks’ bath. The front garden features native and drought tolerant plants such as California buckeye, sticky monkey flower, mock orange, yarrow, native currants, cow parsnip, native grasses, and cattails.

4-1-2-2 The Future for Berkeley Eco-House

Berkeley eco-house is currently developing plans to expand the structure and provide more Residence for volunteer docents (figure 4.8). A south facing greenhouse will demonstrate passive solar heating while providing space for plant propagation, and an upper deck will demonstrate intensive rooftop landscaping.

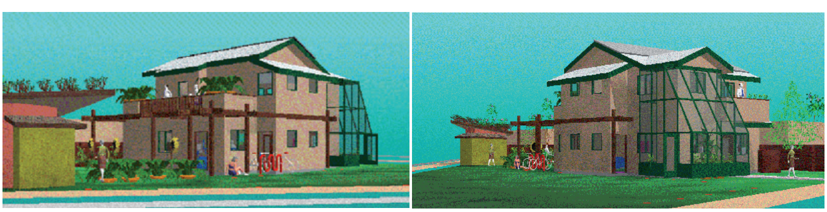


Figure (4.8) Berkeley future extension perspectives (Berkeley, 2007)

4-1-3 Lara Calder, Eco- House, Sydney, Australia, 2008 (Lara Calder, 2008)

- **Overview**

The primary inspiration for eco house design is the concept of temporal shelter strongly informed by an indigenous response to the land and climate.

Figure (4.9) Lara Calder eco house perspective, Sydney, Australia (Lara Calder, 2008)

- **Context**

The Lara Calder eco house is an intelligent response providing a suitable and sustainable building from for suburban development in western metropolitan Sydney. It offers an alternative to resource-hungry low-cost project homes.

In its intended suburban context, car provision has not been given a high priority. The major re-evaluation of private transport will need to be addressed in the future.

4-1-3-1 Construction

The primary structure is six timber portals. Over these portals, a high-tech fabric "fly" is suspended. In each portal bay pre-fabricated units are suspended and configured to produce prefabricated pods have weatherproof roof, walls and floors, however the primary weather barrier is the fabric canopy (figure 4.9, 4.10).

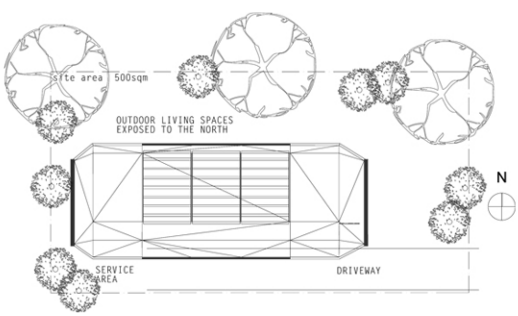


Figure (4.10) Lara Calder site plan , scale 1/400 (Lara Calder, 2008)

4-1-3-2 Materials

Materials are generally selected for their low embodied energy. The structure necessarily includes steel and plastic-based elements; however, these are minimized in favour of predominantly timber, cement and plaster products. The portals are laminated timber pinned to concrete footings. The fabric is a PVC waterproof membrane.

The prefabricated units have a rigid steel outer frame with timber frame infill panels to walls and roof. The roof is a concrete slab panel. The units are clad in painted fibre-cement with a liquid membrane roof, window and doorframes are timber, and double-glazing is used throughout the house.

4-1-3-3 Affordability & Aesthetic

The scale of the Lara house is modest at 164 sq m; the emphasis is on efficient planning and provision of one multi-functional living space. The bedrooms are big enough to contain ancillary uses. In Sydney's climate, it is expected that for much of the year, the outdoor spaces can be used as additional rooms.

The aesthetic is the simple shelter overlaid with some extremely contemporary compo entry juxtaposed with familiar building elements.

4-1-3-4 Compliance

The Lara Calder house is intended for a suburban western Sydney context. The scale of the dwelling is considered appropriate for a regular shaded 500 sq m block with a larger setback from the north boundaries and minimal setbacks on all other boundaries.

A tow story structure is considered to be appropriate scale for sib urban development and falls within current guidelines for most existing council DCP's.

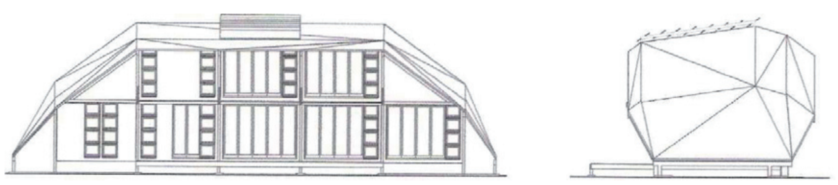


Figure (4.11) North elevation & west elevation (Lara Calder, 2008)

4-1-3-5 Climate

Sydney is a temperate climate; although there are four distinct seasons, much of the year conditions are suitable for human comfort. The design response for this building utilized passive solar principals (including provision of thermal mass), good insulation (including window and door), good convective ventilation and cross ventilation.

Figure (4.12) Lara Calder eco house plans (ground, and first floor) scale 1/200 (Lara Calder, 2008)

4-1-3-6 Passive Solar Design

A connectedness with the outdoor throughout the year is a feature of Sydney's climate and a key consideration in the design of this house. North window overhangs are configured to admit low angle winter sun and shade from summer sun. The insulated concrete floors provide thermal mass. Wide opening doors on both levels acknowledge the being nature of Sydney's climate while smaller south-facing windows facilitate cross ventilation and the necessary "relief valve" to combat over heating in summer.

All windows and doors are double-glazed. Windows are generally awning type allowing for good sealing when closed and to act as large louvers when open (figure 4.13). Fabric blinds are provided for additional thermal comfort and to secure warm ambient temperatures on cool nights.

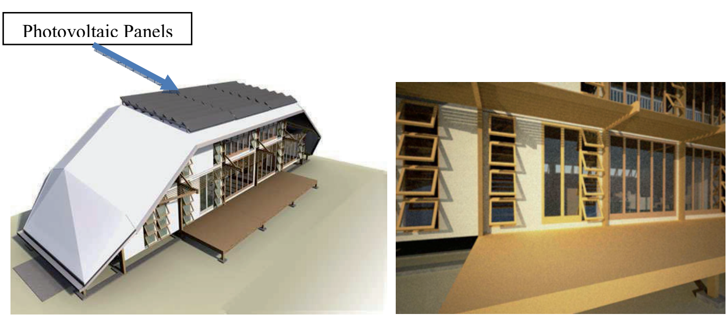


Figure (4.13) North elevation windows (Lara Calder, 2008)

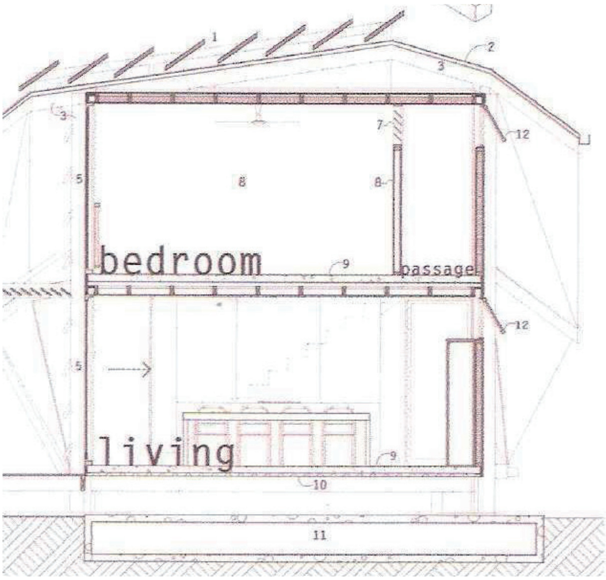


Figure (4.14) Cross section of eco house (Lara Calder, 2008)

1- Photovoltaic panels and solar hot water panels
2- Fabric canopy
3- Timber portal
4- Timber sunshade
5- Double glazed timber framed doors
6- Timber deck
7- Timber louver panels to passage
8- Plaster board on the timber frame
9- Concrete
10- Insulation
11- Rain water storage tank
12- Double glass timber windows

4-1-3-7 Energy Efficiency

- **Cooling**

- No air-conditioning proposed for the house. -
Cooling will be providing by ceiling fans. Cross breezes and the use of the thermal mass in the floor (figure 4.16).

- **Lighting**

Low energy fluorescent lighting proposed throughout the house.

- **Insulation**

- High insulation levels are a key feature of the design. -
The pods are fully insulated and all openings are double-glazed.

- **Heating**

The design intends for the passive solar design to take care of most of the space heating requirements. A simple fan and duct system is proposed to redistribute warm air as required (figure 4.15).

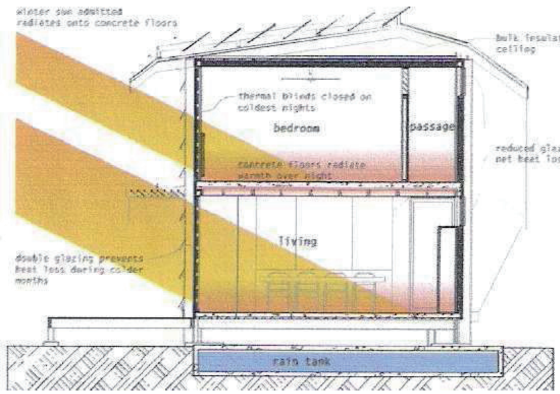


Figure (4.15) Lara Calder eco house winter performance diagram (Lara Calder, 2008)

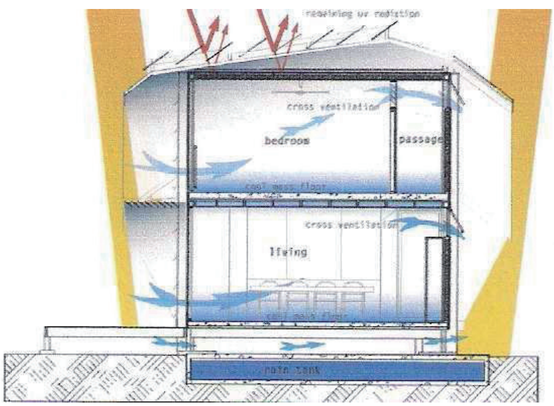


Figure (4.16) Lara Calder eco house summer performance diagram (Lara Calder, 2008)

- **Water Heating**

- Hot water will be provided by a gas boosted solar hot water storage cylinder - Solar panels will be roof-mounted (adjacent to the photovoltaic cells) and the water cylinder is located on the south side of the house

- **Appliances**

- Gas cooking appliances (oven and hob) and high efficiency white goods is proposed. - It is expected that most clothes drying can be accomplished with a clothesline and using an available rain-sheltered breezeways beneath the fabric roof.

4-1-3-8 Water management

The primary objective is to reduce the demand of potable water. The design anticipates a municipal potable water supply supplemented by non-potable stored water and on-site wastewater treatment. There is no proposal to treat sewage on site; it is anticipated that suburb-scale black water drainage infrastructure will exist.

- **Rainwater**

The fabric roof is provided with a barge/guttering system to direct the water to concrete storage tanks in the ground between the portal footings. There are four tanks assigned to rainwater collection with a total capacity of 30.000 litres. The stored rainwater is used for laundering and exterior uses. Overflows from the rain tanks could be directed to a neighbourhood collection and reuse system for irrigating public areas, parks etc.

- **Wastewater**

Wastewater from showers and basins is collected and treated in the fifth tank and stored for toilet flushing only. Storage is small capacity due to the requirement for fast cycling of this water.

4-1-3-9 Waste Management

Waste management during construction is addressed by factory prefabrication of the elements in the aboveground components of the house can be delivered by a medium-sized truck. It is expected that several key elements (trusses, steel module frames, windows and doors ...) can be reused.

4-1-3-10 Eco Materials

All timbers are to be local plantation-sources and all paints VOC, free and water-based.

Table (4.3): Lara Calder eco house materials

House features	Materials
Roof canopy	PVC coated high-tensile fabric (filtering and waterproof)
Trusses	Laminated timber (painted)
Stair	Timber with closed risers
Structural frame	Mild steel
Floors	Concrete (polished)
Wall infill	Timber frame
Wall and roof	Fibre Cement (painted)
Roof Finish	Liquid Membrane (reinforcement fibre glass)
Doors	Timber frames and leafs, insulated glazing units(painted)

Interior Finishes	Habitable Rooms	Service Rooms
Floors	Polished Concrete	Tiles on Concrete
Walls	Plasterboard (painted)	Tiles on fibre cement
Ceiling	Plasterboard (painted)	Plasterboard (painted)
Joinery Fitments	MDF (painted) & laminate	MDF (painted) & laminate
Interior Doors	Flush timber leafs in timber frame	Flush timber leafs in timber frame

(Source: Lara Calder, 2008)

4-1-4 Ramallah Eco House, West Bank, Palestine, 2009 (Med-Enec, 2010)

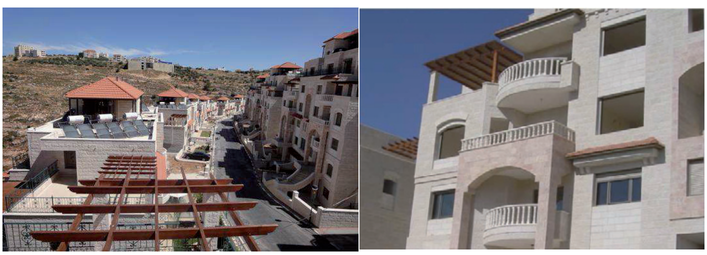


Figure (4.17) Ramallah eco house, West Bank, Palestine (Med-Enec, 2010)

- **Location**

Three story residential villa in a larger building block at the north-west outskirts of Ramallah / Al Bireh, West Bank, Palestine

Each block consists of 5 flats with a total floor space of approx. 340m². A geothermal heat pump system provides heating and cooling.

Partners: Palestinian Energy Authority and Union Construction and Investment (UCI)

- **Project background**

The objective of the Ramallah eco house is to increase building construction efficiency and to promote the use of clean, renewable geothermal energy for heating and cooling at a lower operating cost than a typical conventional system. It is expected to attract project developers and investors to geothermal energy and to raise awareness at government level and among the public to use this cost and energy efficient technology.

The geothermal concept installed, involves a water to air electrical heat pump, using a vertical ground-loop and a duct distribution system. (Med-Enec., 2010)

- **Profitability**

From a financial point of view, the Ramallah eco house allows reducing the primary energy consumption by around 25% (figure 4.18) associated with energy cost savings of 60% for heating and cooling compared to a conventional building. The additional investment cost compared to a conventional building is approx. 40,000 € which leads to a pay pack time of about 6 years, once experience has been gained.

4-1-4-1 Main Technical Features of the Eco House

The energy concept of the Ramallah eco house is based on a the use of a geothermal ground water / air heat pump designed for heating and cooling and on the improvement of the insulation of the building envelope.

