THE ANALYSIS OF PASSIVE DESIGN STRATEGIES TO PROVIDE ENERGY EFFICIENCY IN RESIDENTIAL BUILDINGS IN TRIPOLI, LIBYA

NESREEN ABOUD

JULY 2017

THE ANALYSIS OF PASSIVE DESIGN STRATEGIES TO PROVIDE ENERGY EFFICIENCY IN RESIDENTIAL BUILDINGS IN TRIPOLI, LIBYA

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Submitted by: **Nesreen ABOUD**

Approval of the Graduate School of Natural and Applied Sciences, Çankaya University.

Prof. Dr. Can ÇOĞUN
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Asst. Prof. Dr. İpek MEMİKOĞLU
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Asst. Prof. Dr. Özge SÜZER
Supervisor

Examination Date: 13.07.2017

Examining Committee Members

Asst. Prof. Dr. İpek MEMİKOĞLU	(Çankaya Univ.)	
Assoc. Prof. Dr. Nur AYALP	(TOBB ETU)	
Asst. Prof. Dr. Özge SÜZER	(Çankaya Univ.)	

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Name, Last Name	:	Nesreen, Aboud
Signature	:	
Date	:	13.07 .2017

ABSTRACT

THE ANALYSIS OF PASSIVE DESIGN STRATEGIES TO PROVIDE ENERGY EFFICIENCY IN RESIDENTIAL BUILDINGS IN TRIPOLI, LIBYA

ABOUD, Nesreen
M.Sc., Department of Interior Architecture
Supervisor: Assist. Prof. Dr. Özge SÜZER

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The main aim of this research is to analyze the passive design strategies for residential buildings in Tripoli, the capital of Libya, in order to reduce energy consumption and provide thermal comfort to the users of residential buildings. The stages of the study started by finding out the energy consumption rates in residential buildings in Libya and conducting wide literature studies pertaining to the passive design strategies for effective energy conservation. Firstly, the weather and temperature data collected in Libya. After that, certain passive design strategies for Tripoli - Libya analyzed by using the simulation and analysis program "ECOTECT". By the use of this program, data including the thermal mass, best possible orientation, the loads of heating and cooling in the residential buildings along with direct effects of building materials, significance of window size on the temperature and comfort in the buildings were analyzed, based on the designed 'typical Libyan residential building' model. Moreover, the energy consumption in the model building measured. The results of the project analyzed and methods to enhance the energy performance in residential buildings in Libya found out, in order to provide guidelines to designers in general, and to architects in particular. The results of this study show that the proper orientation of the buildings and the use of insulation materials in suitable proportions can provide a 60% increase in comfort and enhance the interior environmental conditions in enclosed spaces. Finally, evaluation of the thermal comfort level conducted by using the PMV method it found out that the building was providing thermal comfort at a maximum level.

Keywords: ECOTECT, Energy Consumption, Energy Efficiency, Passive Design Strategies, Residential Buildings, Tripoli, Libya

ÖZ

LİBYA, TRABLUS'DAKİ KONUT YAPILARINDA ENERJİ VERİMLİLİĞİ SAĞLAMAK İÇİN PASİF TASARIM STRATEJİLERİNİN ANALİZİ

ABOUD, Nesreen

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Bu tez çalışmasının amacı, enerji tüketimini azaltmak ve kullanıcılara ısıl konfor sağlamak bağlamında, Libya'nın başkenti Trablus'ta yer alacak konut yapıları için pasif tasarım ilkelerini analiz etmektedir. Çalışmanın ilk evreleri, Libya'daki konut yapılarında enerji tüketim oranlarını saptama ve etkin enerji tasarrufu sağlayabilmek çerçevesinde pasif tasarım stratejilerine ilişkin kapsamlı bir literatür taraması şeklinde başlamıştır. Öncelikle, Libya için iklim ve sıcaklık verileri toplanmıştır. Bunun sonrasında, ECOTECT simülasyon ve analiz programı kullanılarak Trablus, Libya için belirli pasif tasarım ilkeleri analiz edilmiştir. Söz konusu program kullanılarak, tipik bir Libya konut yapısına dayanarak tasarlanan model üzerinde; ısıl kütle, en iyi yönlenme, ısıtma ve soğutma yükleri ve yapı malzemelerinin bunlara doğrudan etkisi, pencere ebatlarının ısıl konfor açısından önemi gibi faktörler veriler üzerinden analiz edilmiştir. Bunların haricinde, yapıdaki enerji tüketim miktarları da hesaplanmıştır. Bu çalışmanın bulguları ile, tasarımcı ve mimarlara çeşitli kılavuz ilkeler oluşturabilmek için Libya'daki konut yapılarının enerji performanslarını artıracak yöntemler ortaya konmuştur. Çalışmanın sonucunda, doğru yapı yönlenmesi ve yalıtım malzemelerinin uygun kullanımı ile iç mekanlarda %60'a varan oranlarda konfor artışının ve çevresel koşulların iyileştirilmesinin söz konusu olabildiği görülmüştür. Sonuç olarak, bu model için ısıl konfor seviyesi PMV metodu ile değerlendirilmiş ve yapıda maksimum seviyede ısıl konfor sağlandığı görülmüştür.

AnahtarKelimeler: ECOTECT**,** Enerji Tüketimi, EnerjiVerimliliği, KonutYapıları, Pasif Tasarım Stratejileri, Trablus, Libya.

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CHAPTER 1

INTRODUCTION

Energy is one of the main necessities of the civilized societies and it is necessary for everyday life. Accompanying with technical and industrial development, global needs for energy are increasing, which increases the electricity production cost because in many countries, oil used to produce it. Therefore, there is a contradiction because countries have to choose between oil and energy but the overall growing trends need energy conservation.

The reality of energy consumption in Libyan buildings refers to the fact that mostly, electricity consumed for cooling and heating because of the extreme climatic seasonal variations in Libya. Moreover, the issue of global warming is increasing the temperatures during summers and that is increasing energy needs. With increasing demand for cooling, air conditioning consumes a lot of energy, and the generated electricity only fulfills 50-70% of the population needs (Annual Report, 2012). The problem is that the increase in energy consumption in the buildings for purposes of cooling and heating in Libya has increased the dependence on mechanical cooling techniques to provide thermal comfort. One of the main objectives of architectural design is to provide comfort to the occupants while reducing energy consumption in the building.

The load of electricity in Libya gradually increases every year. Moreover, Libya is one of the rich countries in renewable energy resources such as wind and solar power (Annual Report, 2008).

Recently, buildings in Libya have needed excessive cooling units in order to maintain thermal comfort at a desirable level. Therefore, the Libyan citizens have been paying higher energy costs, and the authorities have been trying to find solutions to improve buildings in terms of thermal comfort, energy efficiency, and design buildings with new innovative concepts in Libya. This proves the importance and the necessity of the chosen subject.

1.1. Aim and Scope

The aim of this study is to evaluate the passive design strategies for residential building to control the indoor thermal conditions, reduce the climatic effects, and provide thermal comfort to the occupants. This study will also help to increase awareness about energy efficiency in buildings, which achieved by using passive design strategies to reduce the effects of harsh climatic conditions. In addition to improving the thermal comfort of the users within the building, it also aims to identify certain passive design issues such as; the appropriate orientation for residential buildings in the city of Tripoli, and the suitable materials to be used in the building fabric and window to wall ratios for providing energy efficiency.

1.2. Methodology

This study examines the effects of passive design strategies on energy consumption in residential buildings particularly focusing on Libya. A residential building model is part of the simulation program ECOTECT, with an area of 109 m2 to conduct the study for analyzing the passive design strategies for Libya. In addition, experts designed a model according to the characteristics of typical modern residential buildings constructed in Libya. Moreover, the researchers examined the building design using the ECOTECT data analysis software to evaluate the thermal comfort of the building. And to find the optimum values for certain design elements such as; orientation, thermal mass, heating and cooling loads, passive gains and losses, window to wall ratio and total energy use during the year for buildings in the city of Tripoli – Libya, in order to reduce the heating and cooling loads.

1.3. Structure of the Thesis

The thesis has three sections: First section about the introduction of the thesis while the second section aims to make background study and the third section is practical research work.

First section consists of the general introduction of the thesis, aim, and the methodology of the thesis. In addition, it clarifies the general structure of the thesis.

Second section consists of two chapters which through reflects the scientific background of the researches which been made on reviewing the literature of resources, theses, books, scientific magazines and internet. In addition, the last section reflects the main body of the research, which is study the location, and climate of the case study and the whole analyzing processes and results that found. Figure 1.1 clarifies the general structure of this thesis.

In order to check the thought of the thesis, it has been deepen into different methodologies and that was about the effect of passive design strategy on the energy performance. This project started in finding a mean to measure the level of the interior comfort and associate it with the quantity of energy consumption. The reading about this subject helped on taking a decision in the analyze method by the computer program. This thesis focuses on the residential buildings in Tripoli-Libya because the housing sector consumes most of the energy in Tripoli. Following is the description of the work, which we have carried out for our research:

Chapter 1: contains on an introduction for this thesis and basic information such as aims and the objectives of this research, and then it describes the methodology which been used, in addition to the diagram of providing the general structure of this thesis .

Chapter 2: this chapter and chapter three include the literature review associated to this thesis. Therefore, chapter two includes background about the global warming, renewable energy resources, and the energy consumption in Libya.

Chapter 3: includes general background about the passive design strategy factors such as the orientation, heating and cooling strategy, the passive design strategy of the building, the thermal mass and everything associated with applying the passive design strategy in the buildings.

Chapter 4: before starting the practical part which included at this chapter, it provides the information which been collected about the case study city. In addition, it is clarified at this chapter many concepts and includes the research questions. As well as, it includes the following methodology of the analysis part. This part checks the research questions. There is a design building has been designed as topical building in Libya. The main program, used in the simulation is ECOTECT analysis program, in order to reach the suitable orientation for Tripoli city at the Mediterranean climate with the analysis of the quantity of energy consumption at the buildings before reaching to suitable materials. In addition, the tool finds the PMV value as the temperature of the skin and the interior temperature of the building and an analysis to give a clear image about the building occupiers feeling and the suitable materials for this climate. This computer simulation displays with each case study of the building and checks from each side such as the room temperature and the effect of gain on the building fabric. As well as, reach the best orientation and measure the loads of heating and cooling with measuring the window area according to the wall. The results obtained so far are present in the last part of this chapter.

Chapter 5: the results, which are the main part of this chapter

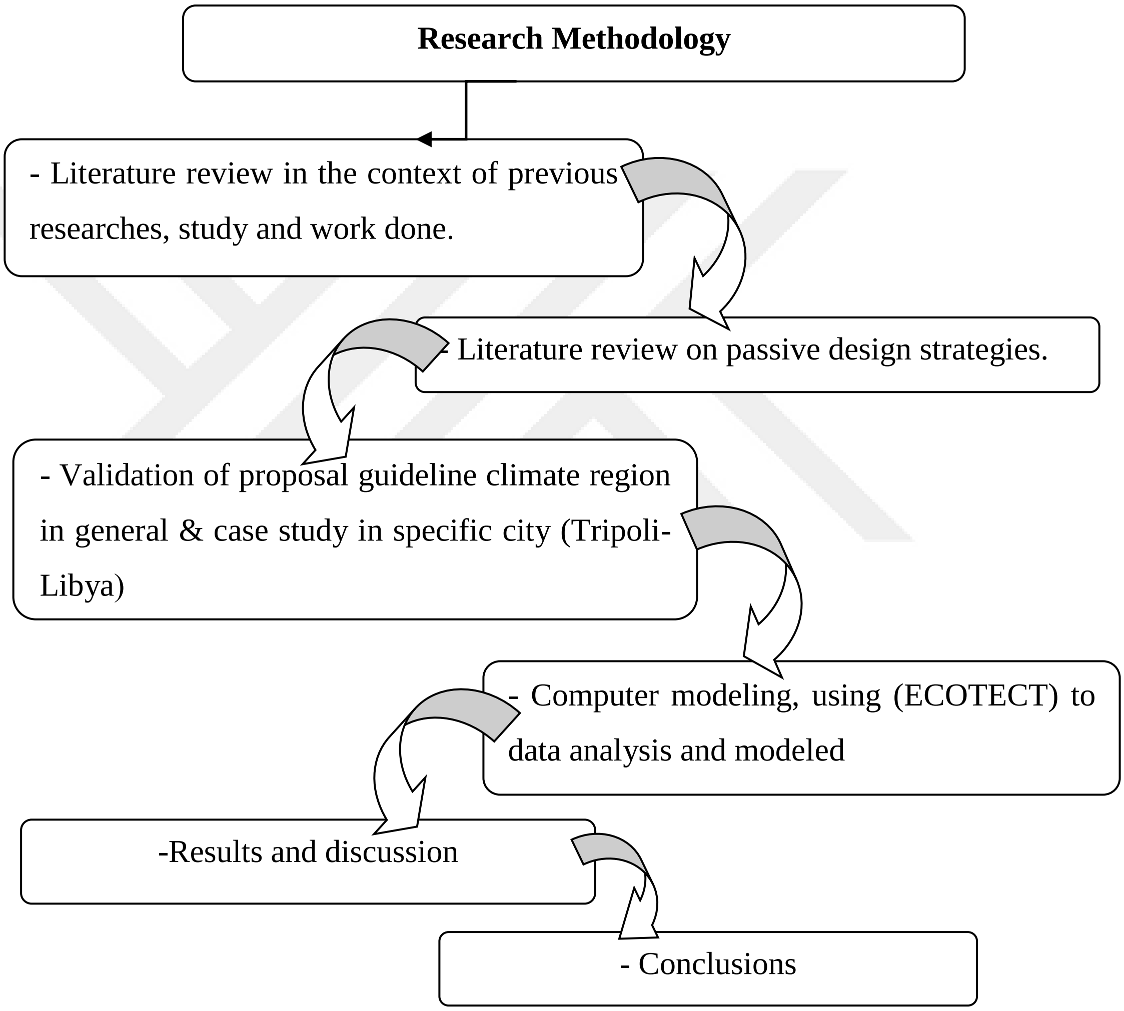


Figure 1.1 Research methodology

CHAPTER 2

GLOBAL WARMING AND ENERGY CONSUMPTION

2.1. Global Warming and Sources of Green House Gases

The climate is changing and if this change continues in a similar fashion, it will be very hard for humans to survive in the altered conditions and continue their everyday activities. In 1896, a Swedish chemist Svante Arrhenius studied industrial revolution and its effect. He noted that the industries were emitting carbon dioxide and the total amount of carbon dioxide was increasing in the atmosphere. He also noted that the concentration of carbon dioxide and coal combustion emissions are increasing in the atmosphere. His study developed the understanding that carbon dioxide was heating the Earth. Moreover, he predicted that if the carbon dioxide increases, global climate would become several degrees warmer. He also pointed out the issue of the greenhouse effect as the figure 2.1 shows a simplified illustration (Morrissey & Justus, 2000).