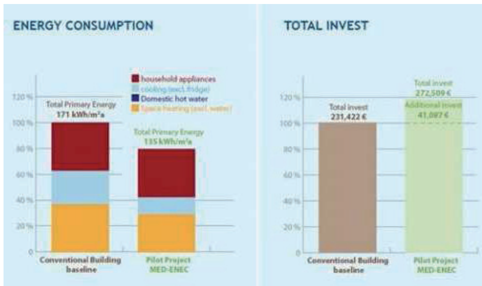


Figure (4.18) Ramallah eco house energy consumption (Med-Enec., 2010)

4-1-4-2 Basic Measures with High Moderate Cost Efficiency

- Reduction of heating and cooling load by 20% due to enhanced insulation of the building envelope.
- Improved and airtight windows.
- High efficient electrically powered geothermal heat pump with vertical heat exchanger.
- Expected Coefficient of Performance (COP) of the heat pump of 5.3 for cooling and 4.0 for heating.
- Solar collectors for domestic hot water.

Figure (4.19) Payback period of Ramallah eco house (Med-Enec., 2010)

4-1-4-3 Main Results of the Ramallah Eco House

Ramallah eco house project yields energy cost savings of 60% for heating and cooling, compared to a conventional building (figure 4.19).

The application of the same technologies in future projects will only demand about 5% additional cost, with a very attractive pay-back period of only 6 years. (Med-Enec., 2010)

4-2 National Eco-House Examples

4-2-1 El-Tahrir Passive Solar house, South Tahrir, Egypt, 2006

(Halfway between Cairo and Alexandria Desert Road) (DDC, 2006)

Figure (4.20) The passive solar house, South Tahrir, East facade and photovoltaic panels. (DDC, 2006)

A passive farmhouse in South Tahrir was selected as an eco house example. The building performance was evaluated using “TRNSYS”, and monitored during two years of occupancy (2004-2006) to evaluate the performance and energy/carbon emissions reduction. The design took into consideration active design strategies including solar domestic water heating, photovoltaic electricity generation and thermal solar air conditioning

4-2-1-1 El-Tahrir Passive House Background

Out on the buff-coloured desert, halfway between Cairo and Alexandria in an area called South Tahrir, where the dry hot winds sweeps along sucking moisture from every living thing, there lays a green farm with a Passive Solar House (PSH). The PSH was constructed for the American university in Cairo (AUC) Desert Development Centre (DDC), which uses its 578 acres as a nucleus for strategic desert development including agricultural experiments and energy efficient architecture. The vision of the DDC was to design sustainable and ecologically friendly buildings. To determine the appropriate methods to achieve such a design, a PSH demonstration facility, serving as a pilot project, was constructed on-site to test and demonstrate various practices. (DDC, 2006)

4-2-1-2 El-Tahrir Eco House Description

The South Tahrir PSH is located at 30.55′ latitude north, 30.67’ longitude east and 197 m above sea level in an open reclaimed farm. The PSH was built in 1980’s by architect Samir Hosni, professor of architecture at Alexandria University, as a prototypical farmhouse to accommodate one single family. The architect followed Hassan Fathy’s architecture principles and ideas, incorporating Egyptian vernacular devices that considerably enhance thermal comfort by lowering temperatures indoors and outdoors (Fathy, 1986). Additionally, and in an attempt to integrate the philosophy of the DDC for sustainable desert development, the architect integrated passive design archetypes that had disappeared from fashion for being considered arcane and pejoratively indigenous. The building is built of adobe bricks made of local materials and design elements of domes and vaults and interior courtyards. The baseline

PSH is a one-story home of approximately 180m2 of liveable space. As shown in (figure 4.21), the living spaces are separated from the animals' sheds and storage area by a courtyard. The entrance porch, accessed from the courtyard, opens on the other side onto the patio and divides the house into a sleeping area to the left (bedrooms and bathrooms) and a living area to the right (living/dining room and kitchen).

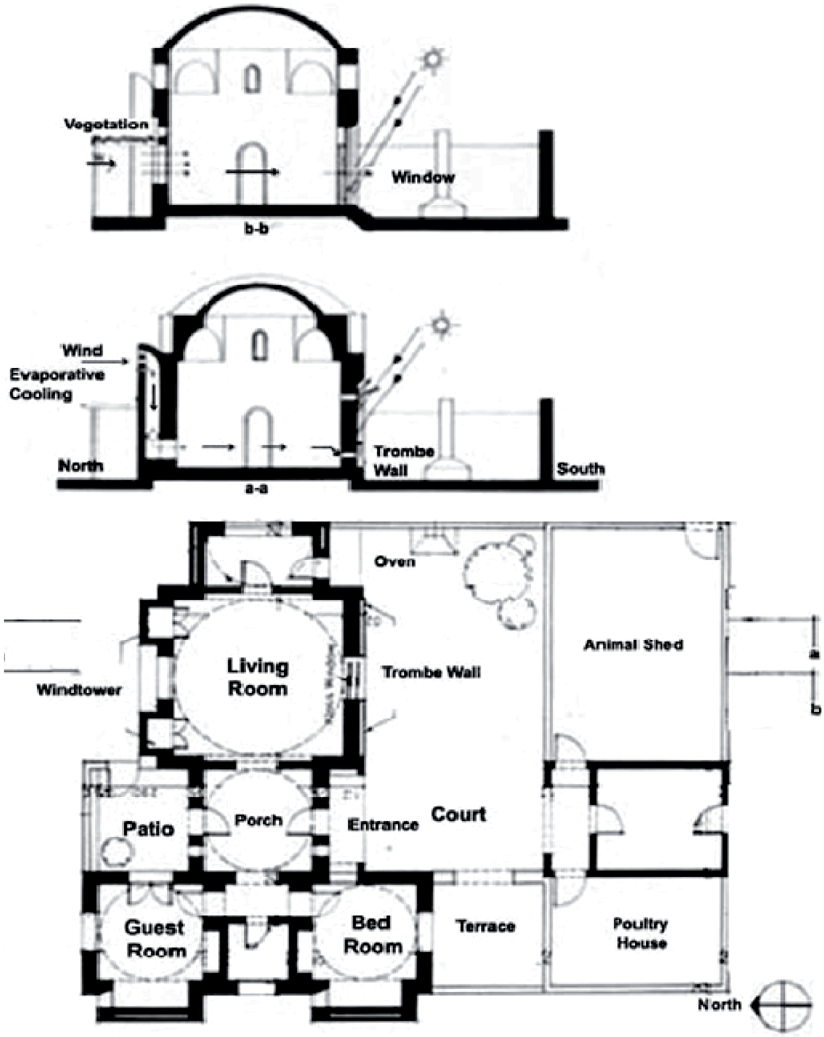


Figure (4.21) Plan and section of El-Tahrir eco house, South El-Tahrir (DDC, 2006)

4-2-2 Sharm El-Sheik tudents Residential Building, Sharm El-Sheik, Egypt, 2010 (Med-Enec, 2010)

Refurbishment including solar cooling of the South Sinai governorate project, an administrative building with 567 m² floor space and training facilities as well as accommodation for students in Sharm El-Sheikh.

Figure (4.22) Sharm el Sheikh, students residential building (Med-Enec, 2010)

Background

The demonstrated solar cooling concept has an enormous energy saving potential in the MED-ENEC countries, as HVAC systems are very common and consume significant amounts of energy. The concept is suitable for residential buildings and small scale office buildings. In addition to the high-tech solution of the solar chiller, several low-tech techniques such as shading devices, leakage prevention, thermal insulation and efficient lights are shown. The dissemination will be aimed at these two aspects of the pilot project: Solar cooling and the "quick wins".

The main components of the system are 82 m2 evacuated tube collectors with operation temperatures below 100°C and the 3 rotartica single effect absorption chillers each of maximum 8kW maximum cooling capacity with a maximum total of 24 kW. (Med-Enec., 2010)

Profitability

Sharm El-Sheikh project is characterized by extremely high investment costs which are nearly 10 times higher than for a conventional building. Primary energy consumption, however, is reduced by almost 50% due to the implementation of solar cooling and passive measures. The cost efficiency of the pilot project as realized is therefore not interesting with approx. 30 years. Only when considering large scale dissemination and learning effects it becomes economically feasible with a payback period of approx. 15 years.

4-2-2-1 Main Technical Features of the Project

The South Sinai governorate project with app 600 m2 floor surface is selected to demonstrate the possibilities of cooling with solar energy. An absorption chiller uses the heat of the sun to generate cooling energy. The heat of the sun is efficiently collected with an evacuated tube solar collector. Apart from the pump-energy to drive the different circuits of the system no additional energy is needed. In addition to installing the solar absorption chiller, several passive, energy efficiency measures were taken to reduce electricity consumption and to reduce the cooling load. (Med-Enec., 2010)

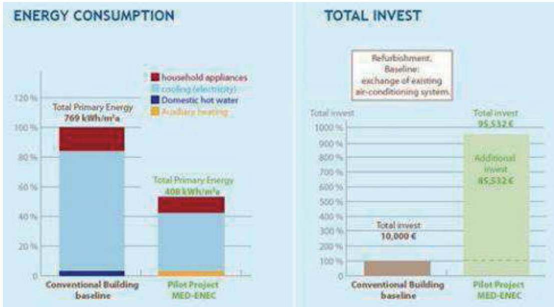


Figure (4.23) Student residential building energy consumption and total investment (Med-Enec, 2010)

4-2-2-2 Basic Measures with High Moderate Cost Efficiency

Special thermal insulation with reflective coating on the roof

- 24 sealed windows to prevent air leakage
- 20 additional shading devices
- 60 energy efficient light bulbs
- Occupancy sensor for lighting control in two corridors
- Demonstration measure: solar cooling system
- 3 lithium-bromide absorption chillers with total refrigeration capacity of 24 kW
- 82m² evacuated tube collectors to supply 85°C hot water to the chiller

4-2-2-3 Main Results of Sharm El-Sheikh Project

The energy consumption of the existing building is reduced by almost 47% through the implemented refurbishment measures (figure 4.23), mainly due to the solar cooling and passive measures. (Med-Enec., 2010)

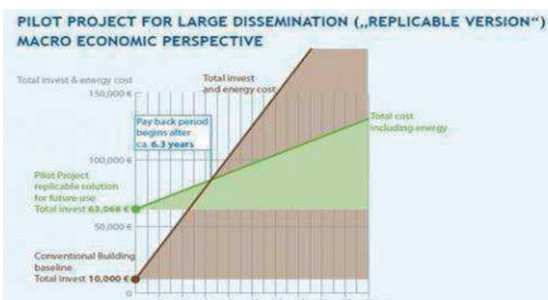


Figure (4.24) Student residential building payback period (Med-Enec, 2010)

However, cost-efficiency of the realised pilot project is moderate (30 years) due to high learning cost and difficult access to products and know-how. Cutting-edge technologies such as absorption chillers and tube collectors for solar cooling were imported from Europe and China to Egypt for the first time as one off products. Project payback period begins after 6.3 years according to figure (4.24) (Med-Enec., 2010)

4-3 Comparison between the Eco House Examples According to the Ecological Design Categories

Table (4.4): Ranking of the eco-house examples (international & national)

Item / Eco-House	Oxford	Berkeley	Lara Calder	Ramallah	El-Tahrir	Sharm El-Sheikh
Eco House Perspective						
Indoor Environmental Quality	A	A	A	B	B	A
Energy Efficiency	A	A	A	A	A	A
Water Management	A	A	A	B	C	B
Eco-Materials	A	A	A	B	A	C
Eco-Sites	A	B	B	B	A	C
Cost Savings	A	A	B	B	A	B
Total Score	**540**	**530**	**520**	**490**	**510**	**480**
Final Arrangement	**1**	**2**	**3**	**5**	**4**	**6**

A= 90, B=80, C=70 Points (Made by the researcher)

Final arrangement of the eco-house examples according to the ecological design categories is as follows:

1- Oxford, UK, 1995
2- Berkeley, US, 2007
3- Lara Calder, Australia, 2008
4- El-Tahrir, Egypt, 2006
5- Ramallah, Palestine, 2009
6- Sharm El-Sheikh, Egypt, 2010

Note: This comparison is a point of the researcher view according to the ecological design categories and available data of these examples.

4-4 Eco House Design Guidelines

Ecological residential building guidelines "Eco House Design Guidelines" which could help the architects, designers and the decision makers to turn their buildings towards the eco-friendly buildings by using the following guidelines:

4-4-1 Indoor Environmental Quality

Aim:

To improve the quality of life throughout good healthy home

Guidelines:

- Avoid using asbestos in all its form: white, brown, or blue
- Avoid using lead and remove all lead pipes from home.
- In order to avoid the growth of legionella, thermostats in water tanks should be set to 55 deg C and lipped fitted lids should be placed securely over water tanks. Do not allow cracks in construction where mineral fibres can infiltrate a room.
- In order to avoid the growth of mould:
- Eliminate cold bridges in the external and internal walls.
- Remove moisture in the home with good zoning of wet activities and a range of good opening windows, vents and repair any cracks in the structure.
- Have moisture-absorbing walls such as a plaster finish with a water based eco-paint finish.
- Paints containing: solvents, white spirits, turpentine, VOCs, heavy metals such as cadmium, lead, mercury or formaldehyde are not preferred. Avoid all paints with chromium.
- Put a plant at home to clean up the internal air quality.
- Use sand and lime plaster.
- Mud plaster is excellent and could be mixed with will-fired wood ash, or mixed with rammed earth from the tested local soil.
- In risk areas, radon concentrations could be reduced by placing an upper forted, impermeable membrane between the concrete lower slab and the ground, or a well-ventilated crawl space beneath the floor.
- All cracks and openings in basements should be sealed.
- Avoid organic solvents by the following:
  - Using water-based eco-paints and varnishes that do not contain ammonia.
  - If you are using glue, paint strippers or varnishes, open the windows wide and ventilate the rooms really well.
  - If you have bedding dry cleaned, air it thoroughly before using.
  - Use wallpaper that is made of paper and not synthetic materials such vinyl. If you paint over it chose eco-paints that do not contain solvents or vinyl.
  - Avoid using wood preservatives in enclosed spaces and avoid storing them in the house.

4-4-2 Energy Efficiency

Aim:

To reduce carbon emissions and atmospheric pollution by encouraging local energy generation from renewable sources to supply a significant proportion of the energy demand

Guidelines:

4-4-2-1 Renewable Energy Resources

- Using renewable energy resources such as solar energy and wind energy

- Solar energy
  - Photovoltaic Panels, Solar hot water system

4-4-2-2 Shelter Design

- **House types**
  - Adjoining houses, row houses and group arrangements (all continuous on East-West axis) are advantageous.
  - The evaporative cooling process of the courtyard houses makes it an effective design strategy in hot arid climates.
  - When considering orientation, East and West walls should decrease North and South walls should increase.
  - Integrated cooling systems, Wind catcher (the Malqaf) is recommended
- **Colours:**
  - Use white paints on sun exposed surfaces
  - Use dark absorptive colours where reflections toward interior are expected
  - Use dark colours for deep surfaces for winter radiation absorption

4-4-2-3 Building Envelope (Roof and Walls)

- **Roof Insulation:**
  - A maximum “U” value of 0.9 watt/m2 deg C is recommended for roofs.
  - “U” value 0.4 watt/m2 is recommended for East and West walls. (HBRC,2006)
- **Wall Insulation:**
  - Use construction bricks with insulation materials to increase its thermal resistivity and decrease its thermal capacity especially in East-West walls.
  - Thermal insulation layer in walls should be placed in the direction of heat source.
  - Reflective thermal insulation should be used on outer layer of the wall.
  - Lightweight interior and exterior plaster of low thermal conductivity could be used for wall finishing.
  - Eco-paints should be used as an aid to wall thermal insulation.
- **Openings and Windows:**
  - Use low inlets and high outlets to produce a good pattern of air movement.

- A slot between wall and sunshade is required for airflow that is more direct. When using wind pressure for cooling, a large inlet and a small outlet is recommended because it results in a lower maximum speed but a better distribution of air over the space
- Double glass windows with low-solar gain are recommended

- **Shading devices:**
  - Connect shading devices to the building only at necessary points, leaving an open air space in between.
  - Horizontal shading devices are recommended for southern orientation while vertical and egg-crate types work towards east and west orientation.

- **Home Office**
  - Provide space and services that enable a suitable quiet room to be used effectively as a home office.
  - Many job functions can readily be performed remotely, so it is quit feasible for individuals to work from home on either a full or a part time basis.
  - Working from home for many people requires a telephone line as well as a connection to the internet for data transference

  The benefits of working from home include reductions in transport movements. Increased time available for home worker and greater opportunities to participate within community activities (Communities, UK, 2008)

4-4-3 Eco-Materials

Aim:

To encourage the use of materials with lower environmental impacts over their lifecycle

Guidelines:

Selecting low embodied energy materials such as:

Concrete, loam, polyethylene, polypropylene, bitumen and softwood

- Use salvaged or reclaimed wood
- Choose formaldehyde-free plywood and MDF; choose timber treatments that are as harmless as possible.

4-4-3-1 Using recyclable and renewable materials

The basic selection will be added to conclude with and recommend because the basic selection is a practical solution, having low environmental impact and being easy to implement, without giving rise to practical problems.

- Hollow concrete elements but the large-scale availability of concrete elements with reclaimed aggregate
- Sand-Lime-Brick and cellular concrete are preferable to concrete with reclaimed aggregate to reduce threats to the environment and the broad range of its applications. Often there is no increase in cost.
- Brick work is already used on a large scale and is included in the basic selection.

- Natural insulation materials are included in the basic selection because of its suitability and current application.
- Concrete with reclaimed aggregate is included in the basic selection. Availability may be problematic however.
- Plywood or softwood, possibly with a solid implant based on borate, is included in the basic selection as these are common types of doors.
- Softwood internal window frames.
- Honeycomb door with hardboard skins.
- Fibre cement and synthetic resin bonded sheets are included in the basic selection.
- Using single glazing in the living areas and double-glazing in the bedrooms.

4-4-4 Water Management

Aim:

To reduce the consumption of potable water in the home, and encourage the recycling of used water (grey water) for external water used.

Guidelines:

4-4-4-1 Irrigation Systems

- **Sprinklers** system is more efficient than surface systems. Although evaporation losses are still a major factor, percolation losses are considerably reduced.
- **Trickle irrigation system** is extremely efficient in terms of water use. It has been estimated that a trickle system will use 66% of the amount of water that a sprinkler system will use and only 40% of the water required by a surface irrigation system.

4-4-4-2 Grey Water System

Grey water system is water that is mildly soiled from washing, bathing or showering, as opposed to "black water", which is water flushed from toilets. After treatment, it can be used for garden irrigation and toilets flushing. Systems to recycle grey water have become increasingly prominent in recent years.

4-4-5 Ecological Sites

Aim: To encourage development on land, and discourage the development of ecologically valuable sites

Guidelines:

- Check the site for contamination, if contaminated then it could be treated with neutralizing chemicals, removed or replaced with clean top soil
- Do not use chemical, instead, pick off larvae by hand and collect snails and slugs by using bee traps.
- Green belt is the basic rule for an eco garden.
- Compost organic waste matter from the kitchen, along with dead leaves and plant and grass trimmings
- Encourage birds, butterflies, bees, and other forms of wild life by planting species that are attractive to them, such as nectar-producing flowers.

Conclusion

Ecological Items		Guidelines
Indoor Environmental Quality	**Indoor materials**	• Avoid using asbestos, lead, growth of legionella or moulds, and radon • Put a plant at home • Use sand, lime and mud plaster (mixed with rammed earth). • Using water-based eco-paints and varnishes • Avoid using wood preservatives
	Thermal comfort	• Temperature (dry bulb) : 19-23 degree C • Relative Humidity : 40 – 70% • Air Speed: 0.1 – 0.3 m/sec • Sound: Max. 46 DBA • Lighting: Max. 500 lux
Energy Efficiency	**Renewable resources**	• Solar energy Photovoltaic Panels, solar hot water system
	Shelter design	• Orientation, East and West walls should decrease North and South walls should increase. • Integrated cooling systems: Wind catcher (the Malqaf) • Use white paints on sun exposed surfaces
	Building envelope	• A maximum "U" value of 0.9 watt/m2 deg C is recommended for roofs. (HBRC, 2006) • A maximum "U" value of 0.4 watt/m2 deg C is recommended for East and West walls. (HBRC,2006)
	Home office	• Provide space and services room to be used as a home office • A telephone line as well as a connection to the internet for data transference
Water Management	**Irrigation**	• Trickle is the most suitable system when water saving is required.
	House water Usage	• Grey water system • Rain water tank
Eco-Materials	**Low embodied energy**	• Concrete, loam, polyethylene, bitumen and soft wood • Use salvaged or reclaimed wood
	Recyclable materials	• Hollow concrete elements with reclaimed aggregate • Sand-Lime-Brick and cellular concrete are preferable
Eco-Sites	**Site selection**	• Check the site for contamination • Replace the soil with clean top soil.
	Eco-Garden	• Use row of trees to filter the house air • Locality is the basic rule for an eco garden.

Chapter 5: Case Study

5-1 Eco-House Challenges in Egypt

The old historical Egyptian temples and residences were among the first energy efficient buildings in the world based on the current knowledge of bioclimatic, green, desert, passive and ecological building principals.
The famous Egyptian well-known Hassan Fatty is a pioneer in ecological architecture that considers all above-mentioned issues in addition to the human and local culture dimensions in desert or arid areas.
Houses, and city walls was built based on sun baked bricks made of Nile mud and straw while stone structures were mainly used for temples and tombs.
The absence of rain, the scarcity of wood and abundance of sunshine made adobe the preferred building material. Not surprising, given the scarcity of fuel, the ancient Egyptian rarely used burned bricks.
The venerable art of building with adobe was adopted for all building; stones from rock were reserved for the dead.
Most of the ancient Egyptian buildings practices and culture have unfortunately almost disappeared leaving no trace in our modern massive building construction even among those, which are constructed in the middle of the desert.
The Giza pyramids are the oldest green structures in the world for several reasons:

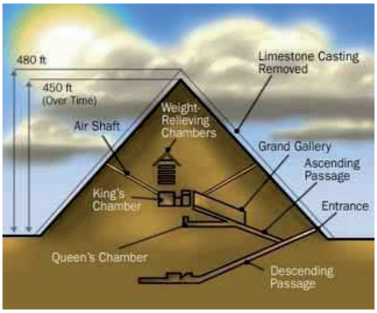


Figure (5.1) Inside the great pyramid of Khufu, Giza, Egypt (EGBC, 2010)

- Sustainable structural system (optimized geometry for High-Rise structure).
- Natural materials and Durability with minimum maintenance
- Natural ventilation and Lighting system
- Harmony with surrounding environment

5-1-1 Present & Future Challenges Facing Egypt

- The increase in population (1.3 million/year)
- Over concentration of population on 5% of total area of Egypt

- Concentration of urban population in the two main agglomerations (Cairo and Alexandria regions)
- An extra infrastructure system for about 60 million (2035) peoples are needed concentrated most probably in the desert and this requires a big amount of embodied energy as well as operating energy and effort.
- The limitation of conventional energy resources in Egypt
- Conventional technology as well as the use of high intensive energy industrial construction for production of building materials
- The construction sector produced around 30% of solid waste generation and this is considered one of the biggest challenges facing the population cities

Table (5.1): Population in Egypt

Year	Population (millions)	Area of agricultural land (M. Acres)	Individuals share (Acres)
1897	9.7	4.9	0.5
1966	33.2	6	0.2
1970	38.2	6.12	0.18
1990	55	7.2	0.13
2004	71	7.8	0.11
2008	78.6	8.43	0.107
2009	80	8.5	0.10

Source: Goueli, 2002

As shown in table (5.1), population in Egypt has increased from 9.7 million in 1897 to 80 million in 2009. Although, the area of cultivated land was gradually increased from 4.9 million acres in 1897 to about 8.5 million in 2009, the individual share decreased from 0.5 acre to 0.1 acre per person (Goueli, 2002)

5-1-2 Energy Efficiency in Egypt

Now, and almost 50 year later, Egypt's large population suffers from the magnitude of the same problems in addition to more and more reliance on and demand for energy. Despite the low electricity consumption rates in Egypt (1120 kWh/capita in 2002) compared to international consumption, electricity consumption for residential purposes increased by 12% in 2007 (Beshara, 2008). In summer 2008, the total electric demand peaked to 21,530 MW, compared to 19,250 in 2007. Consequentially, most governorates, especially Upper Egypt, witnessed daily blackouts ranging from 5 to 8 hours.

Analyses confirm that an increased penetration of energy intensive appliances in households is one of the major reasons. Additionally, since the beginning of the long hot summers in the last decade, the hot seasons have been extended from April to October. As a result, more than half of peak load of energy consumption is used to satisfy air conditioning demands alone. In 2008, annual sales of air conditioners reached 150,000 units. Consequently, air conditioning of buildings became the single largest consumer of electricity and it accounts for nearly 60% of the nation's peak power demand and over 30% (6,500 MW) of annual energy consumption in the residential sector. This demand is expected to grow annually by more than 12% (Beshara, 2008)

5-1-2-1 Energy Limitations

Energy is a critical resource needed for development. Apart from small quantities of coal in Sinai, fossil fuels in the form of oil and gas are known to exist around Gulf of Suez and the northern part of the western deserts. With the present increase in oil prices and its unsustainable production, as well as the international move against CO2 evolution caused by burning fossil oils, it is imperative that Egypt must devote more efforts to promoting the use of renewable energy (solar, wind, biogas, and biomass).

Table (5.2) Yearly energy production & consumption in Egypt (Unit = MOTE)

Year	1991/92	1999/2000	2004/2005	2019/2020
Production	55.10	60.70	69.70	104.00
Consumption	31.90	38.70	43.70	70.00
Balance	23.00	22.00	26.00	34.00

Source: Bishay, 2010

The changes in production and consumption of oil & gas are showed in table (5.2) over the period from 1991 to 2020. Although the balance shows an increase, it should be emphasized that Egypt in most cases has to pay 50% of the production to the foreign partner. (Bishay, 2010)

- **Concerning Primary Energy:**

In 2007, Egypt's primary energy total consumption was 63 MTOE. This is expected to reach 210 MTOE by 2030. (MTOE: Million Tons Oil Equivalent)

In 2007, primary energy consumption was mainly in industry (34%) and residential and commercial buildings (23%). The later is expected to reach more than 35% by 2030. Different studies have shown that the primary energy supply will not meet demand starting from 2015; this gap is widening after 2020. (Beshara, 2008)

- **Concerning Electricity:**

In 2007, current installed capacity was 22000 MW. This is expected to reach 74000 MW by 2030. This would require the addition of more than 50000 MW. The peak demand was 18500 MW. It is expected that this demand will reach 62000 MW by 2030. (Beshara, 2008)

In 2010, electricity consumption in residential (39.9%), industry (32.6%), commercial (8.1%) and governmental (4.7%), buildings reached 58% of total electric energy demand in Egypt. (Ministry of Electricity and Energy, 2010)

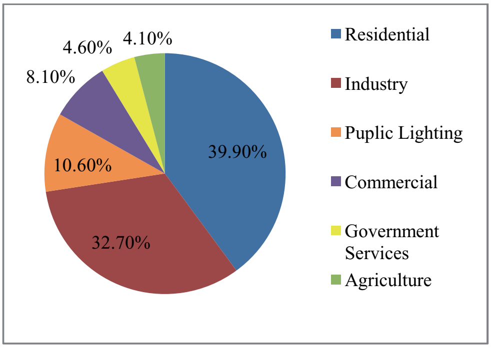


Figure 5.2 Electricity Consumption in Egypt, (Ministry of Electricity & Energy, 2010)

5-1-2-2 Renewable Energy

Renewable energy represents an important option for the change in energy mix. In 2009, renewable energy, mainly hydropower, accounted for 12 per cent of Egypt's electricity generation. Egypt's hydropower potential is about 3,664 MW with an estimated energy of 15,300 GWh per annum. Renewable resources wind and solar energy offer significant potentials. (Med-Enec, 2010)

Figure (5.3) Wind energy, Red Sea, Egypt

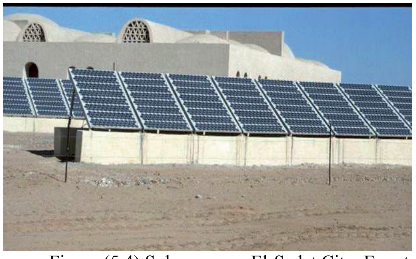


Figure (5.4) Solar energy, El-Sadat City, Egypt

- **Wind Energy**

Egypt is endowed with an abundance of wind energy resources especially in Suez Gulf area which considered one of the best sites in the world due to high and stable wind speeds. The west of Suez Gulf zone is the most promising sites to construct large wind farms due to high wind speeds which ranges between 8-10 meter/second in average, proximity to load centers and transmission infrastructure, and availability of large uninhabited desert area. There are also other promising sites having wind speed of 7-8 meters/second in the east and west of Nile River near Beni-Suef, Menia and El-Kharga Oasis in the New Valley. (Med-Enec, 2010)

- **Solar Energy**

Solar energy is also rather abundant. Due to its geographic location, Egypt enjoys sunshine all year, with direct solar radiation which reaches 6 KWh/m2/year. The present energy

strategy (the resolution adopted by supreme council on energy in 2007) aims at increasing the share of renewable energy to 20 percent of the energy mix by 2020. (Ahmed, 2002)
This target is expected to be met largely by scaling-up of wind power as solar is still very costly and the hydro potential is largely utilized. The share of wind power is expected to reach 12 percent, while the remaining 8 percent would come from hydro and solar.
This translates into a wind power capacity of about 7200 MW by 2020. The solar component is at this stage considered to start with 100MW of CSP and 1 MW of PV power. (Med-Enec, 2010)

- **Egyptian Residential Energy Code**

In order to reduce the energy consumption in buildings, the Housing and Building Research Centre in collaboration with UNDP & JEF has produced an Egyptian residential energy code to improve the efficient use of electrical energy. The code gives minimum performance standards for building envelope, windows and openings, natural ventilation and thermal comfort, natural and artificial lighting. A great effort has been made to insure its applicability in our buildings here in Egypt specifically to the general climatic conditions of Cairo. (Egyptian residential energy code, 2006)

5-1-3 Water Management in Egypt

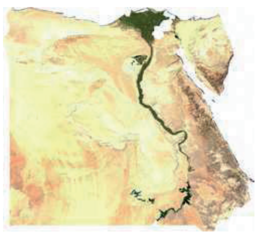


Figure (5.5) Green irrigated land along the Nile amidst the desert (Ministry of Water Resources, 2008)

The management of water supply and sanitation is practiced since at least 5000 years ago in Egypt. At that time, it was a challenge how to make use of flash floods. Like today, agriculture was the major water-consuming sector and therefore ancient Egyptians focused mostly on irrigation. Ancient Egyptians had only one season in which they cultivated the lands, which were enough since the population was much, lower than today.