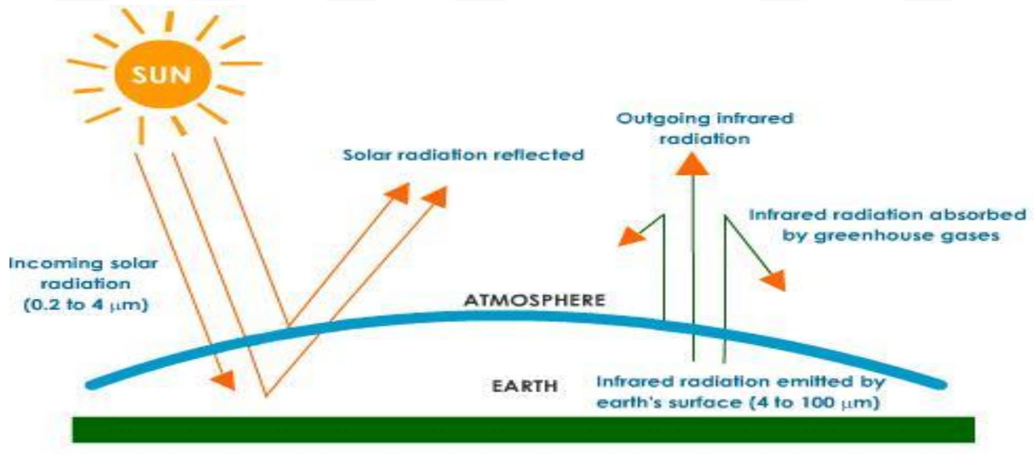


Figure 2.1: Simplified diagram illustrating the greenhouse effect (Change, 1998)

The short waves of solar radiation can pass through a clear atmosphere relatively unobstructed, but infrared radiation waves released from the surface of the Earth are moderately absorbed. After that, the gases, especially water vapor and carbon dioxide, found within the cool atmosphere, release them again. According to his observation, external solar radiation equalizes the exterior infrared radiation. It increases heating both in the atmosphere and in the surface of the Earth, even if there are no greenhouses gases (Change, 1998).

The natural greenhouse gases create suitable climate for humans, animals and plants, and help them live in a conducive surrounding. On the other hand, the world will be a harsh and unwelcoming place for us to live with excessive carbon dioxide. The improved greenhouse effect helps moderate temperature raise on the surface of the earth because of the natural greenhouse effect, but now the density of the greenhouse gases is increasing because of the human actions like carbon emissions, and therefore, it causes global warming that leads to harmful climatic changes including heavy rainfall, storms, and increasing sea levels.

Sources of Green Gases:

Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and chlorofluorocarbons (CFCs) are increasing in the atmosphere and many of studies have established that they are changing the most because their concentrations in the atmosphere has been influenced because of the human actions or activities. In the past, CO_2has been the most important one, but over the past decades, additional gases have also assumed importance and collectively, they are likely to cause global warming over the next 60 years.

According to U.N. Kyoto Protocol on Climate Change 1997 agreement, which was signed with the understanding that the concentration of three gases other than CO_2, including hydrofluoric carbons (HFCs), per fluorocarbons (PFCs), and sulfur hexafluoride (SF6) must be restricted in the atmosphere over the long term (Snow & Prasad, 2011).

Sulfate aerosols, an aftereffect of air pollution, and a natural phenomenon, is essential for fleeting (climate cooling) effects on the earth's atmosphere (Morrissey & Justus, 2000).

2.2. Renewable Energy Resources

In the world future, the renewable energy resources will play a significant role. The energy resources have three categories that are fossil fuels, renewable resources and nuclear resources (Demirbas, 2000).

The renewable energy resources are those resources, which produce energy repeatedly such as the geothermal energy, wind energy and biomass energy, or simply the alternative energy resources (Rathore & Panwar, 2007).

The domestic renewable energy has the ability to provide the home services and needs and decrease the green house emission by zero or almost zero. The development of energy resources has the ability on solving the most crucial tasks such as improving the energy supply and organic fuel economy. In addition, it can solve the local energy problems and water supply, enhance the living standard and the employment level of the local people, and guaranty the sustainable development in the mountains and remote desert regions, enable the countries to fulfill their obligations in terms of implementing the international agreements of the environment protection (Zakhidov, 2008). The renewable energy resources decrease the immigration towards the urban areas according to the work opportunities, which it opens in the rural areas (Bergmann, Colombo & Hanley, 2008). One of the offered options to fulfill the needs of small and rural areas in reliable method is the harvest of the renewable energy resources (Ravindranath & Hall, 1995; Panwar, Kaushik & Kothari, 2011).

2.3. Energy Conservation

Energy conservation in buildings is largely possible through cost effect ways through current and improved technologies as well as sound energy usage pursuit, which is the main concept and it is so simple because if people use less energy, there will be less revival of greenhouse gases, which happens as a result of burning fossil fuels. Fossil fuels are assets, which can be used for purposes other than power generation both in advanced and in developing countries. Power-efficient and power conservation technologies and practices can play a considerable role for minimizing global climate change (Perez- Lombard, Ortiz &Pout, 2008).

Insulation is one of the easily obtainable and energy efficient method nowadays. The benefits of insulation are numerous including thermal performance, comfort, sound control, intensification control, fire control, and personal protection. The thermal insulating properties of insulation materials provide important energy and environmental advantages. Insulating material consists of a set of substances including fiberglass, mineral, wool, foam, and some other materials. Insulation materials minimize the heat transfer in the residential, commercial, and industrial buildings. Insulation products help consumers to minimize energy usage and emission of pollutants.

When thermal insulation is helpful, energy consumption reduces and the environmental balance restores. On the other hand, Burberry (1997) monitored some energy operators and confirmed that designers should minimize the energy consumption in buildings (Pitts, Bin, 2007). Following factors are important for energy conservation:

1. Selection of site
2. Built, form and grouping of buildings
3. The shape and the size of the building
4. Using the building
5. Fenestration (arrangement of windows) and direction

2.4. Energy usage potential in Libya

Solar energy

The solar energy is a perfect energy resource as the daily solar radiation reaches 7.5 kWh/m2 and 3000-3500 hours of sunshine a year. The departments of power generation and investors are struggling to use the flat desert region for power generation as it comprises of 88% of the total Libyan land.

There are several settlements, which are available along the coastline, but the solar power generation is less appropriate for inland areas. However, the installation of solar units with 1.86 kWh of PV capacity took place in Libya in 2006, but this consumption is limited in comparison with fossil fuels.

In the countryside, the decentralized power generation is promoting PV systems and now, they supply power for agriculture specifically to water pumps using solar energy instead of diesel (REEEP Policy Database, n. d.).

Wind energy:

The wind speed is excellent in Libya within average speed between 6-7.5 m/s. There are prospects of using wind turbines in the Libyan coastline, one of which is located in Dinah where the average wind speed is around 7.5 m/s and a German- Danish association has initiated a 25 MW wind power project. Experts have identified several other suitable areas and accomplished the monitoring process in each location for over 12 months. A power project and turnkey installation of the 25 MW wind power plant started operations but later, the project remained incomplete after 2011, when five new wind power projects started operations with a total capacity of 600 MW and the government has plans to extend them to 1,000 MW (REEEP Policy Database, n. d.).

Biomass Energy:

The biomass energy can be a possible source of power generation and it is not only suitable for individual power generation needs but for mass power generation as well (REEEP Policy Database, n. d.).

Geothermal energy:

Despite the great potential, geothermal power generation is not as a viable power generation solution in Libya so far. Studies show the benefits of underground thermal energy storage while the overflowing heat is stored in an underground circulating pipe system. A study has finally been conducted to use low–temperature geothermal source next to the Rwandan city (estimated 1.3 MW potential) or refrigeration (1284 tons at 5º C, or 835 tons at 0º C), which is economically feasible (REEEP Policy Database, n. d.).

Hydropower:

While comparing Libya with its North African neighbors, it has a poorly developed hydropower sub-sector because of the shortage of resources and so far, there are no plans to invest in the hydropower projects or river-based projects (REEEP Policy Database, n. d.).

2.5. Energy Consumption

Energy consumption is the quantity of energy or power that is helpful. There are a similarity between main determinants of energy consumption and creating a comprehensive understanding of the effect of the identified determinates on energy consumption method (Halicioglu, 2009).The energy consumption in buildings depends on seven factors:

1. The climate (e.g. outside air temperature, solar radiation, wind speed .etc)
2. Building related characteristics (e.g. type, area or region, direction
3. User –related characteristics except for social and economic factors (e.g. users' presence etc)
4. Service system in building and the operator (e.g. space cooling/heating, hot water)
5. Building residents (behavior and activities)
6. Social and economic factors (degree of education, energy cost, etc)
7. Indoor environmental quality

Energy Use in Libya:

Indoor thermal conditions and the design of the buildings depend on the thermal performance, form and the construction elements of the buildings, which affect energy consumption in the building. Sometimes the residents have no choice other than using air conditioners during the day and sometimes also during the night in the summer season, which results in high level of power consumption in the country.

In the World Fact book 2010, Libya produced 21.15 GWh of electricity and consumed 18.18 GWh (1giga watt = 1 million kilowatts), where 72% of this electricity was used by air conditioners (ACs). Figure 2.2 shows the electricity usage in Libya (Ministry of electricity, renewable sources) (Alghoul, 2017).

In 1970, the maximum load was 151 Megawatts (MW) and in 1980, it was 795 MW, then in 2011, it was 5515 MW and in 2012, it rose to 5981 MW (Annual Report 2012).

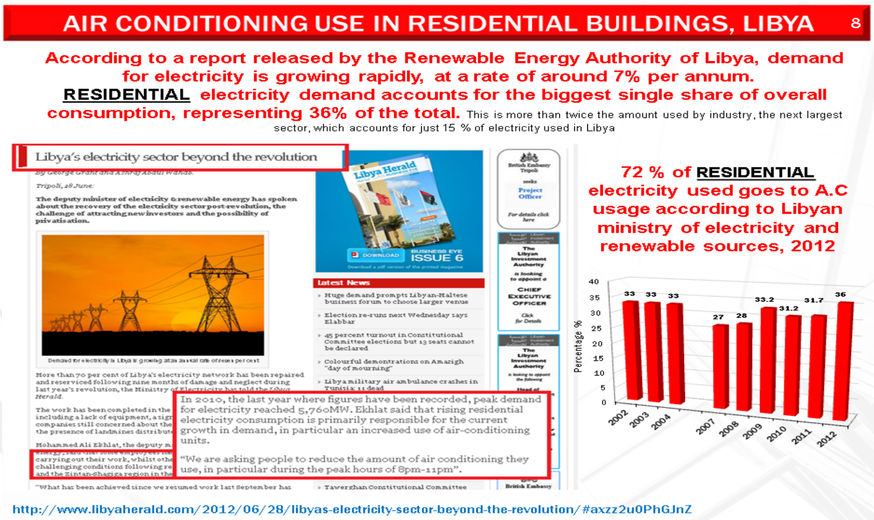


Figure 2.2: The Usage of Electricity and AC System in Residential Sector in Libya, (Annual Report, 2012)

Energy Efficiency in Libya

Unfortunately, energy conservation strategies have a rare use in Libya; therefore, the government should try to increase the level of awareness in the society. A study states that 20% energy conservation is possible until the year 2020. Energy conservation can minimize the need for its excessive generation. By 2020, an energy saving of 2,160 MW is possible in the industry sector and 11.9% in the total domestic use (IEA countries energy statistics, 2009).

The transport sectors the country's main sector for petroleum use and in 2009; it was using of 37.2% the country's energy and, of 40.1% the energy of public and commercial sectors. Libya had the highest electricity generation per capita in Africa, with 4.739 KWH in 2009 (REEEP Policy Database, n. d.). Figure 2.3 shows the details of energy resources used in Libya.

Resource		Libya's resources	Libya in comparison
	Oil	Proven oil reserves of 43 billions BOE with significant additional potential	Largest oil reserves in Africa
	Gas	Gas reserves of 10 billions BOE	Fourth largest natural gas reserves in Africa
	Solar	Average solar radiation of 2,470 kWh/m2/day	One of the highest solar radiation in the world
	Wind	High average wind speed at several locations	Attractive global location for wind farms

Figure 2.3: Energy Resources in Libya (Annual Report, 2004)

CHAPTER 3

PASSIVE DESIGN STRATEGIES

Passive design strategies take into consideration the design of buildings as a key factor for assuring thermal comfort. Thus, the building design facilitate the occupants to take benefit out of the climate such as natural heating and cooling because it increases the comfort of the people living in the building and consumes low amounts of energy.

The passive design is the design that greatly benefits from the natural climate to preserve the temperature inside the building. The passive design decreases or finishes the need to use mechanical heating and cooling, which comprise 40% or more of the total energy consumption at harsh climates. Passive design has great importance that no one can underestimate because it is a feasible solution to provide comfort to people living in buildings as it substantially reduces their energy (electricity/gas) bills. Moreover, it reduces the emissions of greenhouse gases, which add to the lifetime of a building and our planet (Ahsan, 2009).

The passive design strategies use natural resources and forces for heating and cooling in the buildings, such as the sun for heating and breeze/air currents for cooling. Moreover, building shells (roofs, slabs, windows, and walls) need appropriate design by using this strategy, which decreases the unwanted heat. The suitable time for using this strategy is during the planning process; however, the possibility of renewal of the existing buildings and employing this strategy for making them Eco-friendly is quite possible. Moreover, it is possible to do some simple modifications in the existing buildings but in order to get the best results of the passive design, the planners should understand the concepts like how to create and use adjustable shading (Caitlin, 2013)

The basics of passive design differ depending on the strategies and specific features according to the location and climate of the region. Choosing the designer, who has experience in passive design and participation of thermal performance is essential. Suitable and good passive design is critical to provide thermal comfort to the users, as it decreases the energy costs and preserves our environment by decreasing the emission of greenhouse gasses (Ahsan, 2009).

Passive design elements:

Passive design elements are the main strategies, which eliminate or reduce the need for mechanical and electrical systems in the buildings. They greatly improve the users' convenience in the building. Following are the important passive design elements and their aspects:

The environment and its thermal effects:

Before constructing a building, builders must understand the mechanisms of heat loss or gain. Environmental conditions have three major categories: air temperature, direction of wind, and relative humidity. The temperature of the air should be less than the body temperature because in that case, the body will recover the heat loss to maintain a constant temperature. The opposite is true for winters when the room temperature should be higher than the body temperature (Rode, Iversen, Pedersen, & Villumsen, 2005).

Often it is very difficult to maintain the thermal comfort because maintaining thermal comfort is a difficult process. Therefore, often people feel comfortable when heat increases or decreases at a slower rate, and the opposite happen when temperatures immediately change because that creates discomfort.

The environmental situation can determine the thermal comfort, which depends on the quantity and speed of wind because it uses the principles of convectional heat exchange. As long as the wind speed is not too high and the air temperature is not too low, it helps by providing cooling effect during hot climates (Bilgiç, 2003).

Relative humidity in the air refers to the amount of water in the air and when the air contains a large amount of water, it is humid. Warm air has a higher potential to collect moisture. Human body controls body temperature through sweating because sweat creates evaporation to cool down the body (Sushitckii, 2012).

3.1. Fundamental Aspects of Architectural Planning

A designer should consider many basic and important aspects during the process of designing energy efficiency in building. The following explains important considerations:

3.1.1. Site Analysis

The first and the most important aspect of planning/implementing passive design strategies is site analysis because each location has its own climatic characteristics. After its selection, builders should analyze it with attention to details. Plants are important elements as they help adjusting the micro climatic in the design process in terms of controlling the shadows and direction of wind. Shading trees can decrease cooling costs during summer. The use of local plants decreases the need for irrigation, and necessary care. Studying the location of the building and surrounding buildings helps determining which place will be better for construction and how shadows and direction of air will affect the building. The obstructions can make architects change the design of the buildings (Ex, 2010).

The path changes of the sun in different periods of the year (in summer, spring, autumn, and winter) should be understood, as it affects shading and heating needs. Moreover, it makes use of the outdoor spaces as an extension to the indoor spaces and helps adapting to the climatic conditions specifically in summers. If trees are located next to the buildings or the buildings are located next to the trees, shades obtained from the trees. The builders should construct buildings towards east because this feature limits the access of solar energy especially in the afternoon when the sun is low. In addition, poor planning may lead to excessive heat transfer to the interior of the building. Furthermore, in Libya, the paved surfaces of the buildings must be shaded because of lack of green areas surrounding the buildings, which results in lack of shadow and cool air, and besides, the buildings are in the proximity of each other and sometimes attached to each other. The previously mentioned principles cause direct reduction in the use of energy, provide the air for ventilation, and help keeping the buildings cool through shadows of trees and surrounding buildings (Gore, Song, & Eldin, 2011).

3.1.2. Landscape Design and Vegetation

It is an environment-related component of architecture and it supports natural views and environmental design. After the increase of urbanism, the environment gets dirty, which affects the lives of organisms and plants. Experts like Lewis invited citizens to participate and use educational tools for planning ecological landscape in their residential areas (Koglin, 2013).

The important effects of the natural plantation are economic as they reduce energy consumption, reduce noise and pollution, and adjust the temperature by making it relatively humid. Moreover, they have positive psychological effects on the human beings and some studies concluded that planting trees reduce the energy needs for cooling by as much as 10%-40% because they provide the shadow in the summer season and act as a barrier to the solar energy during the noon. In addition, they help consumers stop consuming electricity through ACs in the mornings and afternoons. Since the angle of their shade is different in summers and winters, the arrangement of plants should maximize the shade but in winters, the angle of shade becomes different and the sunlight warms buildings (Reardon, McGee, 2013).

Thus, it can be a worthwhile investment in the buildings of Libya to use effective vegetation. In Figure 3.1, the urban coordination and the relationship between buildings and the environment are illustrated.

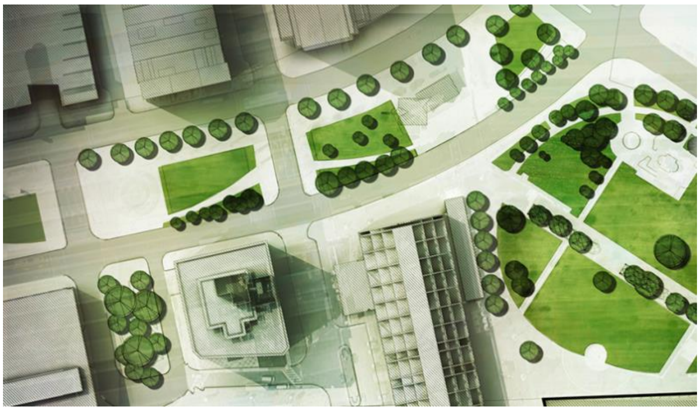


Figure 3.1: Layout between Buildings and Environment (Landscape Amman - Jordan)

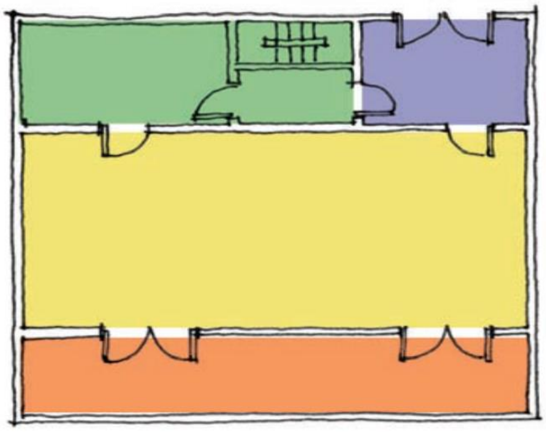
3.1.3. Space Planning

Space planning is one of the important stages in passive design because proper planning of space reduces the use of mechanical energy inside the building and increases the thermal comfort of the users. It is possible to do the space planning keeping in view the overall direction of the building to save energy and create thermal comfort without the use of electric equipment. A study on computer labs suggested that computer labs are the places having greatest internal heat gains, and therefore, these places require refrigeration mostly on the north or on the facades facing east, which minimizes energy used in mechanical cooling. Therefore, while providing thermal comfort, the issue of energy conservation should be under consideration (Koglin, 2013).

Determining spaces and the functions of the design: Every designer takes interest in the available spaces and using those spaces within the building layout, so, it is very important to determine the time used for the space inside the building, but time does not refer to the day or night only, and it identifies the job and work (Baruch, 1998).

Some spaces are not suitable for residential purposes. For example, the lobby, the stairs and the storage; are spaces that are not designed for gathering or for a long time stay, which means that these places do not need a lot of energy for heating and cooling over a long time as shown in Figure 3.2. This is a significant factor in planning as the amount and rate of cooling and heating required for the use of space, and the approximate number of persons using that space is determined (Rekha, 1997)

Moreover, the surfaces surrounding the building determine its environmental conditions as they also affect the thermal comfort of the users.



North facing service zone   north facing buffer entry/vestibule

Primary occupied zone.   South facing buffer zone

Figure 3.2: Space planning and function distribution (Guido, 2009)

Planning benefits:

After finalizing the sites for coding, the need for energy and mechanical cooling decrease substantially. In the same sense, the natural heat sources could provide heat during winters. A good planning reduces the need for heating and improves the thermal comfort inside the building (Bilgiç, 2003).

In many cases, when a building construction takes place next to another, it can be difficult use solar energy. Therefore, the architect must know the amount of local solar radiation and the location of surrounding buildings because it can affect the sun exposure.

It is important to achieve a passive solar design, for example, in some buildings such as schools and offices, the eastern or southeastern exposure may be the best, especially in cloudy areas, which are always foggy. In case if buildings used at night determining appropriate window sizes and thermal balance between seasons is essential (Horton, Forster, 2002)

Buildings exposed to the southwest have the highest percentage of energy needs but spaces located at the northern, northeastern, and northwestern parts are generally comfortable enough without the need for excessive cooling, especially if they already have passive cooling such as natural ventilation.

Temporary buffer space reduces cooling capacity by half in most of the areas and completely removes the cooling energy needs in places, which are towards north. The buffer area has the biggest impact in the areas at the southwestern, the southern, the western, and the northeastern corners. Buffer space reduces heating energy in all the places ranging from 24% in the north to 33% in the south (Winning, 2008)

3.1.4. Architectural Features

The vernacular architecture was present in the ancient civilizations in the effort to adapt and coexist with the surrounding environmental situations where they use the locally available materials from the environment such as sunlight, heat, wind, rain, and others. For example, the ancient Egyptian civilization used the local materials such as brick, papyrus, and wood in their dwellings and temples. The use of stones in vernacular architecture is also essential. In the Islamic architecture, many environmental processors exist, such as the use of domes in addition to the use of interior yards and timber in the oriels. All this was part of humans' effort to adapt to the natural environment. The humankind did not ignore the environment at all but tried various ways to adopt its natural elements until the industrial revolution. That was for the purposes of adopting and providing comfort inside their buildings. The building must be designed and constructed in stylish ways with less need for fossil fuels and high dependence on the natural factors because the ancient communities used this concept. This thought existed since humans' choosing caves facing the south instead of north to receive the sunlight in order to adapt to the climate because they were keen about getting protection and temperatures suitable for their comfort (Maruani, & Amit-Cohen, 2007).

The architectural characteristics are the most important characteristics for the designers to put their fingerprints on. Thus, the designers must put their distinctive fingerprints and merge modernity with tradition and the environmental elements to implement passive design. Further mere, one of the architectural characteristics is careful choice of location. From an optimal and near-perfect point of view, if a builder decides to demolish a building from its location, he should restore the location in its original shape. Some studies show that the environmental processes characterized by the traditional architecture are useful for modern buildings (Swimmers, 2009). They are as follows:

1. Comparison of building materials
2. The design methods and characteristics of the traditional buildings
3. The relationship between traditional and smart design
4. The traditional architecture and the requirements of the modern life
5. The characteristics of the traditional architecture and its environmental effects
6. The suitability of the traditional architecture with the environment

Recently, the costs of buildings increased especially in the residential areas because they are modern buildings, which actually do not fit in to the surrounding environment and look strange. In fact, there is a necessity for appropriate residential buildings, which is in harmony with the surrounding environment for preserving energy and benefitting out of environmental factors (Rao, 1997).

Builders should adapt traditional architectural characteristics in modern designs to preserve energy in the buildings. The technology has solutions to all the environmental problems but that environment-friendly technology uses the local environmental resources to fulfill the local needs and deploys them for thermal comfort in the residential buildings. The courtyard is one of the most important characteristics in the traditional and modern architectures, and its role in the environmental aspects of design is not new. The traditional architecture left architectural solutions for achieving the passive design in the buildings, which was the production of hundreds of years of experiences, unfortunately neglected by some modern architects. It aimed to achieve goals of environment-friendly design for reducing the cost of energy in the buildings and the use of natural energy instead of mechanical power systems, which provide people a healthy and comfortable environment. This approach definitely applies in architectural design. Each architect in their design aims to achieve the desires of the owner in their own way. The architecture greatly affects the surroundings of the building (Bilgiç, 2003). The suggested method will improve the architecture in the following ways:

1. Reduced energy consumption
2. Healthier interiors
3. Economic savings

Thus, the approach of the building design is an important and distinctive factor in architectural design because it represents the first impression of the building in general, irrespective of the internal details. Some buildings are architectural masterpieces because of their aesthetic appearance with the coordination between their lines. Their architectural results are not possible without the integration of the design of the building with the surrounding environment. At the same time, they should fulfill the architectural needs of passive design (Al-Rashid, 2002).