5-1-3-1 Recent development

The current problems and scenarios for the future are putting Egypt in a situation to review its water policy. In order to meet new challenges which refer to water scarcity, infrastructural needs, environment, socio-economic developments and water allocation, new solutions concerning conservation and protection and thus new policies are needed. For those reasons, the National Water Resources Plan has been established. The whole idea is based on an integrated water resources management approach. The plan has three major steps:

- Cooperation with Nile basin riparian countries and the development of new water resources

- Increasing the water use efficiency and making better use of the existing water resources.
- Protection of water quality and environment

Recent developments in Egypt are also concerned with private participation processes. Furthermore, Egypt is engaged in several mega projects like Toshka, North Sinai and South Valley. (Ministry of water Resources and irrigation, Egypt 2005)

5-1-3-2 Current Water Resources

Egypt depends for 97% of its water supply on the Nile. Rainfall is minimal at 18 mm per year, occurring mainly during autumn and wintertime. The 1959 Nile waters treaty between Egypt and Sudan allocates 55.5 billion cubic meter of water per year to Egypt, without specifying any allocation for upstream; riparian is besides Sudan (18.5 billion cubic meters per year). There is no water sharing agreement among all ten riparian countries of the Nile. However, the riparian countries cooperate through the Nile Basin Initiative. (Ministry of water Resources and irrigation, Egypt 2009)

Table (5.3): Water Resources in Egypt (billion meters cube/year)

Source	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2009
Nile	55.5	55.5	55.5	55.5	55.5	55.5	55.5
Ground Water	5	5	5.5	5.9	6.2	6.6	6.6
Treated waste Agricultural	4.4	4.8	5.1	5.3	5.9	6.7	7.8
Municipal Treated waste	0.7	0.8	0.9	1.1	1.3	1.55	1.8
Floods & Rain	1	1.1	1.1	1.1	1.3	1.3	1.3
Water Sea desalination	0	0	o	0.06	0.06	0.06	0.06
Total	66.6	67.2	68.1	68.96	70.26	71.71	73.06

Source: Beshay, 2010

Egypt has four main groundwater aquifers: the Nile Aquifer, the Nubian Sandstone Aquifer, the Moghra Aquifer between the West of the Nile Delta and the Qattara Depression, and coastal aquifers on the North western coast. The Nile Aquifer, the Moghra Aquifer and the Coastal Aquifer are renewable. The Nubian Sandstone Aquifer is non-renewable. (Ministry water Resources and irrigation, Egypt 2009)

5-1-3-3 Water Scarcity

Egypt's water resources based on current agreements range from a total of 66.6 billion cubic meters in 2002/2003 to 73.06 billion cubic meters in 2008/2009 (as shown in table 5.4) these amounts are distributed between agricultural use (from 57.8 to 60.5 billion m^3 /year), to domestic, industrial and other uses as shown in table (5.5).

Table (5.4): Water Consumption in Egypt (billion meters cube/year)

Sector	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2009
Agriculture	57.8	58.5	58.5	59	59.3	60	60.5
Evaporation losses	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Domestic uses	5.4	5.7	6.05	6.5	7.5	8.2	9
Industry	1.1	1.1	1.15	1.15	1.15	1.2	1.25
River Navigation	0.2	0.2	0.3	0.2	0.2	0.2	0.2
Total	66.6	67.2	68.1	68.95	70.25	71.70	73.05

Source: Beshay, 2010

5-1-3-4 Water Use

Egypt is using around 95 % of the available water, which is very critical. Around 86 % of water is used for irrigation, 8 % for domestic purposes and another 6 % by industry (FAO, 2009).

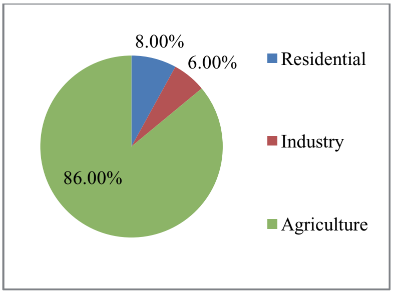


Figure (5.6) Water use allocation in Egypt (FAO, 2009)

The individual annual share of current and expected available water has decreased from 2604 m^3/year in 1947 to 860 m^3/year in 2003 and expected to come down to 582 m3/year with increasing population (table 5.6). Egypt has been facing scarcity of water (share of less than 1000 m3/year) since 1996 (AboZeid, 2008).

Table (5.5): Average Individual's share of water (past, present and future) Unit = m^3

Year	Average Individual's share of water (m^3/year)	Change in Individual's share (%) compared to 1947
1947	2604 (water plentiful)	-
1960	1893	-27.3%
1970	1713 (sufficiency water)	-34.2%
1986	1138	-56.2%
1996	936 (water scarcity)	-64.1%
2003	860	-67%
2025 (expected)	582 (poverty water)	-77.6%

Source: Beshay, 2010

5-1-4 Materials in Egypt

Egypt was divided into eight areas:
North of Sinai, South of Sinai, Delta (East of Delta-East of Tafreea), Suez Gulf (Red Sea), Nile valley, Toshka region (South of the valley), Western Northern Coast and West Delta, and Oasis & East of the Oaynat.

5-1-4-1 Egypt map of available raw building material and its industries

- Clay, Sand, Gravel, Basalt, Granite, Steel, Sand stone, Lime stones& Dolomite, Gypsum and Marble

- **Raw Building Materials Sites in Egypt**

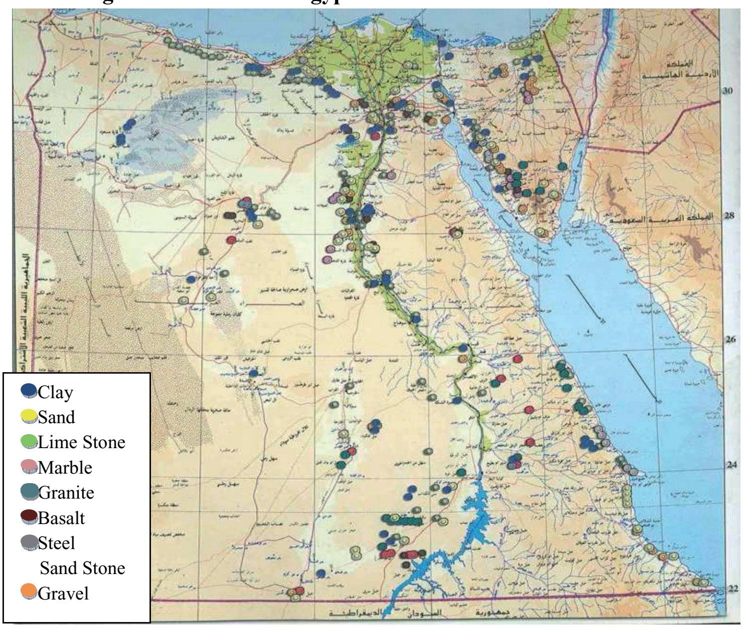


Figure (5.7) Raw building materials sites in Egypt (HBRC, 2008)

5-1-4-2 Building Materials Manufacture Sites in Egypt

Table (5.6) The raw materials found in each area in Egypt

Materials	Location
Clay	Present abundantly in all different eight areas that were previously mentioned, and it is qualified for use in manufacture of clay bricks.
Lime stone	Present in most of the eight areas, and is qualified for use in lime blocks and lime bricks.
Marble	North of Sinai – South of Sinai – Suez Gulf and Red Sea – Nile Valley, and it

Materials	Location
	is qualified for use in cladding
Granite	South of Sinai – Nile Valley – Toshka region and South of the valley – Oasis and East of Oaynat, but it is abundantly found in Aswan and Quina where it is red in colour and of very high resistivity, it is qualified for use in cladding and manufacture of concrete bricks and tiles.
Sand	White sand is abundantly found in North of Sinai and it is known for its high purity, which qualifies it for use in glass manufacture. Sand located in South of Sinai – Suez gulf and red sea – Oasis and East of Oaynat areas is unqualified for use in construction works such as concrete works, mortar and plaster. Sand located in other areas is qualified for use in construction works and in manufacture of clay, sand and concrete bricks.
Gravel and gravel soil	Located in all areas except in Toshka region and South of the valley - Western Northern Coast and West of Delta. It is qualified for use in concrete works in all areas except South Sinai
Basalt	Located in South of Sinai – Suez gulf and red sea – Nile valley - Oasis and East of Oaynat, and Toshka region and South of the valley, it is qualified for use as aggregate in concrete works and manufacture of concrete bricks and in road paving.
Gypsum	Located in South of Sinai – Suez gulf and red sea – Western Northern Coast and West of Delta, it is qualified for use in wall cladding and in manufacture gypsum boards.
Steel	Located in the Nile valley, Oasis and East of Oaynat
Sand Stone	Located in the Nile valley, Oasis and East of Oaynat, it is qualified for use in construction works.

Source, HBRC, 2008 (Made by the researcher)

5-1-4-3 Using Recyclable Materials in Construction

- Using the new type of bricks were created in HBRC in order to make use of solid wastes such as: wastes of ceramic tiles , waste of clay brick and wastes of by- pass cement dust

- Using the thermally insulating clay and cement bricks that contain rice straw

- **Enhancing Building Bricks**

Efforts were made to enhance building bricks because of two reasons:

-To decrease the U value and thermal capacity in order to fit in arid conditions
-To produce a recyclable building bricks with low environmental impact

Bricks were created by HBRC in order to make good use of solid wastes in its different forms.

Figure (5.8) Thermally insulating clay bricks and cement bricks that contain different percentages of rice straw (HBRC, 2006)

5-1-5 Waste Management in Egypt

Solid wastes are considered one of the most important environmental problems in Egypt. According to statistics of environmental ministry, the total amount of solid wastes in Egypt reached 60 million tons annually and that included the following: Industrial wastes, construction & demolition wastes and agricultural wastes…etc.

5-1-5-1 Building Materials Industrial Wastes

- Wastes of ceramic tiles during manufacture
- Wastes of clay brick industry
- Wastes of by-pass cement dust

5-1-5-2 Agricultural Waste

One of the most important examples of agricultural waste in Egypt which caused many troubles is rice straw, where the amount of rice straw reached 2 million tons per year. (Ministry of Environmental Affairs, 2010) the peasants have tried to get rid of it by burning it but this caused what is called “the black cloud” which caused lots of illnesses bedsides and pollution. The burning process raised the soil temperature and emits the ammonia, which present in the soil; and so the soil loses a great amount of one of its most important elements. According to HBRC, studies and the results came out as follow:

-Production of low density construction units using rice straw

-Production of thermally insulated construction units which contain rice straw

- Production of gypsum boards that contain rice straw

5-2 Case Study: Renovation of Railways Training Institute, Wardan, North Cairo, Egypt

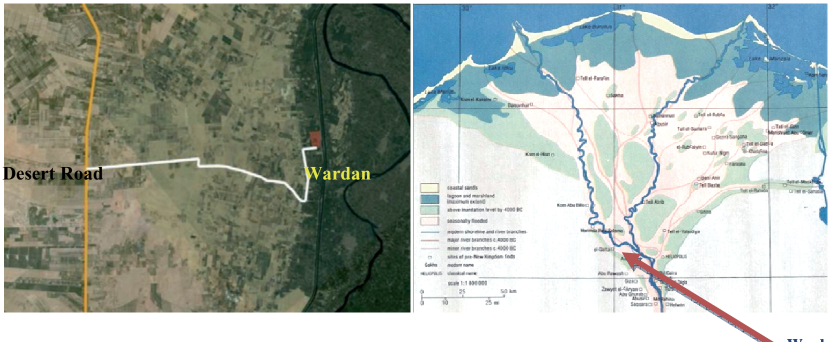


Figure (5.9) Wardan institute, North Cairo, Egypt (Google Maps, 2010)

Location

Wardan Training Institute is located at kilo 58 Cairo/Alexandria desert road, North Cairo, Egypt. It is located at latitude 30° 22'N, and longitude 30° 27'E, and it is 50 kilometres north-west Cairo.

Area: Wardan institute area is 150 acres with its 20 acres isolated garden (1 km South Campus)

Design: Architect: Ezat, H. Abougad, Alexandria, 1964 (Who was one of the pioneers in the Egyptian architectural in the 20th century.)

Background:

The railway industry is considered a special type of industry that requires a certain technical and cultural level of employees, which cannot be obtained from the usual schools or institutes or universities. Egyptian railway training centres were established as the following:

-House of Education (Taaleem-Khana), and was located in the Shobra District, Cairo 1866.
-The school of Arts and Industry (Primary School Certificate), Cairo, 1882
-The Telegraphy School, Demerdash Station, Cairo, 1907
-The School of Arts and Industry (General Secondary School Certification), Cairo, 1930
-Wardan Institute Training Centre, 6 of October, 1968 (Egyptian Railways, 1977)

The existing Training centres proved to be insufficient to cover the recent development in the field and incapable of handling the large number of trainees required to perform the work efficiently, especially during and after the completion of the new projects aiming at the evolution of the organisation, it was decided to construct a vocational training centre up to the standard and level of similar international training centres to fulfil the following:

-Recruitment training for beginners in all railway trades and occupation
-Refreshment training to increase the production efficiency of the employees
-Advanced training of staff ready for promotion to higher posts

Figure (5.10) Wardan institute site (Google Maps, 2010)

On November 29th, 1966, the agreement for the execution of a work plan was concluded with the International Development Association (I.D.A.) of the United Nations and International Labour Organization (I.L.O.). The participation of these organizations in Wardan project with experts and modern equipments, in addition to the mission granted under its financing played a great part in the success of the establishment of this training centre according to the modern international systems.

After singing this agreement, the work on the project started on an area of 150 acres at Wardan; a small city situated at a distance of 50 kilometres from Cairo. This site was chosen to build the institute far from the town atmosphere, with its prevailing occupations of life, in order to encourage the trainees to confine themselves exclusively with their studies and the acquirement of knowledge. This is the case in most of the railways Training Centres in Europe and Japan. (Egyptian Railways, 1977)

Figure (5.11) Wardan institute perspective after the renovation project (Abou-Gad, 2008)

This institute was designed to be a complete self-sufficient establishment with full accommodation for staff and their families together with the trainees. Trainees receive full board in order to allow them to concentrate on their studies and the

acquirement of knowledge for intervals varying according to the prescribed training programmes laid down by the mutual agreement between the railways and I.D.A. experts.
Training was started in 1968 and it is anticipated to fully complete this institute in 1978.
The total expenses of this project after the completion of constructions in 1978 was 7.6 million Egyptian pounds passed on the joint report between the railways and the United Nations representatives from both I.L.O. and I.D.A. (Egyptian Railways, 1977)
Wardan institute was completed actually in 1994. (Abou-Gad, 2008)
In 2007, an agreement was concluded between the ministry of Transport and Arab Academy for Science & Technology and Maritime Transport to renovate and upgrade the institute to be an advanced training centre in Egypt, through the academy experiences in the education and training field.