3.2. Passive Cooling and Heating of the Building

The sun is the only resource of passive heating for the buildings. As we know that in the summer season, the sun's movement takes place from the higher angle in the summer and to the lower angle in the winter season. The passive heating of the building allows the sunlight to enter during the winter season to make it stay warm as Figure 3.3 shows. The unwanted sunlight diverts outside the building by installing horizontal shadings, which means in the absence of proper shading, the sunlight enters the building, which makes it hot. In addition, the sun should not hit the glazing directly because it increases the room temperature. Furthermore, the optimal direction of the building in most of the climates should be towards the north and the directions should be always towards 20 degrees north-west and 30 degrees northeast (Reardon, Clarke, 2013). Therefore, the reflection and solar exposure reduces in warm climates and summer seasons.

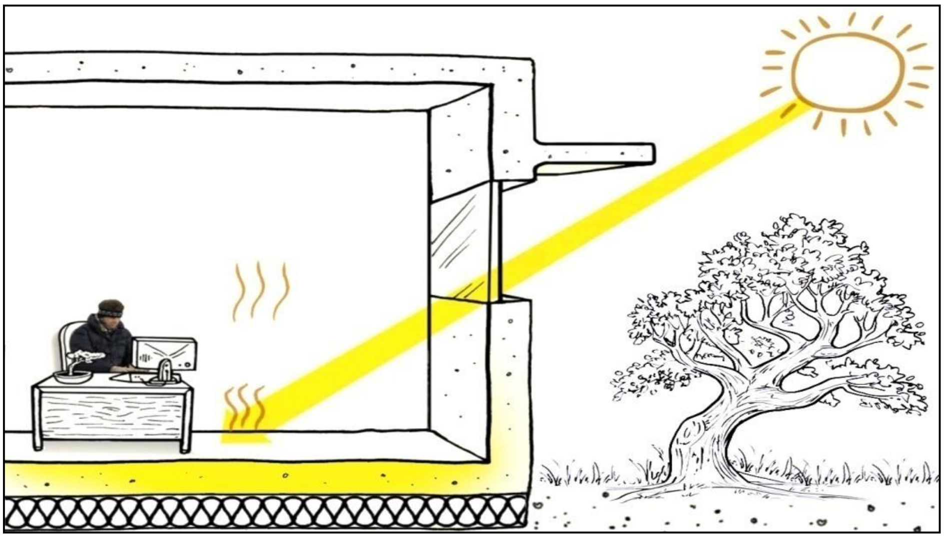


Figure 3. 3: The passive heating of the building allows the sun to enter the building during the winter season to make the building stay warm ("Passive Design", 2015).

Moreover, the designers must take into consideration the area of the window with respect to the wall. The energy must be distributed equally because it helps heating and cooling inside the building. In addition, it helps to provide the required quantity of breezes in to the building, especially for the living rooms. In addition, placing the living areas behind facades or attached to balconies helps getting fresh air and ventilating the indoor air. The thermal performance and the passive energy strategies of the building for high-efficiency cooling of the buildings is possible through low degree of emissions, which results in optimal comfort throughout the year. In some cases, builders need more budget for construction but it gives great benefits in the long run (Schnieders, Feist, & Rongen, 2015).

3.2.1. Passive Heating Strategies

In the passive solar building design strategies, designs of doors, windows, walls, and floors limit the heat inlet during the summer season and collect it during the winters. Experts call it passive solar design because it does not involve the use of mechanical and electrical devices like active solar heating system (Doerr, 2012). The best way to take full advantage of the local climate is the key to designing a passive solar building. Window size and placement, thermal insulation, glazing type, and shading are the elements that must be taken into consideration while designing a passive solar building (Mikler, Bicol, Breisnes & Labrie, 2008). The passive solar design techniques apply easily to new buildings while the old and existing buildings can be either modified or reconstructed.

As stated before, the passive solar building techniques use the solar radiation without mechanical and electrical devices. The passive solar buildings convert the sunlight into usable energy and they make use of direction of wind for the ventilation purposes with little use of other energy resources. A common example is a solarium on the equator-side of a building. The passive cooling is the use of the same design perceptions to decrease the cooling devices during the summer season. The techniques of passive solar design comprise direct and indirect solar gains for room heating, solar cookers, solar chimneys and solar water heating systems depending on the thermos siphon, thermal mass used, and phase-change materials. The passive solar heating design heats and cools the house by taking benefits from the solar energy and it reduces 40% of the energy consumption (Winning, 2008).The passive heating and cooling are necessary for most of the climates. Several heating and cooling design goals conflict because they need different emphasis depending on the needs of the climate. The climate zone monitoring helps understanding the needed strategy for providing comfort during harsh weather conditions (Reardon, Mosherm & Clarke, 2013)

Passive Solar Heating:

This technique is one of the least expensive techniques to heat the house. This system aims to allow the heat to enter during the winters. Moreover, the effectiveness of this system depends on the building occupants, who should remember to open and close the windows according to the weather requirements (Bilgiç, 2003). Following are the properties of this system:

1. It has low cost for new houses.
2. It is friendly for different construction types.
3. It is effective and beneficial for all the climates even when heat is required.
4. This system is installable after buying a house with correct orientation.

5. This system is installable after buying a relatively old house, apartment, or villa after analyzing its orientation and shading.

Passive solar heating requires careful application of the following passive design principles:

1. Daytime living areas must be towards the north (see orientation's. 36, p. 47).
2. Passive shading of glass (see shading.p.64) and the glazing system need quality materials (see glazing, p. 56).
3. There should be suitable areas for glass on northern facades (see thermal mass .p. 38 and glazing .p. 56).
4. Thermal mass for storing heat must exist (see thermal mass .p. 38).
5. Insulation is very helpful (see insulation .p. 42).
6. Floor plan design must fulfill the needs for heating.
7. The used glazing system must be appropriate for the climate (see glazing p. 56).

This concentrates heating towards the needed areas, increases the heat gain, decreases the heat loss during the summer, and winters respectively. The concrete or stone floor slabs and other effective thermal materials have high densities and heat capacities. Their optimal fixing helps managing the internal temperature because they expose to sunlight during the winters and insulate the heat loss. The material releases heat inside the house during the night that it passively gains from the sun during the daytime. Passive solar design is a holistic system and it is one of the most important characteristics of this system because it depends on the integration of building architecture, material selection, and mechanical systems to decrease loads of heating and cooling. While creating responsive and conservative structures, they should operate using renewable energy resources. It is necessary to consider the local climatic conditions such as solar radiation, wind, and temperature. There is little need for maintenance while using passive solar design during the initial phase of the building construction. The growth of landscape and other obstacles should not obstruct the solar heat (Reardon, Clarke & Mosher, 2013).

How passive solar heating works:

Solar radiation is trapped by the greenhouse action of glass, which should be installed correctly (north facing) and exposed to direct solar radiation. The efficiency of this process is highly affected by the shading, frames, glass type, and orientation of windows. Materials with higher thermal mass absorb the trapped heat and store it inside the houses Figure 3.4 shows. The gained and stored temperature re-releases during the night (Suárez & Fernández-Agüera, 2015).

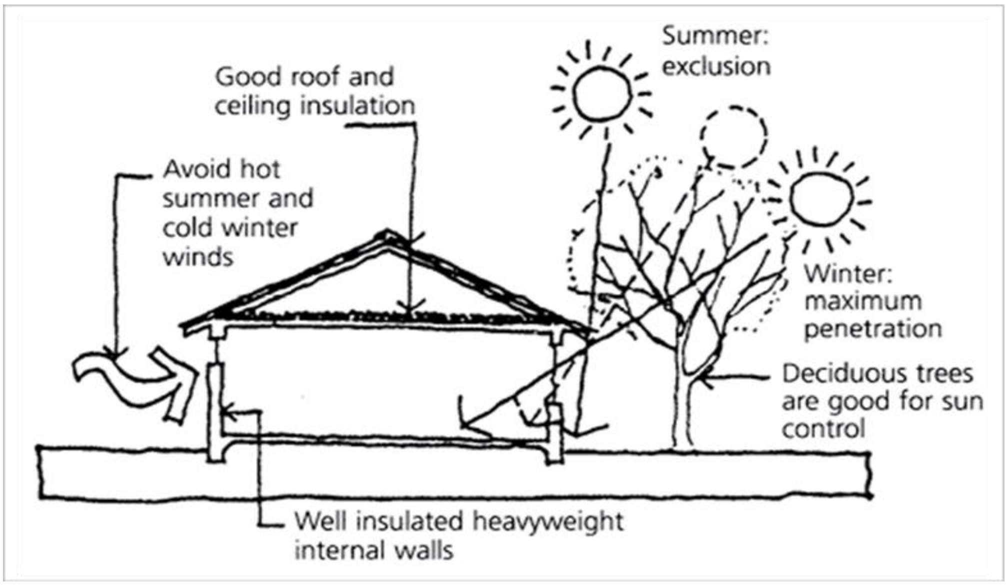


Figure 3.4: Passive Solar Heating (Reardon, Clarke & Mosher, 2013)

The figure above explains how to increase the passive solar heating inside the house. The house must be able to avoid the winter cold and summer heat. The sunlight controls are possible through deciduous trees as they allow better penetration of the solar heat in the house during the winters and they block the scorching heat of the sun during the summer (Reardon, Clarke & Mosher, 2013).

Through the good design of airflow and convection, the heat re-radiates in the needed places. In addition to the high effect of direct re-radiation, the heat conducts by the materials of the buildings and spreads through the air movement. The floor design needs accuracy and the most important rooms must face the equator and receive the best amount of solar heat during winters. In addition, the house design should preserve heat by taking precautions including raised floors and ceilings, insulated walls and suitable-sized windows. In order to increase the effectiveness of the insulation process, the insulation process needs care. In the colder climates, slab on ground need insulation. The airlock usage reduces the air infiltration in doors and windows. The compact shapes that minimize the area of the external walls and roofs are appropriate in the colder climates. As the climate gets warmer, more external wall area with higher rate of openings is suitable for increasing ventilation (Bilgiç, 2003).

3.2.1.1. Orientation for Passive Solar Heating

The living rooms must face the Equator in order to get the best passive heating during the daytime. The optimal orientation to the north is a correct approach but orientation of up to 20° west of north and 30° east of north also permit good passive sun control (Reardon, Clarke & Mosher, 2013)(See orientation p. 47). The passive design increases the comfort and reduces the heating costs even in the houses with poor orientation and limited solar access. Cooling is not possible when there is glass exposure to the sun. The active solar heating system is possible through installing roof-mounted solar-exposed panels. This offers higher flexibility to adapt to the temperature resulted from climate change.

Large windows that face towards the south are suitable for cool climates, which are suitable for passive solar heating because they are subject to the solar heat in all the seasons. The hybrid heating system is a type of passive systems that takes assistance from mechanical devices (Fathy, 1986).

The passive solar system uses similar basic systems as compared to those, which were common in the traditional architectural design. This is normally comprised of the buildings with rectangular floor plans, elongated east-west axis. A glazed south-facing wall, a thermal storage media exposed to the solar radiation, which penetrates the south-facing glazing, overhangs and other shading devices, which appropriately shade the south-facing glazing from the summer sun, and windows in the eastern and western walls, and preferably in none on the northern walls. It is necessary to incorporate an adequate thermal mass in order to get the most of passive solar heating out (Sameti, & Kasaeian, 2015).

Specific guidelines:

The architect/designer must confirm that the area of the thermal mass is six times larger than the accompanying glass, if possible. There is the need to reduce thermal mass for rainy or foggy climates.

Placement of the mass should assure that the sun directly heats it or its installation is in the shape of thin layers in the rooms, in which, there is higher solar energy. The mass surface color of the thermal mass is of secondary importance. Darker colors with absorption range 0.5 to 0.7 are very effective (Reardon, Clarke & Mosher, 2013).Generally, the interior walls must be light-colored in order to widen the space by reflecting light. Shading, mass, insulating values and glass area highly depends on the climate. There is also the need for the glazing to save solar heat. Experts believe that the relationship between mass and glass area is not linear. For example, doubling the area of glazing requires a triple of effective thermal mass.

Economics:

Indeterminate passive solar heating altitudes are sun tempering that can decrease a building's auxiliary heating requirements from 5% to 25%. Therefore, all the costs need calculation for comfortable survival in a building in temperate/cold climates. Energy consumption reduces from 25% to 75% in a building heated through passive solar method while the cost effectiveness remains the same during the life cycle. These approaches are applicable to many buildings especially for small buildings in hot/cold climates ("National Institute", 2016). Through good design and the dependence on good passive solar architectural design, it is possible that the solar passive buildings are cost effective as compared to the conventional buildings. In regions where there are no experienced passive solar architects, the costs of the passive solar buildings may be higher than the cost of the conventional buildings as mistakes may happen during the construction or when buying construction materials, especially the windowpanes. For instance, houses built using glazing reject solar energy. This is a mistake because the glazing used for windows should suit the solar energy needs of the building. During the summer season or in permanently hot climates, the requirement for energy increases because of air-conditioning systems.

3.2.1.2. Thermal Mass

The thermal mass of the buildings stores solar energy during the day and re-radiates it at night. It changes the temperature of high-density materials in the buildings such as bricks, tiles, and concrete. Light materials used in construction such as timber have lower thermal mass. Thermal mass has the ability of a material to absorb and store heat energy. To make a big difference in the house in terms of thermal comfort, and for decreasing heating and cooling bills, and reducing the environmental impact of burning fossil fuels for energy production, an architect should use thermal mass appropriately and correctly because the misuse can cause a worse interior environment without any comfort at all. The passive design should assure passive ventilation of the building and thermal mass insulation making use of suitable glass areas in appropriate directions by taking advantage of the sun and natural factors while making use of appropriate shade (Ministry for the Environment, 2008). There are four factors of internal environment, which greatly affect the internal thermal comfort of the building through passive design including airspeed, air temperature, surface temperature, and humidity. These factors are the most common factors in the traditional design process because each factor differently affects the thermal comfort of the building. Humidity and air temperature affects the thermal comfort only by 6% and 18% respectively. Their speed and surface temperature represent 50% and 26% of the thermal comfort (Reardon, McGee, Milne, 2013).

There are many characteristics, which define thermal performance, namely density, thermal delay, and conductance. Low-density materials such as rubber are lousy conductors of heat. A good thermal conductor should have the ability to absorb and re-emit heat and it should have the ability to store heat, such as brick and concretes, they have high density and they are good conductors of heat. Thermal delay depends on conductivity and thickness of the insulation levels so it should be different in sun facing walls.

Table 1: Time difference for thermal delay between different materials (Reardon, McGee, Milne, 2013).

Material (thickness in mm)	Time lag (hours)
Insulated Brick Veneer	5.0
Concrete (250)	6.9
Double Brick (250)	7.0
AAC (200)	7.0
Adobe (250)	9.2
Rammed Earth (250)	10.3
Compressed Earth Blocks (250)	10.5
Sandy Loam (1000)	30 days

The effectiveness of the flywheel depends on heat loss time of the external wall of the building. The effect of using heat generated during the day and heat lost at night in the winters are termed as flywheel balance.

Thermal mass is the ability of a material to store heat and materials suitable for thermal mass are heavy materials (with high density) as they can store large amounts of thermal energy to provide warmth in the winters. In summers, thermal comfort exists when the heat loss from the body equals heat gain, or vice versa.

Thermal design requirements:

It makes use of the benefits of energy efficiency through thermal mass in low-rise buildings, which means when thermal mass is helpful as a part of passive design, natural ventilation techniques can effectively eliminate the heat and they do not need to be artificially modified (Bilgiç, 2003).

The thermal mass may be extremely useful in structures that require air conditioning and it is suitable for cooling at night and for reducing thermal loads during the day in the summers. According to some studies, eliminating the need for cooling during the winters can provide up to 27% of the benefits of cooling in the overall building. In addition, up to 38% in the overall heating (Gabril, 2014).As for the mass of air, some studies have confirmed that the energy savings are possible from 70-90% in commercial buildings by using the energy efficient techniques in combination with thermal mass (Naresh, 2014).

There is a link between windows and thermal mass. In winters, the mass needs heating for comfort and the heat comes directly from the solar energy provided in the direction of windows. Moreover, appropriate shade in the summers blocks extra solar energy. Generally, specifying large area for windows increases thermal comfort by heating the thermal mass (Bilgiç, 2003).

The most economical way is to bring the thermal mass inside the building in contact with the ground because pairing with the earth provides occupants with more stable temperatures than outside. In the summer, if the slab is without insulation and the floor has a carpet, a huge heat loss will happen to the ground. If the opposite happened during the winters, it provides the ability to store heat from the windows. The stability of the internal temperatures of any space is necessary. The temperature in indoor spaces goes up almost instantly if there is a little thermal mass in the room.

Heat reduces through shading and ventilation in the winters, and thermal comfort increases inside the building through release of solar heat stored in the material during the day. Heat loss from the building can happen when the sun is prevented using insulating curtains on the windows or by the using double glass constantly in place (Reardon, McGee, Milne, 2013).

Therefore, mass constitutes an essential part in energy efficient design; however, it alone does not provide thermal comfort inside the building. The thermal mass forms an important part of the complex design of the building; which is why, the thermal mass is an integral component of passive design for better energy efficiency.

Thermal mass works during the summer to absorb heat during the day and it is suitable for comfortably cooler nights. In winters, the thermal mass stores the sun and helps maintaining heat in the house, it acts like a thermal battery as figure 3.5 showing, thermal mass is not an alternative insulation; however, it works like a buffer to store the heat and release it later. The correct use of thermal mass delays the heat flow throughout the building cover up to 10-12 hours, and the result is a warm house at night during the winters and cooler house during the days in summer (Ji & Plainiotis, 2006).

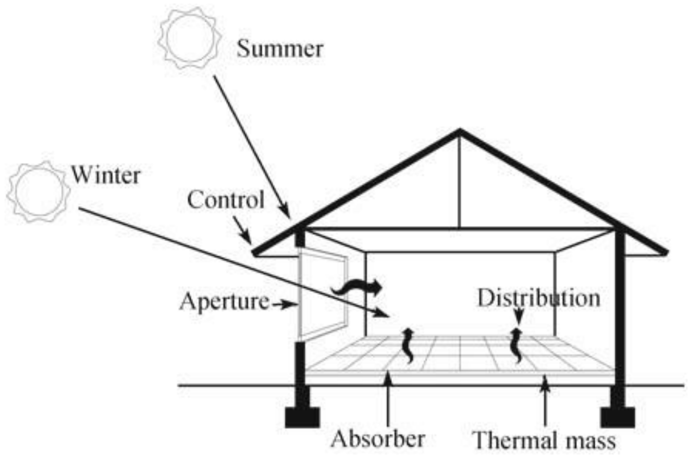


Figure 3. 5: The control for heating and cooling during the seasons (Tian & Qin, 2007)

Guidelines for using thermal mass:

1. Heating select thermal mass site in areas that receive direct sunlight or heat from the heating devices as figure 3.6 showing
2. Heating and cooling: Thermal mass determines the location inside a building on the ground floor for perfect summer and efficiency in winters
3. Determine the thermal mass in rooms facing north with good solar energy, and exposure to cooling in the summer nights along with additional heating or cooling sources (Reardon & Clarke, 2013)
4. Determine the additional thermal mass near the center of the building especially if the users plan to use the heater
5. Cooling: protect the thermal mass of the sunlight in the summer with the shadow and insulation, if necessary. Allow cool breeze or air streams to pass over thermal mass and extract all of the stored energy

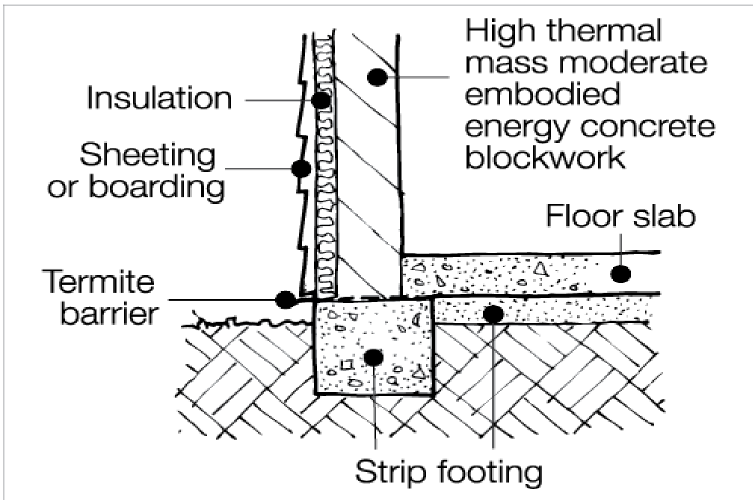


Figure 3. 6: Joint of a thermal mass wall and floor slab (Reardon, McGee, Milne, 2013).

3.2.1.3. High-Performance Insulation

Insulators are very important to maintain the temperature during the summer and the winters because they increase the efficiency of the buildings and help reducing the global warming gas emissions. They also improve health and comfort inside the buildings because they work like a barrier, which allows the heat to flow in and out of the building, so, it is essential to maintain the warmth a building during the winters and coolness in summer, which helps maintaining stable temperature inside the building. Many studies have indicated that well-designed and well-insulated buildings offer convenience to the users throughout the year and prevent paying large amounts for cooling and heating loads. This occurs with full implementation of passive design strategies (Mosher & McGee, 2013).

The level and the type of insulation is influenced by the climatic conditions, influenced by the level and type of insulation because the climate determines whether a building needs insulators or not because the insulation smoothest out daily and seasonal temperature changes. Insulator installation is possible in the already constructed buildings, which sometimes increases the cost of the building; therefore, the most appropriate time to add the insulations is during the building process because it saves the cost, it is more economical and easy to install.

Thermal insulation is one of the methods to keep the buildings cool. Some studies have mentioned that the thermal insulation have a double effect because it reduces the temperature of extra daylight entering the building and provide comfort at night. However, this dual character makes insulation unsuitable for buildings with natural climate control. These contradictions should be resolved. Perhaps the solution lies in determining the cooling load during the design stage. Then whether this load will be reduced using thermal insulation in buildings or not should be determined (Sadafi & others, 2011).

R-value:

The R-value shows internal thermal resistance of the building. Heat transfer insulations work through three processes*:* radiation, heat load, and connectivity.

To avoid condensation and maintain the user's convenience, the interior coated surface temperature must remain high enough during the winters. Cold surface temperatures of the windows improve the user's convenience.

Insulation products come in two main categories- gel and reflective - which are combined in some cases with the compound materials. Comparing between the buffering capacities of the available products is possible by comparing their R-values, which measure the heat flow resistance. Higher R-value means higher level of isolation. Products with the same R-value have the same insulating performance if their installation is appropriate (Thermal Performance, 2010).

Some products are available with performance tests, guarantees, and quality certificates. As compared to the environmental benefits of different products, some recycled materials are also available, for example, some brands of glass, polyester, and cellulose fibers contain large amounts of recycled materials.

Since thermal separators use certain materials to separate the conductive material to avoid the deterioration of the thermal insulation of the cover, it is a common problem called as thermal dam. It is stated that indoor comfort depends on window-to-wall ratio because it is optimal for heating and cooling, and it reduces thermal dam to assure a reasonable target R-value (RSI- values) and the U-value of envelope (Mosher & McGee, Clarke, 2013).

Insulation is possible-to-do in the already constructed buildings, because it is simple to insulate after construction as insulation on the roof, floors and under-floor finishes, and if there is no access to the ground, we can insulate ceilings and walls. It is difficult to add insulation after construction; however, the addition of insulation in existing buildings greatly increases the comfort.

Insulators have many economic, social, and environmental benefits. As to the environmental benefits of insulation, they help reducing the gas emissions by 5%. It is the most cost-effective way of gaining benefits of energy efficiency and renewable energy. It reduces the average cost of heating and cooling by 30%, it provides relief from increasing energy prices and reduces the need for additional power generation, good insulation only costs one-time and lasts for a lifetime (typically from 50 to 70 years) without the need for more maintenance in addition to improving the value of the building. Insulation costs for a typical house is less than 1% of the cost of construction (Sadafi & others, 2011).

Socially, it has many advantages, including providing more efficient use of energy, playing an important role by improving the thermal comfort, increasing productivity at work and providing a healthy environment by controlling the temperatures and noise levels.

The insulation materials are installable on the roofs and ceilings because they operate side by side, and reduce the heat gain from the rooftop. The surfaces of the balcony, which are in the open air and insulated to reduce radiant heat gain. Heat buildup under balconies affects not only space below but also the conditions inside the house. The barriers (the separation wall sections between the ceilings in different heights) must be isolated to the same level of the ceiling. External wall insulation is suitable in cold climates and in other climates as well.

3.2.2. Passive Cooling Strategies

Passive design strategy is popular all over the world since ancient times in order to create and improve the internal environment of the building. With the passage of time, many technologies developed, which created comfortable and safe internal environments. The use of passive design reduces heating and cooling costs, and uses solar heat to make interior spaces comfortable. Cooling and ventilation are big problems in hot and humid climates as they remove moisture from the enclosed spaces. Some elements should be considered while cooling spaces through the use of solar shading: proper guidance, use of the appropriate shading, the use of colors and materials appropriate for the climate, use of plants for cooling effect, the strategy to selectively allow the day light to enter the building, and the use of insulators(Reardon, Clarke,2013).

Passive cooling is a type of building design strategy to reduce the use of mechanical cooling of the building, and to provide appropriate internal comfort. Passive cooling is one of the least costly options both in financial and environmental terms as the direction of movement of the sun and climatic factors used for passive cooling of the building. The cooling requirements should be different and distinctive according to the climate and the location of the buildings (Valladares - Rendón & Lo, 2014).

Feeling comfortable in all the climates requires some form of cooling during certain times of the year, and many ways could be applied to the design or the building can be modified in order to achieve comfort inside the building. Hence, the designer should make an early decision on how to design the building, whether he/she can use passive cooling in the building or needs mechanical cooling or both (mixed). Implementation strategy for passive cooling in the building is as follows:

Passive cooling of the building strategies is an important strategy used in the passive design, because it prevents the building from high temperatures by blocking solar gains. Moreover, removing the internal heat gains (by using the cooler external air to ventilate the interior of the building, and store the excess heat in the thermal mass of the building) (Reardon, Clarke, 2013).

Usually passive cooling takes place along with the passive ventilation strategy to assure passive cooling in the building, increasing airflow and continue passive ventilation in the building during specific periods. Natural ventilation/overnight cooling removes the accumulated heat.

The building cover reduces heat through a number of ways such as buffer zones because they limit the radioactive heat gains and avoid the storage of heat gain during the day, use of light colors because they reflect the heat, shading windows, walls, and ceilings to protect them from direct solar radiation. For substantial heat loss, natural cooling sources should be used including cool air (if available), air movement, direction of the wind, evaporation, reflection of radiation, and ground coupling (Sameti, & Kasaeian, 2015).

Passive cooling sources are as more versatile and complex than passive heating, which comes from a single source (solar radiation). The sources of cooling come with the innovative design of the building cover, air movement, evaporation, heat mass along the ground, and lifestyle choices in most of the climatic zones. Sometimes we need to add mechanical cooling in hot and wet weather or in the extreme weather conditions, which leads to rise in temperature during days and nights (Reardon, Clarke, 2013).