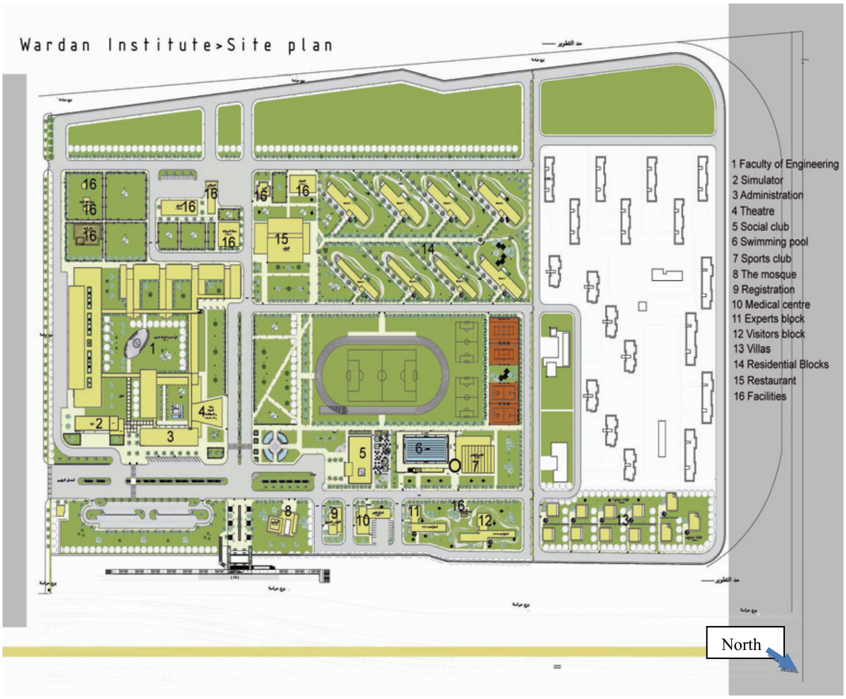
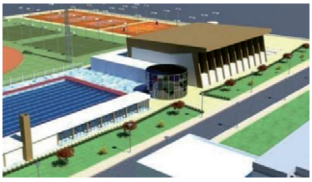


Figure (5.12) Wardan institute master plan "scale 1/5000" (Abou-Gad, 2008)

5-2-1 Project Description

Wardan Institute contents:
Educational zone - Residential zone - Recreational zone - Services zone

Table (5.7): Wardan campus description

Wardan Zones	Description
Educational Zone  Figure (5.13) Educational zone (Abou-Gad, 2008)	-Workshops building (24 workshops) - Labourites (14 labs) -Classrooms (47 classrooms, 3 drawings halls, conference hall and staff offices) - Main Library - Administrational building
Residential Zone  Figure (5.14) Residential zone (Abou-Gad, 2008)	-Students Housing (288 double rooms) -Visitors Housing (15 double rooms) -Experts Housing (36 double rooms) -Staff Housing (18 blocks with 280 flats) -Executive villas (8 villas with 360 m2, 3 villas with 600 m2)
Residential Zone  Figure (5.15) Recreational zone (Abou-Gad, 2008)	Olympic swimming pool -Sports hall -Social club -Sport courts (football, basketball, volleyball, tennis and running track) - Theatre
Services Zone  Figure (5.16) Services zone (Taken by the researcher, 2010)	-Main restaurant & Main Kitchen -Laundry - Bakery - Electrical Station -Water Station - Boilers Station - Schools -Super Market - Clinic - Registration building - Inside Train Station - Mosque -Parking Area - Fire Fitting Department

Staff Housing Area  Figure (5.17) Staff housing villas (A) (Taken by the researcher, 2009)	- 18 housing units with 4 floors - 8 villa with 2 floors (total area 360 m2) villa (A) - 3 villa with 2 floors (total area 600 m2) villa (B) - 3 schools - Super Market
Executive Villa (a), 2009  Figure (5.18) Villa (a) northwest perspective  Figure (5.19) Villa (a) southwest perspective	**Executive Villa (b), 2009**  Figure (5.20) Villa (b) northwest perspective  Figure (5.21) Villa (b) south elevation

5-2-1-1 Staff Housing Unit Description

Orientation: All villas are oriented to north, south. All villas are with two stories

Ground Floor: Entrance hall, living area, dining room, office room, kitchen, housekeeper room, toilet and terraces

First floor: Three bedrooms, bathrooms, upstairs sitting area, kitchen, toilet and terraces

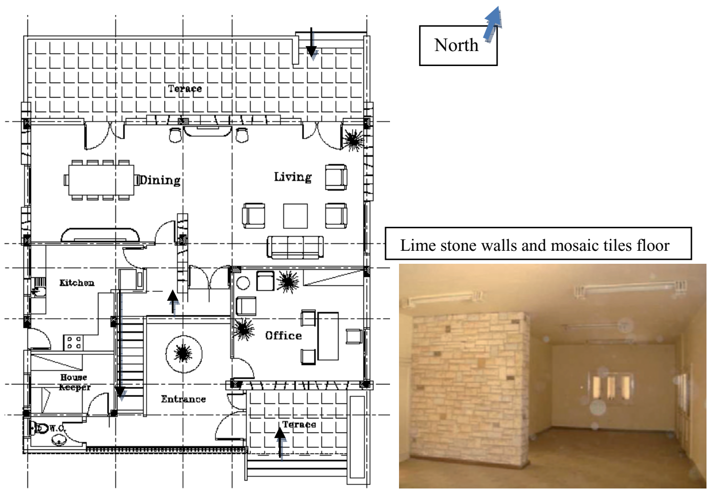


Figure (5.22) Existing villa (a) ground floor plan 1 /200& existing living and dining materials, 2009

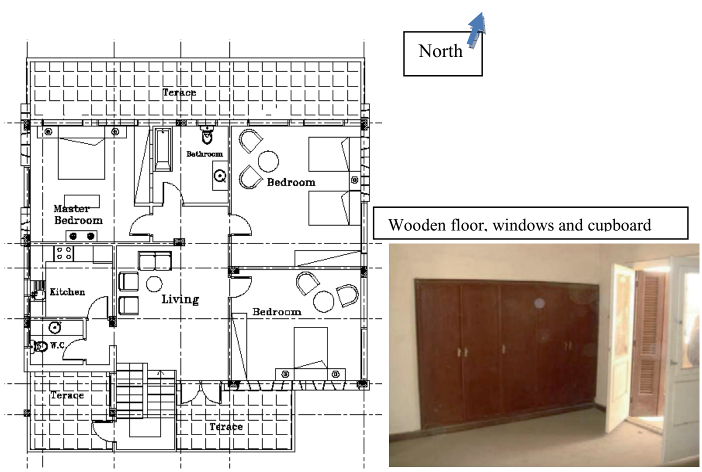


Figure (5.23) Existing villa (a) first floor plan scale 1/200 & existing bedrooms materials, 2009

- **Existing Villa (a) Materials:**

Table (5.8): Existing Wardan villa (a) materials, 2009

Items	Flooring	Walls	Windows	Doors	Piping	Energy
Entrance and Living & Dining area	Mosaic tiles	Cement plastering	Soft wood shutters and glass	Painted soft wood	_	Electricity
Office	Soft wood	Cement plastering	Soft wood shutters and glass	Painted soft wood	_	Electricity
Kitchen	Ceramic tiles	Ceramic tiles	Soft wood and glass	Painted soft wood	Lead, asbestos and steel	Electricity
Bedroom	Soft wood	Cement plastering	Soft wood shutters and glass	Painted soft wood	_	Electricity
Bathroom	Ceramic tiles	Ceramic tiles	Soft wood and glass	Painted soft wood	Lead, asbestos and steel	Electricity
Terrace	Mosaic tiles	Cement plastering	Soft wood shutters and glass	Soft wood shutters and glass	_	Electricity
Roof	Cement tiles	Cement plastering	_	_	Cast iron	_
Elevations	_	Mud brick with cement plastering and lime stone	Soft wood shutters and glass	Painted soft wood	Cast iron	_

(Made by the researcher)

Water: Surface water from the Nile and ground water from two wells are the main water sources in the Wardan campus. Electrical is using to heat the water.

5-2-2 Applying the Ecological Design Guidelines in the Case Study

5-2-2-1 Proposed Case Study Redesign

- **Modified Ground Floor** (figure 5.24)

  - Living & dining area become open area after removing the doors, which closed them towards the main entrance hall to allow the air movement from north to south direction in the ground floor.

  - Wind catchers (air malqaf) are located in the ground floor living area to supply the cold air from lower inlets and exit the hot air to the south malqaf beside the main entrance.

  - Double walls (existing lime stonewall from outside, 5 cm reinforced foam panel "thermal insulation", and rammed earth plastering from inside) are located at the villa walls.

  - Keep the office room in the ground floor for working from home, and open the access door to outside the villa.

Figure (5.24) Proposed ground floor plan "scale 1/200"

- **Modified First Floor** (figure 5.25)

  - The modified first floor plan is provided a master bedroom which contains a private bathroom, extent the second bathroom towards the unused south terrace (50% of south terrace was taken), and modified the kitchen door location

  - Wind catchers (air malqaf) in the first floor (bedrooms) to supply the cold air from lower inlets and exit the hot air to the south malqaf and to the stair windows over the roof.

- Double walls (existing lime stonewall from outside, 5 cm foam reinforced panel “thermal insulation”, and rammed earth plastering from inside) are located at the villa walls.
- Stair clearstory is extent above the roof to exhaust the hot air from the first floor & the stair space along the villa, and provide the villa day lighting through its windows.

Figure (5.25) Proposed first floor plan “scale 1/200”

5-2-2-2 Indoor Environmental Quality

- Remove all lead pipes, asbestos pipes, and water supply iron pipes from villa
- Using polypropylene pipes for water supply and polyethylene pipes for drainage system

Figure (5.26) Existing bathroom & Poly polypropylene pipes in water supply system in the villa bathrooms (Taken by the researcher, 2010)

- **Proposed Indoor Materials**

- Water supply system is a poly polypropylene pipe.
- Sewage system is a polyethylene pipes
- In order to avoid the growth of legionella, thermostats in water tanks should be set to 55 deg C and lipped fitted lids should be placed securely over water tank.
- All cracks and openings in the villa should be sealed.
- Rammed earth plastering is used and could be mixed with cement
- Using water-based eco-paints and varnishes that do not contain ammonia
- Put a plant at villa to clean up the internal air quality.

5-2-2-3 Energy Efficiency (Photovoltaic Panels)

- **Solar Energy**

Using photovoltaic panels to generate electricity & hot water

- **Photovoltaic System Design**

The average solar input over the year, H (kWh/m^2/day):

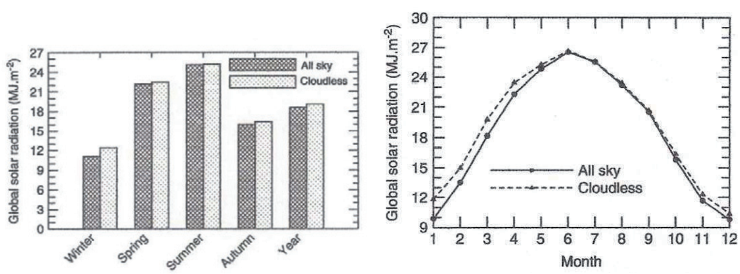


Figure (5.27) The monthly average values of daily solar energy (MJ/m$_2$/day), Cairo region. (Robaa, 2006)

According to the figure (5.27), the average solar input over the year at Cairo region and its environs is 19.11 MJ/m^2/day (Robaa, 2006). To transfer the loads from MJ/m^2 to kWh/m^2 use the following equation:

Average H = 19.11 MJ/m^2 ×0.2778 = 5.31 kWh/m^2/day

Table (5.9): The monthly mean values of cloudiness in the Cairo region

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Clear Sky	22	21	26	28	29	30	31	31	30	29	26	25
Cloudy Sky	2	1	0	0	0	0	0	0	0	0	0	1
Partial cloud sky	7	6	5	2	2	0	0	0	0	2	4	5
Season	**Winter**			**Spring**			**Sumer**			**Autumn**		
Clear Sky	23			28			31			28		

Cloud Sky	1	0	0	0
Partial cloud Sky	6	3	0	2

Source: Robaa, 2006

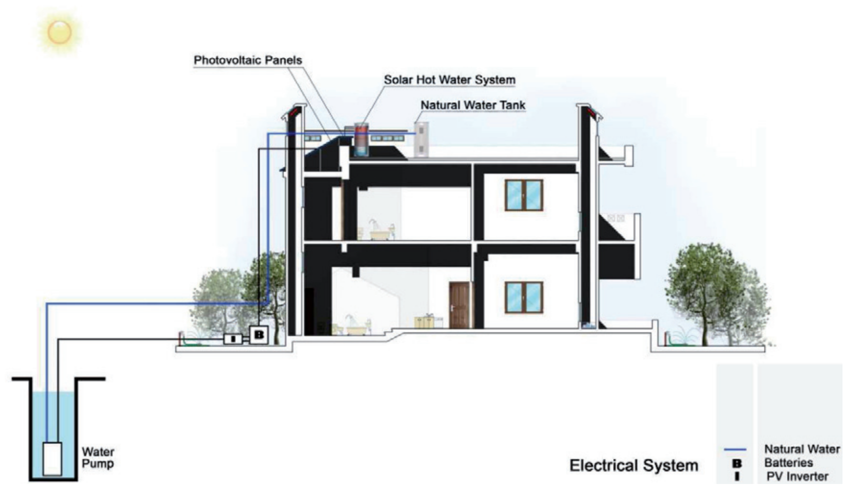


Figure (5.28) Photovoltaic and solar hot water system (water is taken from 25m underground)

- **Calculating the average daily load energy requirements:**

Water pumping is an important item in designing PV systems; the depth of the water level in Wardan campus is 25m under ground level.