To achieve thermal comfort through cooling applications and to let the cold breeze come inside the buildings, a designer must design the building cover to reduce heat gain during the day, and increase heat loss at night. The following guidelines should consider:

1. Floor plan design and shape of the building to respond to the local climate and location
2. Carefully identify sites of thermal mass to store cold
3. Choose the right windows and glass for the climate
4. Proper positioning of windows and openings for ventilation of the building to promote the cross-air movement
5. Shading windows and walls exposed to the sun and ceilings
6. Using the spaces of the roof, living areas and buffer zones to reduce the heat gain

3.2.2.1. The Orientation

The orientation is one of the most important elements in the passive deign because proper orientation of the building integrates the passive design elements of the building. It is important in the passive cooling and heating of the building and takes benefit from the daylight. Moreover, all the passive design elements provide optimal comfort minimizing the need for mechanical devices inside the building for both cooling and heating. The orientation of the building means choose suitable position according to basic directions (East, West, North, and South) for providing comfort users. This is possible correctly by taking into consideration the regional climate, the solar path in the summers and winters as figure 3.7 shows, and shape and height of the surrounding buildings. Thus, as many studies conducted in moderate climates pointed out that the preferred orientation is east west and all the windows and glass surfaces should be towards the south while walls must be towards the north without windows in it. As far as the weather conditions are concerned, the orientation will be useful, if its position differs from the direction of the temperature axis. Good orientation of house increases the efficiency of using the energy and makes it cheaper and more comfortable for living while poor orientation results in excluding the sun during the winter season and causes the temperature rise inside the building during the summer season (Reardon, Mosher, Clarke, 2013).

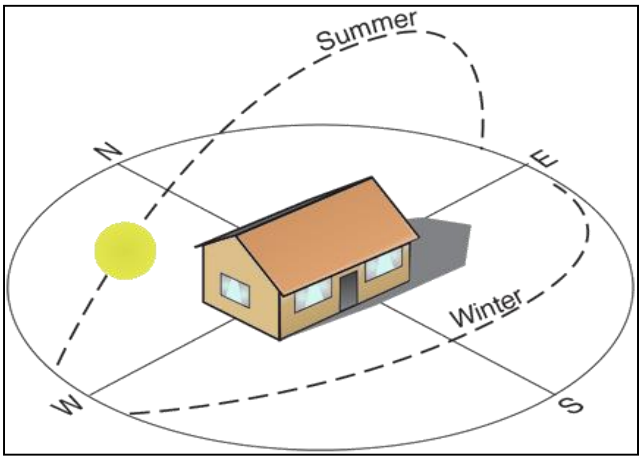


Figure 3. 7: The movement &direction of the sun to orient the building (Reardon, Mosher, Clarke, 2013)

Every designer must understand the issue of orientation carefully and develop understanding of the suitable design possibilities for the buildings by underlining climatic design, as it is clear that average temperature is increasing with global warming and the summers are becoming hotter. Thus, the passive solar heating is still very desirable in the climates that require heating and in summers, it is good to shade the westward windows (Schnieders, Feist & Rongen, 2015).

The suitable orientation of the building means that the buildings must not have sunlight entry in the interior spaces because it increases the temperature, which reduces internal comfort. In addition, the building must be oriented according to the solar path and the openings of the buildings for cooling breezes must be away from the wind laden with dust. Furthermore, the accuracy is important while using sun-breakers that they must have good quality and their position to the sun should be accurate.

Helioden model:

Moving light source that is mimics the solar path above the model of the proposed building. It makes the solar path easy and simple to understand. Today computer-based models used to determine the locations of the seasonal solar energy, identify the locations of the thermal performance with high accuracy and they have the ability to rotate and move the 3D model to understand the solar path. Norbert Yanchter, the designer of Heliodon, the solar simulator in Oxford University, said that using Heliodon to create the shading is completely effective and it solves orientation and shading problems in effective ways. Figure 3.8 and 3.9 illustrates this model (Morrissey, Moore, & Horne, 2011).

Characteristics and drawbacks of Heliodon:

1. The Model 126 Heliodon has a great advantage of keeping the model horizontal and still.
2. This allows a tripod based camera to use for recording purposes.
3. Its only real disadvantage is the close proximity to the light source, which makes sun studies of large models quite inaccurate.

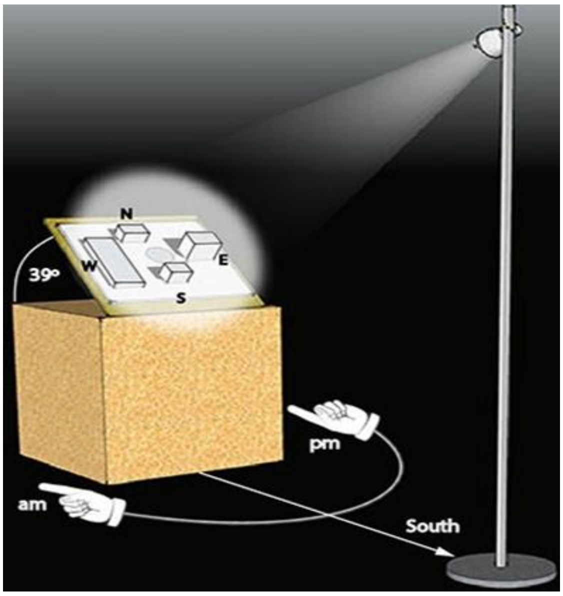


Figure 3. 8: Illustration of the Helioden model ("The Model 126 Heliodon sun emulator", n.d.)

Figure 3. 9: Heliodon model ("The Model 126 sun emulator", n.d).

The goal of this device is to help creating the solar responsive design. With this device, the students and academics can produce, design, and imagine buildings to be more sustainable and they can test them. It helps to find the suitable orientation of a specific building with comprehensive strategies to use the environmental factors for thermal comfort.

Orientation and Layout:

In order to use the energy efficiently in the buildings, the orientation must work in coordination with other elements of the passive design strategy because good orientation reduces the need for cooling and heating assistance inside the building. Moreover, it reduces the emissions of greenhouse gasses, which cause global warming, takes place because the design is according to the direction of wind. In addition, changing direction of the sun in the winter and summer seasons is taken into account. In terms of optimum solutions, the concentration adjustment assures the needed cooling and heating of the building (Bilgic, 2003).

Direct sunlight exclusion from the building in hot dry and humid-dry climates by using the shading of the neighboring buildings and trees as shown in Figure 3.10 shows. Shading the facade during the year and pumping cooling winds in living spaces such as living rooms is always very healthy and helpful for maintaining thermal comfort.

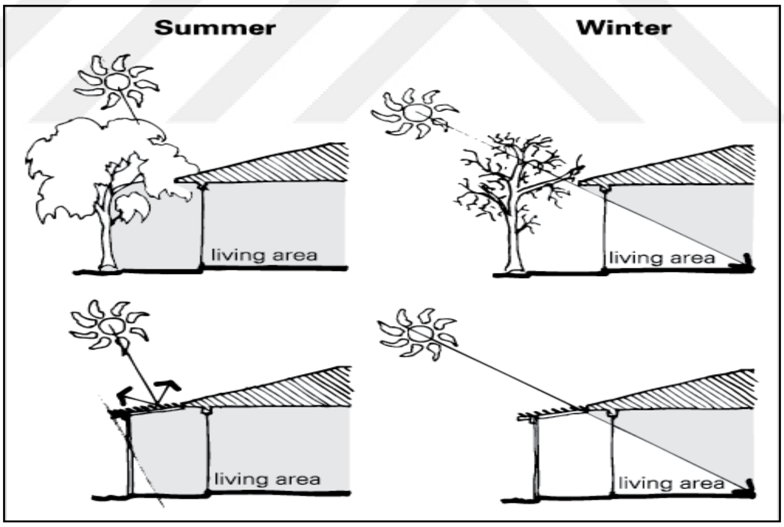


Figure 3. 10: Use of tree shading (McGee, 2013)

The house can become energy efficient if planning is according to the direction of the sun and the prevailing winds. The arrangement of rooms is highly dependent on the function of the place according to the time and use. The temperature of interior spaces guarantees thermal comfort inside the building. Thus, all the areas that do not need special lighting directed towards the north such as corridors, stairways, and service areas while the spaces, which need daylight, must be towards the southern facade. Bedrooms must be towards the southeast or southwest while the eastern side must include the kitchen because the temperatures are less in the morning. The suitable direction increases the natural energy from the sun and wind and decreases the dependence on electrical and mechanical comfort.

It is useful that the wall facing the South should be long to reduce the exposure to the sun during the summer season because in that case, the walls and windows facing north will receive more sunlight in the summer season and the opposite in the other directions especially in terms of heating. Consequently, the passive design feature helps directing the longest axis towards the east and west, but some studies suggested that it is not always possible. Such cases may be outside the influence of the designer. It is necessary to spend more attention on the western facade because increasing temperature in the afternoon increases temperature in the important rooms such as bedrooms. The western facade determines the additional spaces to reduce the solar heat gain and the opening in the west must be shaded enough if possible by using the balconies while the western direction is less problematic because it is warm only in the morning.

Some studies suggest that the solar energy design does not change and changing the direction of wind-flow and the shade can take place by using projections. Moreover, the on-site wind flow can interfere with the protection requirements of the sunrays. Thus, the sun in the winter season spends all of its time in the southern part of the sky while in the summer season; it spends more of its time in the northern part of the sky. This shows that, in the winter the sun is in the southern part with a low angle, unlike the summer the sun is at a high angle. These directions reverse in the southern hemisphere. Consequently, the sun rises in the northeast and sets in the west respectively. In the summer season, it rises and sets in southeast and southwest respectively (McGee, 2013).

In order to choose a suitable orientation for a building, the cooling and heating needs are priorities as Figure 3.11 indicates. A designer must figure out whether the building is in a location where climate needs passive heating or in a location, which requires passive cooling or both passive cooling and heating are required at the same time. Accordingly, some local climatic factors include:

1. Direction of cool wind and monsoon hot winds, the direction of wet winds, and the direction of breeze
2. Location of surrounding buildings and their impact on local geographical characteristics, weather conditions, and natural landscapes
3. Temperature during the evening and daylight (seasonal) and the humidity ranges

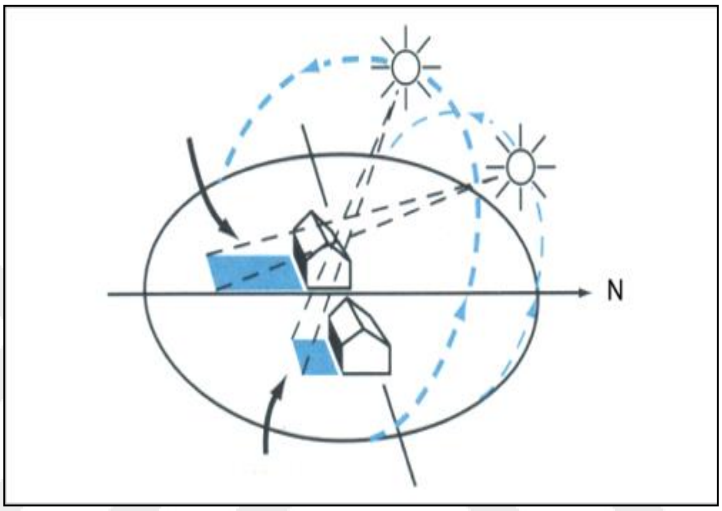


Figure 3. 11: Direction of the sun in summer and winter (McGee, Reardon, Clarke, 2013)

3.2.2.2. Form of the building

The shape of the building has great impact on its energy usage but many other factors including the type of the building, its use, planning, and the primary cost are also very important. Building shape significantly affects area to volume ratio (thin high-rise towers), which can increase or reduce building's energy performance. Square buildings with a smaller envelope area are normally energy efficient. A compact building shape decreases its energy needs and the need for dynamic mechanical systems as demonstrated in the Figure 3.12 (Badea, Beracu & others, 2014).

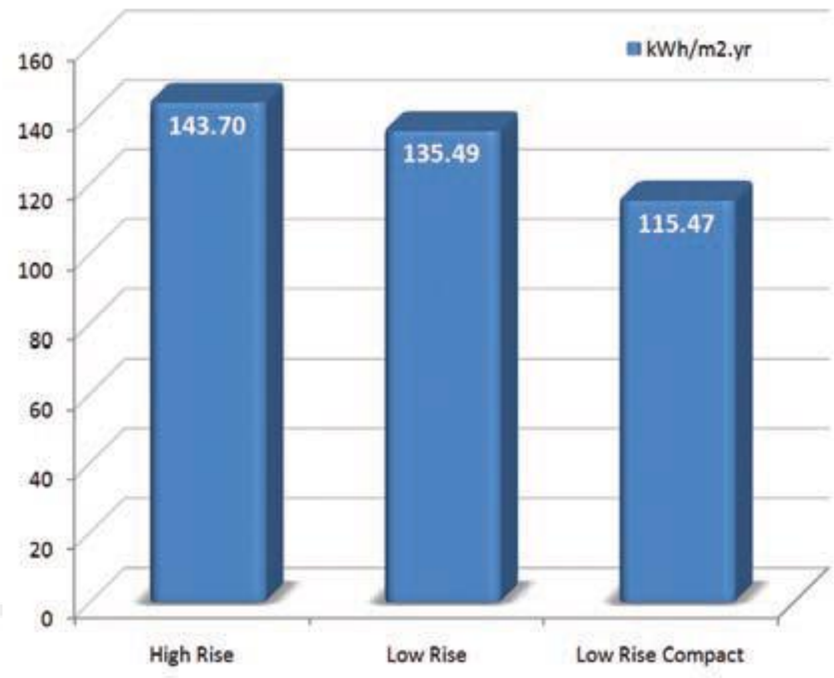


Figure 3. 12: Energy Intensity and Building Shape

Massing optimization can meaningfully affect passive performance often without increasing the cost of capital. The proposed building massing is necessary along with appropriate orientation and observation of other site-specific conditions. The critical effect of the orientation on massing and other passive design components must be studied (Rodriguês, 2010).

Benefits of Appropriate Building Shape:

1. Reduced consumption of cooling and heating energy

2. Reduced dependence on energy during peak hours

Limitations

The urban design conflicts are important such as the shape of street, corridors and the other elements of urban planning.

The small buildings, which significantly depend on heating, are small because their size improves their energy performance (Reardon, Clarke, 2013).

The commercial buildings, which highly depend on cooling, must take a longer shape in the direction of the east-west axis because in that case, there will be a higher possibility of passive cooling strategies. The buildings, which take the compact forms should have specific characteristics, for example, light wells and atria to create day lighting and natural ventilation systems.

3.2.3. Solar Control

3.2.3.1. Day Lighting

The daylight considered as one of the most important strategies in the passive design and the dependence on it is highly beneficial for the user because of its ability to provide energy. The windows facing south bring the warmth feeling in the building and help sunlight enter the building as compared to the windows facing east or west, which bring the direct summer light in morning and evening. The use of natural light in the architectural design provides the energy and reduces the need for artificial lighting and it will decrease the costs of heating and cooling as well. The daylight is a natural thing and it has health benefits. As daylight was the only dependable light source before the invention of artificial lighting, daylight was a source of main light in the buildings before the 1940s. In fact, the natural light provides comfort, reduces eyestrain, and has positive effects on life both indoors and outdoors (Ahsan, 2009).

Often combining the natural and artificial lighting provides more energy and health efficiencies. The daylight is safe and effective as it helps economic swings. During the use of spaces in the evening, lighting should help relaxing. Thus, the temperature must be warmer. Daylight effect improves with coolness in temperatures in workplaces because it alerts and stimulates users during the working hours; therefore, natural and artificial lighting should integrate in buildings, and their benefits improve our lives.

Daylight has many benefits, which increase the quality of the interior environment of the building and help reducing the energy costs. In most of the houses, the daylight just gives light through windows and openings and most of the building designs do not make use of the daylight. Sometimes, a modification on the windows to get proper daylight is suitable. Moreover, psychological and physiological benefits of natural light are important. Daylight can make a space comfortable. Daylight is associated with increasing productivity, decline in absenteeism, less number of mistakes or shortcomings in the products, reduced fatigue and low eyestrain.

Daylight psychologically and physiologically affects the human body from different angles. It improves mood, heightens morale, and relaxes eyes. Sunlight plays an important role for maintaining the overall health. Furthermore, in order to get natural light, exterior and interior colors of the building are significant. Light colors reflect sunlight. Constructing the building towards the north and in spite of the interactivity in providing the natural light, they require at least 25% or more of glass towards the south to get the same contribution of the annual daylight (Caitlin, 2013). Thus, because of using additional necessary glass, benefits of latent heat can be enjoyed in the winter season but the building directing towards north are less effective as compared to the building directing towards south in terms of the cost-effectiveness. The facade of the building should capture the passive heating in the winters because it helps replacing the heat provided by the electric bulbs. Moreover, the direction of the building to the south helps while constructing multi-floor buildings because the solar lighting will reach the medium-sized rooms through the glass placed on the southern side of the building.

The use of high-efficiency glass is better instead of using broad windows (Lyons & Reardon, 2013).

In order to get high quality daylight, experts should develop solutions keeping in view the human nature. The efficiency of daylight cannot be achieved by installing many windows in an undisciplined way, for example, when the direct daylight beam enters into a space, the users will be disturbed, which leads them to block the light and this rejects all the purposes of the light strategy. Thus, the daylight performs in the buildings rather than depending on artificial lighting all the time. Moreover, the furniture has a substantial effect on the effectiveness of daylight strategy, and the finishes must be either white or light colored for better reflection (Zain, Ahmed & others, 2002).

Using indirect light fixtures is important while deciding the location using the computing devices. While designing the buildings, the focus will be on the costs of construction and maintenance. Thus, it must be looked in the best interest of residents' psychological and physical health benefits because they are concerned about performance and cost. The use of daylight decreases the costs and enhances the utility to the building occupants (Michael, 2008).

The daylight systems are good for health, productivity, and safety benefits of the building occupants. The natural light helps protecting the human health. Moreover, the natural light motivates employees in the offices and increases productivity in the artificial environments. The natural light allows good vision to older people (Sushitckii, 2012).

3.2.3.2. Double Glazing and Insulated Glazing

Glazing is one of the important elements in buildings because it connects the internal environment of the building with the external environment and it allows the daylight to enter. In addition, it is the main source of heat gain in the winters and heat loss of unnecessary heat during the summers. The glazing is an important element for energy efficiency in the buildings because it reduces the energy needs and makes a house more comfortable, healthy, and clean. Moreover, it helps creating brighter environment. Furthermore, it minimizes dependence on cooling and heating by saving almost 40% of the buildings' heating energy with a potential further reduce the energy needs up to 87% (Jazaf, n.d.).

Implementing the principles of passive solar energy design can be more specific in some locations, for example, the some of the surrounding buildings may block the sun in the winter season, or the facade of the building should be towards south or west. The solar control glass has an attractive characteristic for the building, and it helps abandoning the use of lamps during the day. In addition, it decreases the cost of operating the building and reduces the energy consumption. Thus, increasing the use of glass in the architecture is imperative for the comfort of the building occupants. Moreover, the solar control glass is significant for big facades; however, their excessive use can result in excessive solar heat gain and in addition, they are effective for noise control (Gupta, 1993).

The glass controls solar energy for comfort inside the building. The glass is a big investment for a house because the glass walls create living rooms full of light, comfort, and harmony with the external environment. Moreover, it reduces the annual heating and cooling bills. In addition, when the glass fixtures are appropriate, it decreases the peak load of cooling and heating, which can reduce the use of air conditioning up to 30%. Therefore, the cost of windows, cooling, and heating are closely linked with each other (Guntermann, 1994).

The glass provides solar light and heat control as figure 3.13 shows, which create more comfortable environment and they can help reducing the expenses, managing costs, reducing carbon emissions, and decreasing or eliminating the need for air conditioning while in winters, it allows the sunlight to enter the building, which makes it warm. The ineffective windows make the building hotter during the summer and cold more intense during the winters. Moreover, the chosen glass must protect the building.

The glass controls the solar energy by three mechanisms, which are managing the reflection, permeability, and absorption. Their description is as follows:

Reflection: reflects the sunlight back to the atmosphere.

Absorption: the rate of absorbing radiation from the glass

Permeability: it partially allows sunlight to pass through windows, which controls the sun factor.

It is not possible to control sunlight in number of methods including the colored, painted, and coated glass curtains because the curtains decrease the gain of sunlight by reflecting the heating.

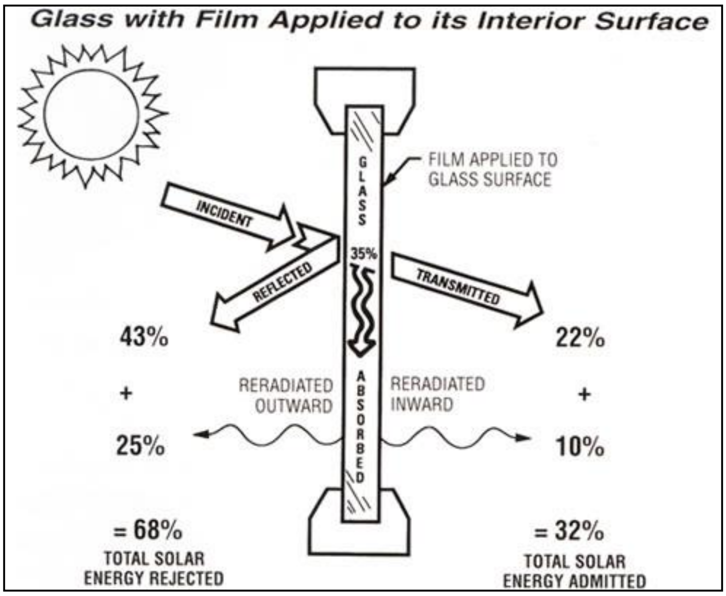


Figure 3. 13: Glass with the film applied to its interior surface (Solar Control, n. d.)

Controlling sunlight creates effective thermal insulation during the winter season and it has a number of other benefits during the summer season:

1. Reduction/elimination of the cost of air conditioning
2. Reduction in solar heat (which means reflection of about 98% of infrared sun rays) (Lyons, Hockings, 2013)
3. Almost complete absorption of UV sun rays
4. Completely controlling the solar energy (reducing the glare to about 99%) (Lyons, Hockings, 2013)

Benefits of window shading films:

It consists of a thin film made up of polymer that contains absorption paint or reflective metal layer. It is an effective means in terms of the cost for reducing solar heat from the windows as figure 3.14 shows. Some of the window films can absorb or reflect the solar radiation. This can be beneficial especially during the hot climates when the cooling is the main concern or elevations that directly expose to long periods of solar radiation. It may cause the decline transmittance of the visible light, which is important while choosing the film.

Glass panels with the application films expose to direct solar radiation and become hotter. They are generally better than the supported film for the window. The UV and SHGC values of films refer to the desired performance.

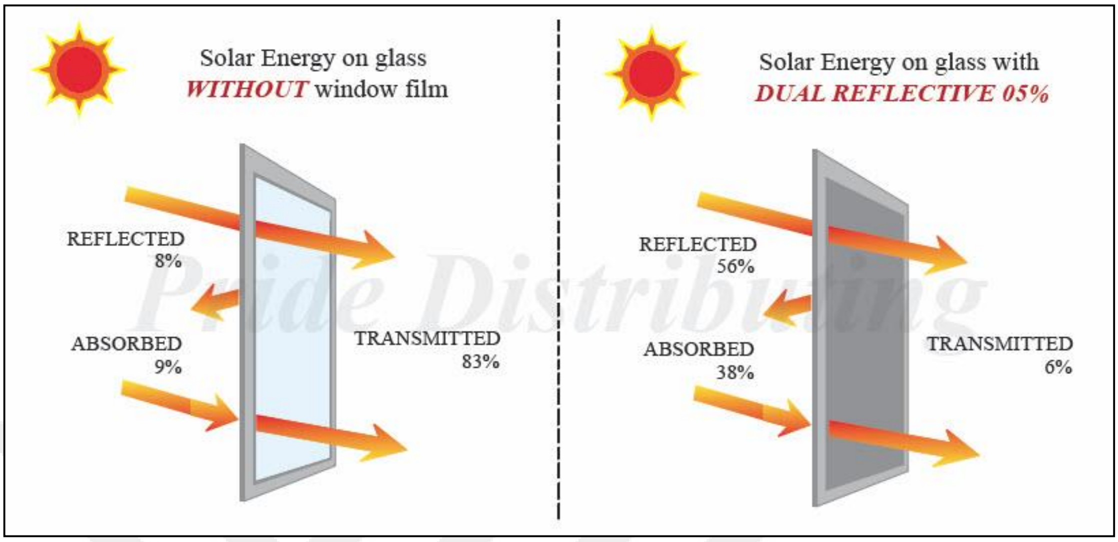


Figure 3.14 shows solar energy on glass without and with the film (solar film, n. d.)

The Design Requirements for Thermal Mass:

The thermal mass is a place to store the heat and not to create the heat. It is beneficial during cold climates and for this, it is necessary to use the glass to allow the solar radiation to enter and warm the mass using the daylight. This means that the thermal mass is appropriate in the warm and hot climates to reduce the gain of solar energy through the glass to absorb the heat from the atmosphere. The thickness of the glass must be suitable and it is preferred to be double with a gap between their parts that allow reducing the insulation characteristics as figure 3.15 shows and its thickness should be always 100 mm or more (Lyons, Hockings, 2013).

The accurate choice of glass enhances the thermal comfort of the user especially if there are many windows and the temperature of the surrounding surfaces has greater effect. This means that the glass must not let heat get inside during the summers and cold during the winters.

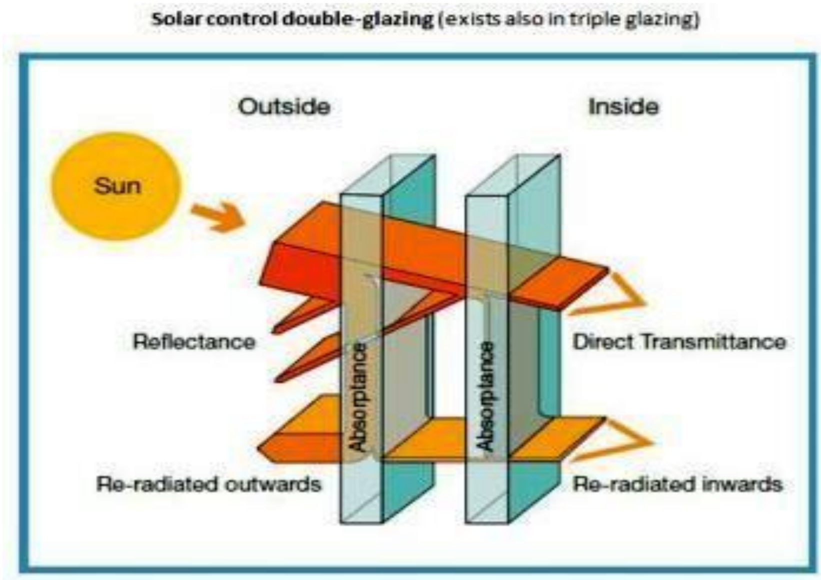


Figure 3. 15: double glazing *(Lyons, Hockings, 2013).*

1. G-value depends on thermal insulation glass selected as inner pane.
2. G-value depends on thermal insulation glass, which is an inner pane (all based on 4 mm thickness) (Lyons, Hockings, 2013).