Water required in the villa = 2 m^3/day

$$Pe = \frac{p\ gh\ Q}{\eta p\ \eta m} \qquad \text{(Buresch, 1983)} \qquad (3)$$

Assuming that ηp= 0.45 and ηm =0.85, Q=0.5 m^3/h and h= 33.5 m

Pe (Electrical Power of Water Pump)= 120W

Figure (5.29) Proposed photovoltaic panels in the south villa elevation (made by the researcher, 2011)

Table (5.10): The daily load energy requirement for Wardan villa (a) unit

Load	No. of units	Load power (W)	Winter operating periods/day	Spring operating periods/day	Summer operating periods/day	Autumn operating periods/day
DC lamps (light)	18	6×60 12× 40	From 17.00 to 22.00	From 19.00 to 23.00	From 20.00 to 24.00	From 19.00 to 23.00
Refrigerator AC	1	100	24 h/day	24 h/day	24 h/day	24 h/day
TV & Receiver DC	1	80	From 17.00 to 22.00	From 18.00 to 23.00	From 17.00 to 24.00	From 18.00 to 23.00
Computer & Printer DC	1	100	From 17.00 to 19.00	From 18.00 to 20.00	From 19.00 to 21.00	From 18.00 to 20.00
Washing machine AC	1	250	From 12.00 to 14.00	From 12.00 to 15.00	From 12.00 to 16.00	From 12.00 to 15.00
Electric Fan DC	8	45×8	_	From 12.00 to 17.00	From 11.00 to 19.00	From 12.00 to 17.00
Motor + Pump AC	1	120	From 12.00 to 14.00	From 11.00 to 14.00	From 10.00 to 14.00	From 11.00 to 14.00
Total Energy (W h/day)			**7940**	**9020**	**10880**	**9020**

(Calculated by the researcher, 2011)

The average daily load energy of villa "a" = **9.215 kWh/day** from table (5.10)

- **PV array sizing**

PV (Area) = $E_L / H \times \eta_{PV} \times TCF \times \eta_{out}$ (Buresch, 1983) (4)

If the cell temperature is assumed to reach 60 C°, then the temperature correction factor (TCF) will be 0.8 (as introduced by Buresch, 1983). Assuming $\eta_{PV} = 17\%$,
$\eta_{out} = 0.85 \times 0.9 = 0.765$

PV (Area) = $9.215 / 5.31 \times 0.17 \times 0.8 \times 0.765 = 16.6\ m^2$ (5)

PV cost according to the market price = 9215 w/h × 1.3$= 10136$ (6)

- **Design of the storage system:**

Battery storage = $N_C E_L / DOD \times \eta_{out}$ (Ahmed, 2002) (7)

N_C : Number of continuous cloudy days according to table (5.9) = 2days(in the worst case)
DOD: The allowable depth of discharge for the batteries

Battery storage = 9.215×2 / 0.8×0.765 = 30114 W h

If a 24 V system is chosen the required amp. Hours of batteries = 30114/24= 1254 AH
If 2V blocks with 1254 AH each are chosen, 12 batteries (2V, 1254 AH) connected in a series

are needed. This battery bank can drive the loads for continuous 2days without any sunshine. The battery charge controller is chosen to maintain a longer lifetime for the batteries.

DC/AC Inverter

The inverter has to be capable of handling the maximum expected power of AC loads. Thus, it can be chosen 20% higher than the rated power of the summation of AC loads. Total power of AC loads = 100+250+120= 470 ×1.2 = 564 W

The specifications of inverter will be 564W, 24 V_{DC}, and 220 V_{AC}.

- **The life cycle cost of photovoltaic system proposal**

From the economical viewpoint, photovoltaic energy systems differ from conventional energy systems in that they have high initial cost and low operating costs.

The price of the PV system and its installation are important factors in the economics of PV systems. These include the prices of PV modules, storage batteries, and the control unit, the inverter, and all other auxiliaries. The cost of installation must be taken into consideration.

For the present PV system, the life cycle cost will be estimated as follows. The lifecycle of the system components will be considered as 25 years except for the batteries, which will be considered to have a lifetime of 8 years. In addition, the annual inflation rate in batteries prices is considered 8.58% and the market discount rate as 8.5%. (Central Bank of Egypt, 16-12-2010)

The cost of the first group of batteries (*A*) =

No. of batteries * cost of battery = 12×250$ = 3000$ (8)

The present worth of the second group of batteries (after 8 years)

$$p = \frac{\mathbf{A\,(1+i)^{n-1}}}{\mathbf{(1+d)^{n}}}$$ (Ahmed, 2002)

$$= \frac{3000(1+0.0858)^{7}}{(1+0.085)^{8}} = 2763\$ \quad (9)$$

The present worth of the third group of batteries (after 16 years)

$$= \frac{3000(1+0.0858)^{15}}{(1+0.085)^{16}} = 2557\$ \quad (10)$$

The initial cost of PV system = PV array cost (according to the market price) + first group of batteries cost + BCC cost + inverter cost + auxiliaries cost

A = 10136+ 3000 + 1000+ 600 + 250 = 14986$ (11)

The PV system installation cost can be estimated as 10% of the initial cost. Also, the annual maintenance and operation cost is about 1% of the initial cost.

Life cycle cost = Initial cost of PV system + Installation cost +Maintenance and operation cost. (12)

Substituting from equations (9), (10) and (11) into equation (12):

Life cycle cost = 14986 + (0.1× 14986) + (2763 + 2557) + (0.01×25×14986) = 25549$

The life cycle output energy = 9.215×365×25 = 84086 kWh.

The cost of 1 kWh from the PV generator = 28067.5 / 84086 **= 0.30$/kWh**

- **The Diesel Generator System** (not recommended in the ecology strategies)

If a diesel generator is used to feed the house in question with its energy requirements, then it is important to estimate its life cycle cost. This will give an indication of the difference in energy cost between PV systems and diesel generator systems.

To estimate the diesel generator life cycle cost, there are some assumptions:

- Two diesel generators will be used, each with a power capacity of 5 kW.
- The diesel generators need reviving every 4 years. The cost of reviving is about 20% of their initial price.
- The cost of annual maintenance, operation and oil changing is about 5% of the initial price.
- Fuel consumption is about 10 l/day.
- The inflation rate in prices is about 8.58%, while the market discount rate is about 8.5 %. (Central Bank of Egypt, 16-12-2010)

The life cycle cost of diesel generator system = Initial cost + (present worth of 20% from the initial cost x 6 times reviving) + (Present worth of 5% from the initial cost for maintenance, operation and oil changing) + (Present worth of fuel consumption for 25 years)

Initial cost (according to the market price) = 2*2000$/ unit = 4000$ (13)

Present worth of reviving $= \frac{A\,(1+i)^{n-1}}{(1+d)^{n}}$

for N= 4,8,12,16,20,24 where, in this equation, A= 20% from the initial cost:

Present worth of reviving = $(0.2 \times 4000)\left[\frac{(1+0.0858)^{3}}{(1+0.085)^{4}} + \frac{(1+0.0858)^{7}}{(1+0.085)^{8}} + \frac{(1+0.0858)^{11}}{(1+0.085)^{12}} + \frac{(1+0.0858)^{15}}{(1+0.085)^{16}} + \frac{(1+0.0858)^{19}}{(1+0.085)^{20}} + \frac{(1+0.0858)^{23}}{(1+0.085)^{24}}\right] = 4420\$$ (14)

Present worth of maintenance, operation and oil changing

$= \frac{A\,(1+i)^{n-1}}{(1+d)^{n}}$ Where N from one to 25 years, and A = 5% from initial cost.

$= \frac{(0.05 \times 4000)(1+0.085)^{n-1}}{(1+0.0858)^{n}} = 4425\$$ (15)

- **Present worth of fuel consumption for 25 years:**

$\sum_{n=0}^{n=25} \times \frac{A\,(1+i)^{n-1}}{(1+d)^{n}}$ where N from 1 to 25 years, and A = first year fuel cost = 10 L/day

A= 10× 365×0.24 = 876 $ (16)

Present worth of fuel consumption for 25 years = $\sum_{n=0}^{n=25} \times \frac{876\,(1+0.0858)^{n-1}}{(1+0.085)^{n}}$ = 19342$ (17)

The life cycle cost of diesel generator system = Initial cost + Present worth of reviving + Present worth of maintenance, operation and oil changing (18)

Substituting from equations (13), (14), (15) and (17) into equation (18):

The life cycle cost of diesel generator system = 4000+4420+4425+19342=32187$

The life cycle output energy=9.215×365×25= 84086.8 kWh

The cost of 1 kWh from the diesel generator = 32187/84086.8 = **0.39$/kWh.**

Table (5.11) Comparing between electricity cost using PV panels & diesel generator

Items	Photovoltaic Panels	Diesel Generator
Electricity Cost (kWh)	**0.30$**	**0.39$**

- **Life Cycle Cost of Unavailable Local Electricity without the Governmental Subsidization**

To feed Wardan institute (100,000 m^2 built area) with the local electricity from the south Cairo electricity company it will cost approximately 4$ million. (Abougad, 2008)
4$million / 100000 m^2 = 40$/ m^2
Villa (a) Electricity cost (Initial cost) = 360 $m^2 \times$ 40$ = 14400$ (19)
Yearly electricity bill without G.S. = 9.125 × 365 × 0.17$ = 567$
Present worth of electricity consumption for 25 years $=\sum_{n=0}^{n=25} \times \frac{A\,(1+i)^{n-1}}{(1+d)^{n}}$

$$= \sum_{n=0}^{n=25} \times \frac{567(1+0.0858)^{n-1}}{(1+0.085)^{n}} = 12530\$ \qquad (20)$$

The life cycle cost of electricity without G.S. = 14400+12530=26930$
The life cycle output energy = 9.215×365×25 = 84086.8 kWh
The cost of 1 kWh from the electricity without G.S. = 26930/84086.8 = 0.32 $/kWh

- **Life Cycle Cost of Local Electricity with the G.S. (Just in case)**

Initial cost of local electricity = 2000$ (Egyptian Railways, 2010)

Yearly electricity bill with G.S. = 9.125 × 365 × 0.05$ = 167$

Present worth of electricity consumption for 25 years

$$= \sum_{n=0}^{n=25} \times \frac{167(1+0.0858)^{n-1}}{(1+0.085)^{n}} = 3690\$ \qquad (21)$$

The life cycle cost of electricity with G.S. = 2000+3690=5690$
The cost of 1 kWh from the electricity with G.S. = 5690/84086.8 = 0.07 $/kWh

Table (5.12) Comparing between electricity cost (kWh) using PV panels, diesel generator and unavailable electricity versus in case the local electricity supply is valid (with/or without government subsidisation)

Items	Photovoltaic Panels	Diesel Generator	Unavailable Local Electricity without G.S.	Local Electricity with G.S. (Just in case)
Electricity Cost (kWh)	**0.30$**	**0.39$**	**0.32$**	**0.07$**

This study shows that the providing Wardan staff-housing unit with the energy supply is:

1. Life cycle cost of the local electricity with the government subsidisation (which is not available in the Wardan site) is less than the photovoltaic system. If this case is valid it will not a permanent case in the nearest future in Egypt.

2. Life cycle cost of photovoltaic system is less than that of the diesel generator system and unavailable electricity supply (without the government subsidisation)
3. In addition to the photovoltaic systems are clean and renewable sources of energy; they do not cause pollution during their use.
4. On the other hand, diesel generators cause noise and pollution (it produces gases and smoke).

- **Solar hot water**

On the roof alongside the photovoltaic panels (solar hot water panels) are connected to a 300-litres tank to supplement the energy demand for hot water.

- **Home office**

Use the office room in the ground floor for working from home. It contains computer, printer and internet link.

- **Thermal Insulation**

Table (5.13): Inside and outside Temperature degree of Wardan staff housing unit in July and August 2010 (made by the researcher on site, 2010)

Date	**Time**	**North Room**		**East Room**		**South Room**		**West Room**	
		Out	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**
1/7/2010	8:00 AM	26	28	28	29	30	28	28	29
15/7/2010	8:00 AM	26	29	29	29	32	30	27	30
1/8/2010	8:00 AM	29	30	29	30	30	29	29	30
15/8/2010	9:00 AM	30	28	30	31	34	31	29	32
31/8/2010	9:00 AM	30	29	30	31	34	31	30	32
1/7/2010	5:00 PM	34	30	30	29	30	32	34	32
15/7/2010	11:00 PM	34	31	30	29	31	33	34	32
1/8/2010	5:00 PM	35	32	31	30	31	32	36	32
15/8/2010	7:00 PM	36	33	32	30	33	34	35	33
31/8/2010	7:00 PM	36	33	33	31	33	34	35	33

According to table (5.13) the temperature degrees in and out the villa as follows: The average temperature degrees in the summer months outside the villa is 32-36 C°, the average inside the villa is 28-34 C°

North Room: The average difference between in & out temperature on the day is: ±3 C°
East Room: The average difference between in & out temperature on the day is: ±1 C°
South Room & West Room: The average difference between in & out temperature degrees on the day is: ±2 C°

- Roof Insulation: Use 5 cm foam layers under roof tiles

- External Wall Insulation

Double walls (existing lime stonewall from outside, 5 cm inside reinforced foam panels “thermal insulation”, and 2.5 cm rammed earth plastering from inside) are located at the external walls to increase the R si (Thermal resistance of inside surface) of these walls.

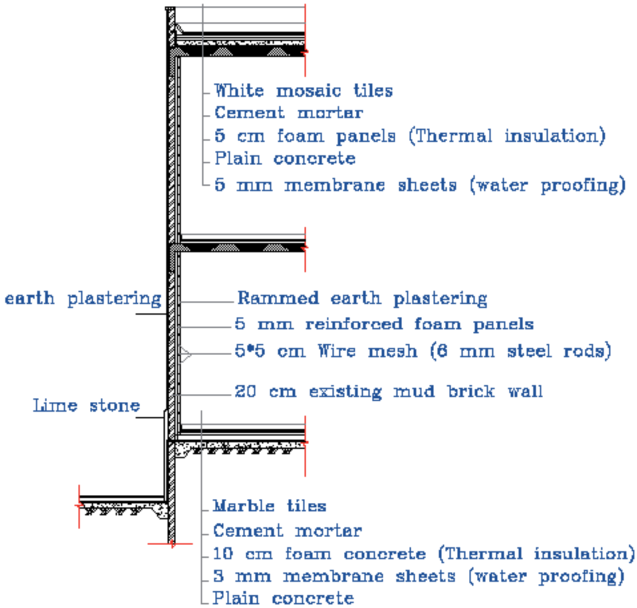


Figure (5.30) Proposed Villa (a) Wall section details scale 1/100

Figure (5.31) Reinforced foam panels “Thermal Insulation” with piping & wooden works (Tridipanel, 2010)

- Colours: White painting for external walls to reflect the solar radiation

- **Natural Ventilation (Air Malqaf)**

- Two wind catchers (malqaf) in the ground floor (living area) to supply the cold air from lower inlets and exit the hot air to the south malgaf in the main entrance.

- Two wind catchers (malqaf) in the first floor (bedrooms) to supply the cold air from lower inlets and exit the hot air to the south malgaf and to the stair windows over thr roof.

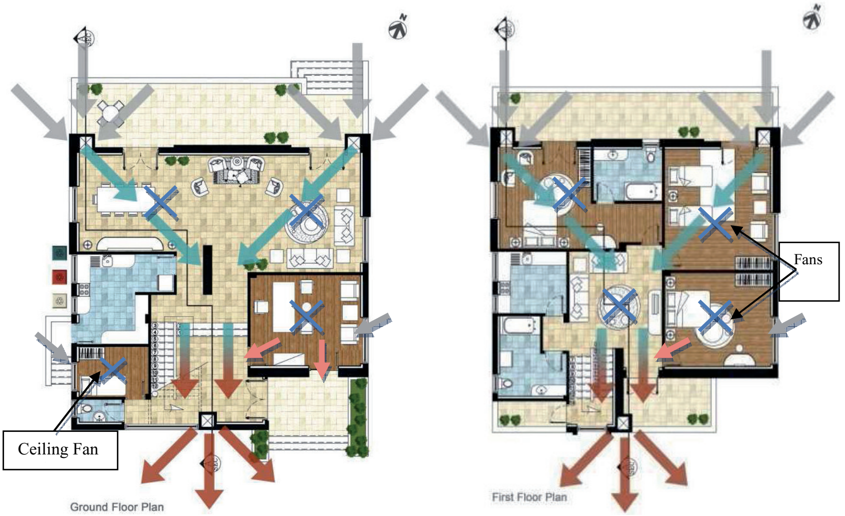


Figure (5.32) Proposed natural ventilation system (Ground & first plan)

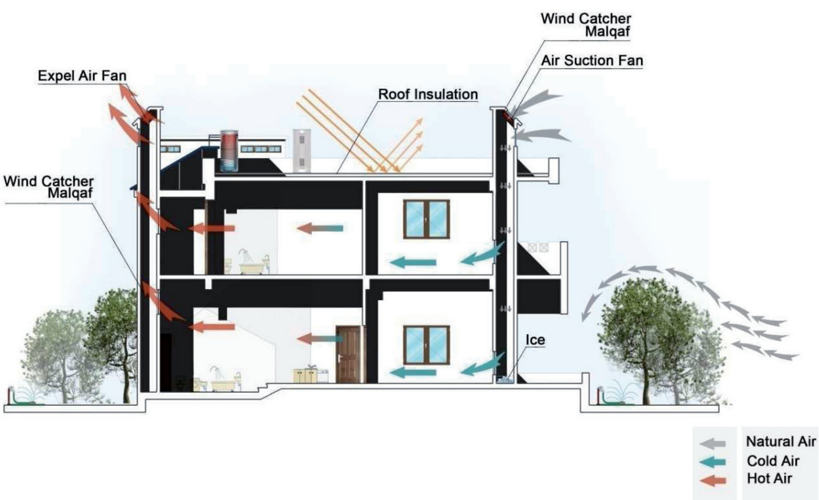


Figure (5.33) Proposed natural ventilation system (villa (a) cross section)

5-2-2-4 Water Management (Grey water system)

- **Water Sources**

Water sources at Wardan institute are from Nile River (Elbaheiry branch) and underground water from two wells.

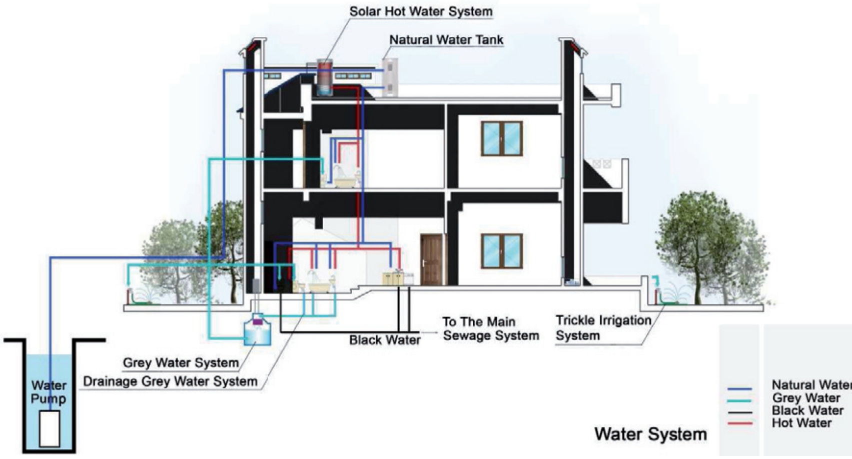


Figure (5.34) Proposed grey water system

- **Proposed Water System: Grey water system**

- Reuse water coming from basin, shower for toilet flushing and storage it in the underground water tank, and reuse the grey water to irrigate the villa garden.
- Collect rainwater from roof and storage it into underground water tank.

5-2-2-5 Eco Materials & Waste Management

Wardan Institute is located in the Nile Valley Region, the available materials in this region according to the HBRC: Limestone, Marble, Granite, Sand, Basalt, Gravel and Clay.

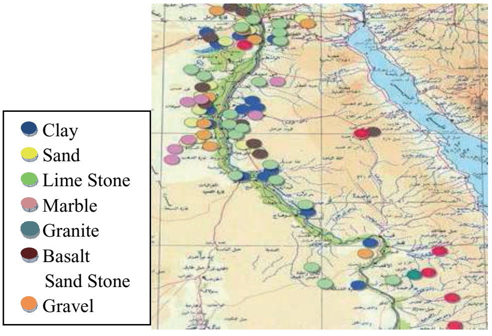


Figure (5.35) Available row materials, Nile Valley Region, Egypt (HBRC, 2008)

- **Proposed Villa Materials**

Table (5.14): The proposed insulation and finishing materials of the case study

Items	Flooring	Walls	Windows	Doors	Insulation	Energy
Entrance and living & dining area	Marble tiles	Eco-painting and thermal insulation	Renovated the existing windows	Renovated the existing doors	_	PV panels
Kitchen	Local ceramic tiles	Local ceramic tiles	Renovated the existing windows	Renovated the existing doors	Membrane sheets 5mm	PV panels
Bedrooms & Office room	Renovated existing soft wood floor	Eco-painting	Renovated the existing windows	Renovated the existing doors	-	PV panels
Bathrooms	Local ceramic tiles	Local ceramic tiles	Renovated the existing windows	Renovated the existing doors	Membrane sheets 5mm	PV panels
Terrace	White mosaic tiles	Rammed earth plastering	Renovated the existing windows	Renovated the existing doors	Membrane sheets 5mm	PV panels
Roof	White mosaic tiles	Rammed earth plastering	_	_	5mm membrane sheets, 5cm foam boards	PV panels
Elevations	_	Double walls with rammed earth plastering	Renovated the existing windows	Renovated the existing doors	5cm inside reinforced foam panels	PV panels

(Made by the researcher, 2011)

- **Waste and Recycling Management**

Wardan campus practices garbage separation and recycles materials locally. The campus's waste and garbage are stored, separated and recycled at source in colourful baskets are beside the buildings as follows:

White basket for paper, red basket for glass and blue basket for organic waste

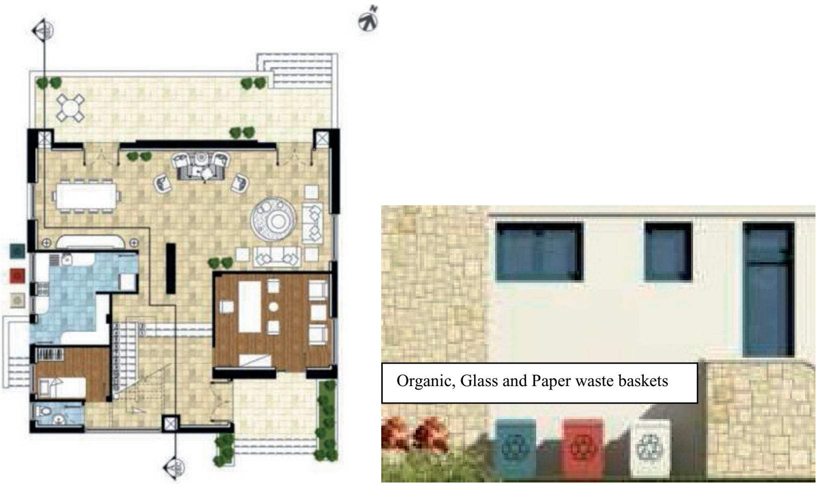


Figure (5.36) Proposed waste materials baskets beside kitchen door (ground floor plan & west elevation)

5-2-2-6 Ecological Sites

- Using trickle irrigation because it uses approximately 66% of the amount of water that a sprinkler system will use and only 40% of the water required by a surface irrigation system

- Using a raw of trees (Green belt) towards the prevalent air direction to filter it from the sand and dust

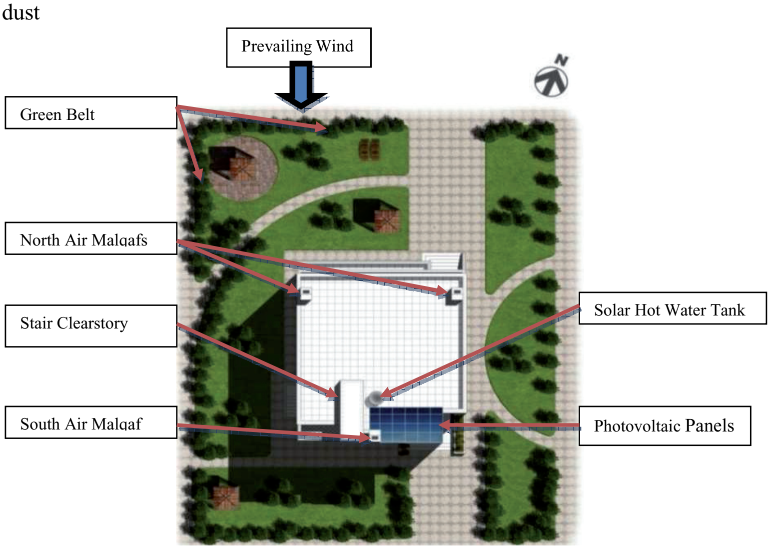


Figure (5.37) Proposed villa (a) ecological site scale 1/400

5-2-2-7 Proposed Case Study Renovation Drawings

Figure (5.38) Proposed villa (a) perspective

Figure (5.39) Proposed villa (a) site plan 1/500

Figure (5.40) Proposed north elevation

Figure (5.41) Proposed west elevation

Figure (5.42) Proposed north elevation

Figure (5.43) Proposed west elevation

- **Comparing between the Existing & Proposed Case Study Drawings (Before & After Renovation)**

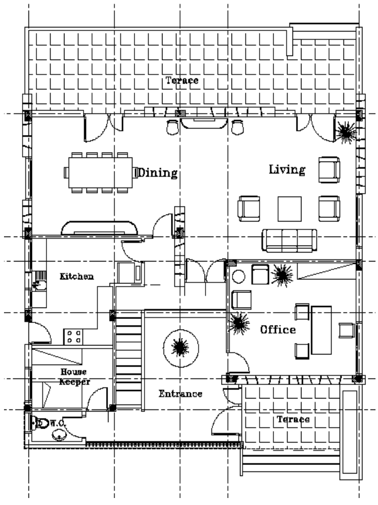


Figure (5.44) Ground floor plan (Before)

Figure (5.45) Ground floor plan (After)

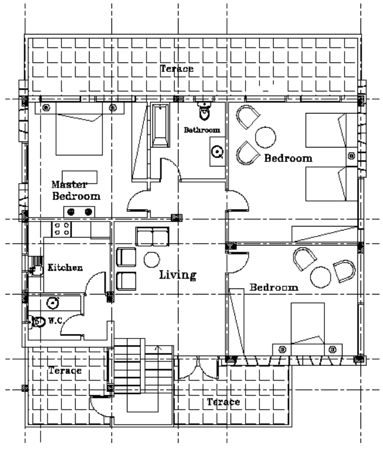


Figure (5.46) First floor plan (Before)

Figure (5.47) First floor plan (After)

Plans drawings scale 1/200

Figure (5.48) South perspective (Before) Figure (5.49) South perspective (After)

Figure (5.50) West perspective (Before) Figure (5.51) West perspective (After)

Figure (5.52) North perspective (Before) Figure (5.53) North perspective (After)

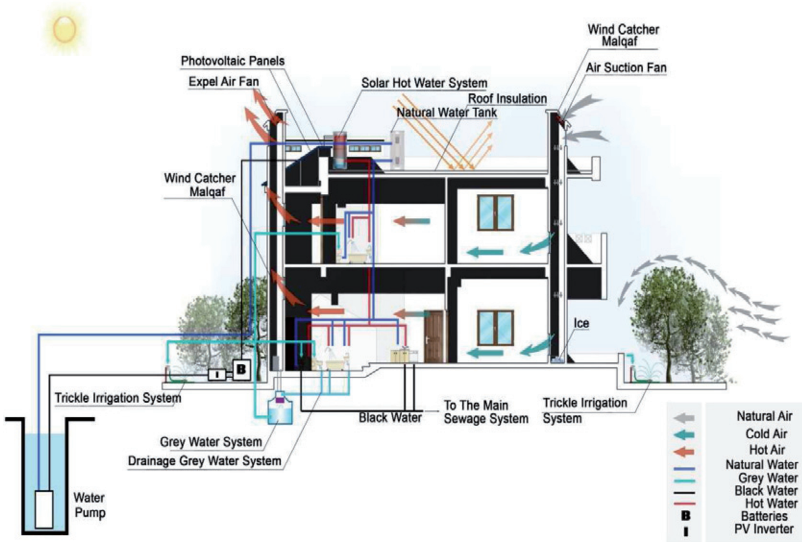


Figure (5.54) Overall ecological design section of Wardan staff housing unit (made by the researcher, 2011)

Figure (5.55) Wardan campus perspective after renovation project, 2011

5-2-2-8 Proposed Renovation Budget (2010 - 2011)

Items Work	Typical Renovation	Typical Budget	Proposed Renovation	Propos-ed Budget	Saving
Demolition Works	Removing all the materials accept the wooden floors.	5,000 EGP	Removing all the toxic and damaged materials	10,000 EGP	+5,000 EGP
Maintenance Works	Wooden floors and cupboards	5,000 EGP	Doors, windows, wooden floors and cupboards	15,000 EGP	+10,000 EGP
Water Insulation	Polyester 5 mm layer	5,000 EGP	Polyester 5 mm layer	5,000 EGP	0.0
Thermal Insulation	_	_	Roof and walls insulation with 5 cm reinforced foam panels	8,000 EGP	+8,000 EGP
Reinforced Concrete	_	_	Air catchers, photovoltaic slab and stair clear story.	5,000 EGP	+5,000 EGP
Plain Concrete	Insulation protection layer	5,000 EGP	Insulation protection layer	5,000 EGP	0.0
Brick Works	Mud brick	5,000 EGP	Air catchers, walls with clay bricks which contains rice straw.	7,000 EGP	+2,000 EGP
Plaster Works	Cement plastering	10,000 EGP	Rammed earth plastering	5,000 EGP	-5,000 EGP
Ceramic Works (Walls)	Ceramic tiles	15,000 EGP	Local ceramic tiles	10,000 EGP	-5,000 EGP
Ceramic Works (Floors)	Ceramic tiles for all villa floors	25,000 EGP	Local ceramic tiles for kitchen and bathrooms	10,000 EGP	-15,000 EGP
Marble Works	Local marble for stairs only	5,000 EGP	Local marble for living and entrance area floors	15,000 EGP	+10,000 EGP
Int. painting Works	Eco- paintings	15,000 EGP	Eco- paintings	15,000 EGP	0.0
Ext. painting Works	Cement dry mix plastering	20,000 EGP	Rammed Earth plastering	10,000 EGP	-10,000 EGP

Windows	Aluminium windows	30,000 EGP	The existing wooden windows are renovated	_	-30,000 EGP
Doors	Soft wood with HPL finishing layer	25,000 EGP	The existing wooden doors are renovated	_	-25,000 EGP
Electrical Works	Transformers, cables, generators, main and distribution panels	86,400 EGP	Distribution panels and electrical features	10,000 EGP	-76,400 EGP
Photovoltaic System	_	_	Photovoltaic panels, inverter and batteries	89,916 EGP	+89,916 EGP
Plumping Works	Wells, tanks, piping and plumping features.	40,000 EGP	Piping and plumping features.	20,000 EGP	-20,000 EGP
Underground Water	_	_	Submergible pump in the well and water tank	10,000 EGP	+10,000 EGP
Grey water System	_	_	Grey water filter, pump and underground tank	5,000 EGP	+5,000 EGP
Air Conditioning Works	Air conditioning units, compressors and connections	60,000 EGP	_	_	-60,000 EGP
Air Fans Works	_	_	Ceiling and wall fans	3,000 EGP	+3,000 EGP
Total in EGP	**356,400 EGP**		**257,916 EGP**		**-98,484**
Total in USD	**59,400$**		**42,986$**		**-16,414**

Table (5.15): Comparing between the typical and proposed renovation budget

These budgets are including the infrastructures (Electrical and water supply).

- Total typical renovation budget will be: **59,400$**
- Total proposed renovation budget will be: **42,986$**
- Total cost savings will be: **16,414$**

The conclusion of this comparison explains that the proposed renovation budget of Wardan staff housing unit is lower than the existing renovation budget. In addition to the proposed renovation is eco friendly than the existing case. (Total cost saving is 28%)

5-2-2-9 Life Cycle Cost Analysis of Proposed and Typical Renovation Alternatives (2011):

Table (5.16) Comparing between life cycle cost of proposed renovation& other alternatives

Items		Typical Renovation Case (Alt.1)	Cost	Typical Renovation Case (Alt.2)	Cost	Proposed Renovation Case (Alt.3)	Cost
Initial Cost	**Energy**	Available local Electricity	2000$	Unavailable Local Electricity	14400$	PV System Installing	14986$ 1498.6 $
	Ventilation System	Air Conditioning	10000$	Air Conditioning	10000$	Air Malqafs + fans	1500$
	Thermal Insulation	-	-	-	-	Roof and Walls	2000$
	Initial Cost	**12000$**		**24400$**		**19984.6$**	
	Use Life	24 years		24 years		24 years	
Replacement Cost	**Replacement Cost**	Air Conditioning Units 12 Years = 3186.74$ 24 Years =1015.53$		Air Conditioning Units 12 Years = 3186.74$ 24 Years = 1015.53$		PV Batteries Units 8 Years = 1399.90$ 16 Years = 653.03$ 24 Years = 304.66$	
	P W	**4202.27$**		**4202.27$**		**2357.59**	
Annual Cost	**Maintenance Cost** (1% of Initial cost)	Air Conditioning Units	100$	Air Conditioning Units	100$	PV System	149$
	Operation Cost	Electric. Bill with G.S.	360$	Electric. Bill with G.S.	360$	Electric. Bill	0.0
		Electric. Bill without G.S.	1080$	Electric. Bill without G.S.	1080$		
	P W with G.S	**4598.98$**		**4598.98$**		**1488.98$**	
	P W without G.S.	**11798.98$**		**11798.98$**			
NPW	**NPW with G.S.**	**20801.25$**		**33201.25$**		**23831.17$**	
	NPW without G.S.	**28001.25$**		**40401.25$**			

- **Replacement cost of alternative 1 & 2 (every 12 years of air conditioning units)**

$$P = \frac{F}{1(+ i`)n} \quad (22)$$

Where: P= Present worth, F =Future amount of money, i' = Interest rate and n= number of years. (Assuming the market inertest rate = 10%)

P1 = $\frac{10000}{(1+0.1)^{12}}$ = 3186.74$

P2 = $\frac{10000}{(1+0.1)^{24}}$ = 1015.53$

- **Replacement cost of alternative 3 (Every 8 years of PV batteries units)**

P1 = $\frac{3000}{(1+0.1)^{8}}$ = 1399.90$

P2 = $\frac{3000}{(1+0.1)^{16}}$ = 653.03$

P3 = $\frac{3000}{(1+0.1)^{24}}$ = 304.66$

- **Annual Cost: (Maintenance and operation costs)**

$$P = \frac{A\ (1+i`)^{n} \quad -1}{i\ (1+i`)^{n}} \quad (23)$$

Where: P= Present worth, A = Annual cost, i' = Interest rate and n= number of years.

P alternative 1& 2 with G.S. = $\frac{460\ (1.1)^{24} \quad -1}{0.1\ (1.1)^{24}}$ = 4598.98$

P alternative 1& 2 without G.S. = $\frac{1180\ (1.1)^{24} \quad -1}{0.1\ (1.1)^{24}}$ = 11798.98$

P alternative 3 = $\frac{149\ (1.1)^{24} \quad -1}{0.1\ (1.1)^{24}}$ = 1488.98$

Net present worth of annual savings with G.S. = 4598.98 – 1488.98 = 3110$ (24)

Net present worth of annual savings with G.S. = 11798.98 – 1488.98 = 10310$ (25)

- **Payback period**

Payback period = Total net present worth / net present annual savings (26)

From table (5.16) total net present worth of the proposed case = 23831.17$

Substituting from equations (24), (25) into equation (26):

PBP of proposed renovation case against typical renovation case with G.S. =

23831.17$ / 3110$ = **7.7 years**

PBP of proposed renovation case against typical renovation case without G.S. =

23831.17$ / 10310$ = **2.3 years**

Conclusion

- The proposed renovation budget of Wardan staff housing unit is lower than the existing renovation budget. In addition to the proposed renovation is eco friendly than the existing case. (Total cost saving is 28%)

- The net present worth of the proposed renovation case is less than typical renovation case when the electricity governmental subsidization is not valid.

- The net present worth of available local electricity with the governmental subsidization is less than the proposed renovation case; but this case is not permanent case in the nearest future in Egypt.

- The payback period of the proposed renovation case is 7.7 years (with the governmental subsidization)

- The payback period of the proposed renovation case is 2.3 years (without the governmental subsidization)

- Life cycle cost of the local electricity with the government subsidisation (which is not available in the Wardan site) is less than the photovoltaic system. If this case is valid it will not a permanent case in the nearest future in Egypt.

- Life cycle cost of photovoltaic system is less than that of the diesel generator system and unavailable electricity supply (without the government subsidization)

- In addition to the photovoltaic systems are clean and renewable sources of energy; they do not cause pollution during their use.

- On the other hand, diesel generators are not recommended for ecological buildings because it produces gases, smoke and causes noise & pollution.

Chapter 6: Conclusions & Recommendations

6-1 Conclusions

-The proposed ecological renovation of the case study is more economical than the other alternatives. In addition to the proposed renovation is eco friendly than the conventional case. (Total cost saving is 28% according to the conventional renovation method)

-An ecological building is the promising solution to face the future challenges particularly; climate change and global warming

-The main ecological residential design principles are:

- Indoor Environmental Quality
- Energy Efficiency
- Eco Materials & Waste Management
- Water Management
- Ecological Sites

-When choosing an environmental rating system for an ecological building around the world, it is generally preferred to use the local system.

-No environmental assessment scheme is perfect. Context is important.

-BREEAM, LEED, CASBEE and other systems are a measurement tool and not a design tool.

-International certification systems continue to learn from each other's mistakes

An Eco-House should provide:

-Healthy living conditions through selecting eco materials and avoiding materials that cause sick building syndrome and allergies and cancer, and selecting a site that is clear of any contamination or radiation in a new eco house.

-Thermal comfort through following passive cooling strategies that are classified according to bioclimatic "Givoni" chart

-Natural ventilation throughout the wind catcher (malqaf) and house openings

-Energy efficiency through a set of design principles for renewable energy resources, shelter design and building envelope

-Solar energy to generate the electricity and hot water

-The solar radiation data has a great effect on the performance of photovoltaic systems.

-Effective day lighting to reduce the need for electric lighting

-An space and services that enable a suitable quiet room in the house to be used effectively as a home office

-Thermal insulation for roof and walls to reduce the energy consumption and improve the indoor air quality

-Low embodied energy materials with minimal environmental impact are used in the construction and finishing works

-Recyclable and renewable materials to avoid harming the landscape resources of the earth that may not be able to recover

-Grey water system to reduce the water consumption

-Trickle system is the preferred irrigation system in the house gardens to saving the potable water

-Eco gardening by adopting landscaping that fits with our hot arid climate.

An Eco-House should be Economical through:

-Applying economical but ecological design factors through selecting economical systems that use local and natural building materials that provides thermal insulation and could be recycled and consumed low energy during construction and operation.

-In order to achieve an eco, eco- house, cost analysis and life cycle cost should be applied throughout all the design and renovation processes

6-2 Recommendations

- The ecological design of the existing buildings is recommended to provide comfort to the occupants, save the running operation costs and at the same time preserve the environmental resources for the next generations.

- Renewable energy is the actual solution to face the future challenges in the energy demands. Specially, solar energy and wind energy.

- Application of the solar energy (photovoltaic systems) in the existing residential buildings depends on the following steps:

    1- Choosing the PV system

    2- The site information (environmental data): where the data of solar intensity, ambient temperature, relative humidity and cloudiness must be available

    3- The electrical load information: the data of load type, profile and requirements are very important for good design.

- To get an optimum photovoltaic system design for a family house, it is very important to collect the meteorological data for the house site

- To ensure that the PV system works well the following steps should be done:

    1- Make sure you have a performance warranty from your installer

    2- In hot dusty areas PV modules may have to be washed every day

    3- The angle of tilt PV panels influences the amount of dust

    4- Make sure there are no exposed electrical connections when cleaning modules as water and electricity do not mix

- Water saving should be managed efficiently to control the waste throughout the grey water system in the buildings and irrigation.

- Grey water should be filtered before using in the irrigation systems

- Providing eco materials in the market to be available and in reach for consumers, architects and contractors to use

- Home office is the promising solution to face the energy, pollution and traffic problems in Egypt; particularly in Cairo.

- Providing of storage space for household recyclable materials by the local authority collection facilities

- Enforcement of Egyptian energy residential code through the building permits process and training designers on using and applying the code.

- Enforcement of green pyramids rating system in Egypt to assessment and evaluate the new buildings design and renovation process of the existing buildings.

- The householders should be encouraged to turn their buildings towards ecology by reducing their operation costs and governmental taxes.

- The Egyptian government should subsidize the renewable energy to generate the demanded electricity in the buildings particularly; the photovoltaic systems.

▪ Future Studies:

-Directing future studies towards designing cost effectiveness modules for cost analysis studies to help the planners and designers in evaluating the economic feasibility and take the decisions needed.

-Applying the ecological design guidelines in an existing residential building in the urban spaces.

-Applying photovoltaic system in a residential tower and introducing its maintenance and operation programs.

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Appendix 1

The requirement of building envelop for non air conditioned buildings in Cairo and Delta region according to the Egyptian Residential Energy Efficiency Code, 2006

- **Example: Non air-conditioned buildings in Cairo**

Wall and roof insulation according to the building orientation

Table (App.1.1): The requirement of building envelop for non air conditioned buildings in Cairo and Delta region

Orientation		External Service Absorptive	Req. R value for Construction Elements				Window Wall Ratio " WWR"							
			Min. Req. R value m^2.C/W	0.4	0.6	0.8	< 10%	< 20%	< 30%	> 30%	< 10%	< 20%	< 30%	> 30%
				R value for Thermal Insulation			Solar Heat Gain Coefficient SHGC				Shaded Glass Ratio SGR			
Roof		0.7	2.7	2.3	2.1	1.9								
Walls	N	0.38	0.55	0.15	NR	NR	NR	NR	0.71	0.67	NR	NR	40 %	50 %
		0.50	0.59	0.19	NR	NR								
		0.70	0.67	0.27	NR	NR								
	NE/N	0.38	0.74	0.34	0.14	NR	0.65	0.55	0.45	*	50 %	60 %	70 %	*
		0.50	0.85	0.45	0.25	NR								
		0.70	1.03	0.63	0.34	0.23								
	E/W	0.38	0.92	0.52	0.32	0.12	0.55	0.45	*	*	60 %	70 %	*	*
		0.50	1.08	0.68	0.48	0.28								
		0.70	1.35	0.95	0.75	0.55								
	SE/SW	0.38	0.82	0.42	0.22	NR	0.55	0.45	*	*	60 %	70 %	*	*
		0.50	0.95	0.55	0.35	0.15								
		0.70	1.17	0.77	0.57	0.37								
	S	0.38	0.67	0.27	NR	NR	0.71	0.64	0.55	*	50 %	60 %	70 %	*
		0.50	0.75	0.35	0.15	NR								
		0.70	0.89	0.49	0.29	NR								

(*) Not allowed to open windows in this wall (Source: HBRC, 2006)

For example, the exterior building envelope must comply with the following requirements: -

R values for Typical Roof Construction are Equivalent to:

R value 0.3: equivalent to 12 cm concrete, 6 cm of sand, 2 cm of mortar, 2 cm of tiles R value 0.4: equivalent to 12 cm concrete, 8 cm of sloped concrete, 6 cm of sand, 2 cm of mortar, 2 cm of tiles. R-value 0.6: equivalent to 20 cm hollow concrete blocks, 8 cm of sloped concrete, 6 cm of sand, 2 cm of mortar, 2 cm of tiles

R value 0.8: equivalent to30 cm hollow concrete blocks, 8 cm of sloped concrete, 6 cm of sand, 2 cm of mortar, 2 cm of tiles.

- R values for Typical Wall Construction are Equivalent to:

R value 0.4: equivalent to 12 cm clay brick, 2 cm of plaster on both sides.

R value 0.6: equivalent to 25 cm clay brick, 2 cm of plaster on both sides.

R value 0.8: equivalent to 38 cm clay brick, 2 cm of plaster on both sides.

- R values for Typical Insulation Materials with R si & R so, are Equivalent to:

R value 0.59 = 2 cm expanded polystyrene insulation

R value 1.18 = 3 cm expanded polystyrene insulation

R value 1.75 = 6 cm expanded polystyrene insulation

R value 2.35 = 8 cm expanded polystyrene insulation

If insulation is placed to the inside of the wall the R value is reduced by 30 %R value of 100 mm non vented cavities in the wall is considered 0.16 m^2 C/W
Outdoor surface thermal resistance = 0.04 m^2 C W
Indoor surface thermal resistance = 0.123 m^2 CW (Egyptian residential energy code, 2006)

Appendix 2

Electricity consumption prices in the residential buildings with the governmental subsidization in Egypt

Table (app.2.1) Electricity consumption prices in the residential buildings with the governmental subsidization in Egypt from 2008 till present.

Monthly Electricity Consumption	**Cost kWh / EGP**
50 kWh (the first consumed amount)	0.05 EGP
51- 200 kWh	0.11 EGP
201- 350 kWh	0.16 EGP
351-650 kWh	0.24 EGP
651- 1000 kWh	0.39 EGP
1000 kWh and over	0.48 EGP

Source: Ministry of Electricity and Energy, 2010

The total governmental subsidization in electricity consumption prices in Egypt equal 4.99 billion EGP in 2009/2010 (Ministry of Electricity and Energy, 2010)