Correct windows add to the energy performance by two mechanisms, which include heat transfer and acquisition of solar heat.

Delivery: U-value:

U-value measures how easily the windows deliver the heat. It is a measure of the rate of non-solar heat loss or gain through the windows. The average of the heat in the conditions of U means the total effect of window assembly, which includes frame, glass, seals, and dividers. A simple formula can help measuring the impact of enhancing the U-value. The amount of energy, which can penetrate from the glass unit (in wet condition) equals the U-value (the free union) multiplied by a number of digressing differences in the air temperature on each side of the glass unit (A).

TAU= watt (W)

Therefore, a building contains 70 m2 of windows and glass doors with aluminum frames and glass, the U - value will be 6.2 in winter nights when the temperature is 15 °C cooler outside, the loss of temperature will be:

70× 15× 6.2=510.6 W (Lyons, Hockings, 2013).

The calculated effect is equal to the heater or air conditioner operated using energy. If the U-value of the window is nearly half, the loss of heat value decreases using a double glass. In this example, 3,000 W of heat loss is possible, which is equivalent to the energy use by fifty incandescent bulbs of 60 W each (Lyons, Hockings, 2013).

The thermal properties of glass: Thousands of glasses and frames are available for making a choice but appropriate selection is very important to enhance the energy efficiency.

The effect of glass on thermal performance:

The effect of glass is complex because it should be according to climatic conditions. Correct direction, appropriate design, right kind of building materials, information about temperature, humidity, solar radiation, direction of wind, thermal mass, and insulations are very important for a truly energy efficient building. The openings of the windows and doors must allow natural cooling through ventilation. Shading and thermal properties of the glass systems allow the solar radiation when the weather is cold and block it when the weather is hot. The effect of the glass is the interaction of all the above-mentioned factors. In the design phase, some simple concepts are important to improve the thermal performance.

The types of windows frames and effects:

The window frame and its material have a very important impact on the thermal performance. Aluminum window frames are light, strong and durable and they are available with variety of coating and oxidized options. The value of the insulation reduces by windows because aluminum is a good heat conductor. It contains many types including black type that absorbs high quantities of the solar heat. A large amount of energy takes place during the aluminum manufacturing but it can be recycled.

Wood frames are insulating and natural but they lead to gaps, which allow air infiltration. Thus, the wood types must be durable or treated to prevent the deformation and decay. In the composite frames, aluminum exists in a thin section on the external parts with wood. The materials such as fiberglass provide strength, insulation and it is easily available.

3.2.3.3. Window to wall ratio

The doors and windows highly affect the human activities inside the buildings and the use of energy. Doors and windows are important parts of external cover of the building. Good use of windows helps increasing the benefits of daylight, breeze, and ventilation inside the building and decreases the need for mechanical heating or cooling; therefore, it is important while designing the windows. A window takes highly considerable space in a wall, so, taking special care is necessary while designing them.

The good application of this strategy gives benefits of the natural daylight and provides about 80% of the internal light. In addition, it provides the feeling of security, comfort and provides attractive lighting inside the building. In addition, it offers enough natural ventilation and cooling and thus, decreases the need for mechanical ventilation and cooling. Windows always gain about 87% of temperature and about 40% of the heating energy (James, 2008). Thus, good window placement with accurate manner with double glass and thermally broken frames prevents heat conduction. Moreover, the double glass blocks 60% more temperature as compared to ordinary glass. Thermal internal blinds prevent heat loss through the windows during the winter season. The blinds do not have high effectiveness but with suitable glass, frame, and shading, they provide internal comfort. This is possible with a good look at the building location in terms of the proper orientation of the windows. For example, in Australia there is need for shading on the windows from the northern side and a room in the eastern side in order to prevent the solar radiation in the summer from heating the house in the early morning and from letting the house get hot in the afternoon. Moreover, shading should be on windows on the southern hemisphere side to prevent the direct solar radiation. The southern part must contain more windows because it gains heat during the winter season and decreases load of cooling during the summer season. The reduction in windows and their sizes in the east and west are important because they can gain temperature during the summer season. In the historical and old places, buildings and trees are located closer to each other, which limit the sunlight. Doors and windows may highly affect cooling/heating in the building, daylight control, and security of the building.

Size and openings of the windows:

Sometimes, large openings are not good because they cause temperature loss or gain in unwanted ways with more-than-needed brightness and glare inside the building. This means that the openings, windows, and doors allow entry of the daylight through transparent or semi-transparent fixtures inside the building. Slot placement is an important part for the construction because intelligent use of windows and corridors can create thermal and visual comfort. The net area of the glass in the windows is always about 80% of the total window area. It is a rule of thumb that the area of window must be 40% or less as compared to the total area of the wall for enough insulation during cold climates and it is one way to analyze the window to wall ratio (WWR) (Khan, Su, Saffa, 2008;).

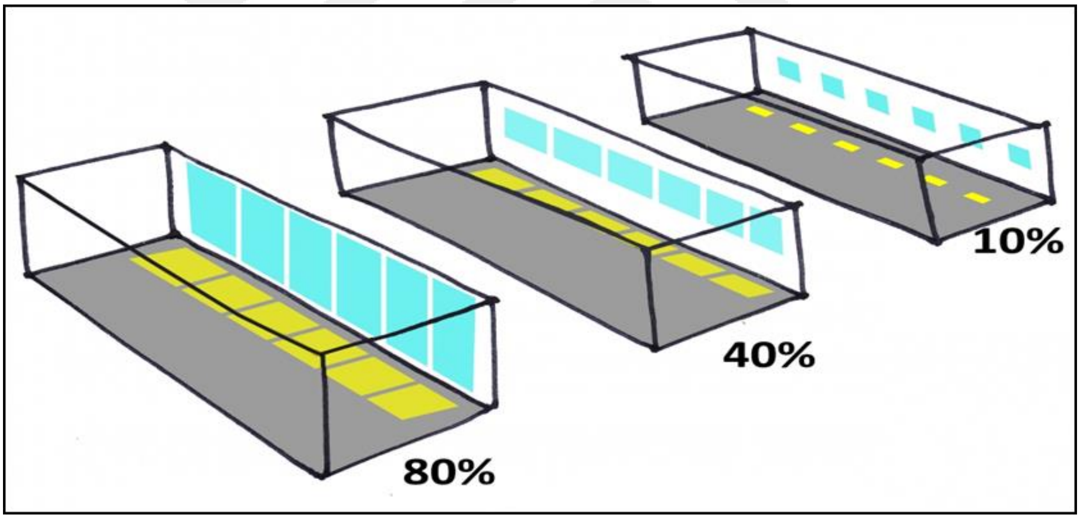


Figure 3. 16: Window-to-Wall Ratios (McGee, 2013).

There are many frames of the windows, which are as helpful for good windows and glass inside the building, and the more common types of frames are wood, aluminum, vinyl, wood with aluminum, and fiberglass. The efficiency of windows varies greatly and mainly depends on the type of the frame and glass for high performance and energy efficiency. The suitable size for the openings depend on their position in the building according to the area of the wall, the direction of the building, the properties of the glass and the window frame (Glass Range for Architects, 2009).

People are healthier and productive when they have the possibility to have access to daylight. In order to get the optimal performance, the size of the windows must not exceed 70% of the wall size and it is better to design windows, which cover just 30% of the total wall area. Windows and openings, allow daylight and fresh air to get in, and allow the occupants to communicate with the outdoor environment. Moreover, they help warming the buildings using solar energy (Caitling, 2013).

3.2.4. Passive Solar Shading

Fixed horizontal shading devices can increase the solar access by the windows facing south throughout the year without any effort from the user. Effective passive shading is possible. Fixed shading above openings allows solar energy to enter the buildings because during winters, the sun's angle is lower but they reject the high angle summer sun. So in order, to regulate the solar light in the building, adjustable shading systems used. This takes into account variable conditions for autumn and spring and helps rapid response and flexibility to climate changes (Reardon, Mosher & Clarke, 2013).

The shading strategy is important and it complements the other strategies mentioned above. The shading strategy is important because it prohibits about 90% of the temperature inside the building during the summer months. In addition, the shading enhances the interior comfort for the building occupants and offers energy. Moreover, while choosing the suitable shade for the building and studying the climate, various shading techniques of fixed or modifiable shadings help such as the shade of trees and plants. Moreover, the shading of glass is the best mean because it reduces too much of unwanted temperature gain, which causes concern for the building occupants. For example, when the glass has no control or suitable frame, this will become a major source of heat in the building. Sometimes, shading is designed inappropriately, which prevents the sun from entering the building while the wide range of shading during the summer season can reduce the daylight and this increases the use of artificial lighting inside the building. In addition, the possibility of shading the non-isolated and dark colored walls is a good way to reduce the thermal mass in the building (Reardon, 2013)

In most of the climates, radiation should be inside the building for heating during the winter season but it is inappropriate during the summer season because the temperature resulting from the sun passes through the glass and absorbs in the building parts and furnishings the colored walls can reflect about 70% of the temperature gain in the summer season. In addition, the shading resulting from the wall and the ceilings is important to reduce the temperature gain during the summers. The shading requirements differ according to the climatic trends and type of building. For example, in the southern direction, fixed or horizontal shading requires modification above the window. And extends from each side while in the east and west, there is a need for fixed, vertical slots or adjustable blades whereas, in the NW and NE directions, there is a need for adjustable shading or pergola with chrome, which is conducive to allow the solar heating. In SE or SW directions, planting trees and evergreen plants can be helpful. Many architectural designers use computer programs, which calculate the solar movements and recommend shading for different locations and topography based on digital scanning of the location (McGee, 2013).

Methods for corner shading:

Eaves, openings to point the correct corner, pergolas, and umbrellas or all of them can help managing the sunlight during the whole year without needing any effort by the occupants. The summer sun is in the high corner during the summer and excluded easily from south by fixed horizontal devices above the openings. Sometimes there is a need for high shading from the east or the openings that face the west. Thus, fixed shading of glass facing south is required (Valladares - Rendón & Lo, 2014).

An area of the glass must be facing the eastern or western area as least as possible because the openings facing east and west have different design requirements. At noon, shading is difficult and during that time, it is a good direction for ventilation. Suitable shading means adjustable shading like outdoor curtains. In addition, the balconies or pergola is helpful to shade the eastern and western sides of the building and they work in combination with plants to filter the unwanted sun. The balcony design should reduce the daylight. Plants, falling vines, shade cloth and screens apply side by side with the pergola to provide the seasonal shade. Moreover, the pergola can provide isolation during the summer from all of the directions while the evergreen chrome deals with solar heat but they are helpful only in the tropical climates. The interior shading does not prohibit the temperature gain but reflects it and this can only happen through glossy surfaces, which reflect the sunrays without absorbing them.

The plants are good for less temperature on the earth surface and the surrounding area. The double glass is not an alternative to the shading in the hot climates because the effective shading can exclude 100% of the direct solar heat. Thus, double glass reduces the surrounding temperature (McGee, 2013).

Table 2: Shading requirements

Shading requirements vary according to climate and house orientation, as shown below.

Orientation	Suggested shading type
North	Fixed or adjustable horizontal shading above window and extending past it each side
East and west	Fixed or adjustable vertical louvers or blades; deep verandas or pergolas with deciduous vines
NE and NW	Adjustable shading or pergolas with deciduous vines to allow solar heating or verandas to exclude it
SE and SW	Planting: deciduous in cool climates, evergreen in hot climates

Shading types:

There are many devices, which used to shade the buildings, and some of them are permanent while others are temporary but the most common of them include Overhangs, wings or the vertical fins, which act as fixed shading means. Reflecting horizontal surfaces (light racks) in addition to the trees are as part of a natural view, glass and the interior controlling devices such as metal curtains or the adjustable alcove are also useful. The fixed shading devices are easy for construction and maintenance because they are economical, permanent, safe, and comfort creating without interference in the daily life. They can shade a complete façade of the building. There is only one shortcoming, which is associated with fixed shading, and that is lack of transfer because these fixtures cannot transfer to other locations or corners. The external shading is more effective for fixed internal shading devices and it is helpful on the external walls and windows because they reduce the direct solar energy intake.

Overhangs are as the devices, which work on prohibiting the direct solar radiation from entering the windows and doors and even the walls during specific times of the day and year. The overhangs on the balconies or directly across the windows are part of good energy-efficient design strategy. Moreover, the shade of the overhangs can help reducing the quantity of the radiation to reach the buildings. In addition, the overhangs are as more effective on the southern facades.

Wings, wall of wings or vertical fins are specialized form of shading in the Eastern and western directions. Moreover, the plants can provide the shade and act as windbreakers for the building. In addition, they promote visible environment and help the cooling process. The pergola with vertical screen prevents the lower corner of the sun and the adjustable shading allows the user to select the required level of shade. This gives benefits in the spring and autumn for heating and cooling. Fixed shading in the east and west means shading in the hot climates while in the cold climates, the eastern shading has importance because the sun corners in east and west is low and the structure of the vertical shading is beneficial because it allows the light, ventilation and expels the solar radiation. Overhangs, pergola, vertical structures such as the screens, climber covered with lattice and vertical umbrellas are also effective.

Calculating the corners of the sun:

The corners of the sun in the sky need angle calculation, which is possible through the solar coup and moderation in the following way: (McGee, 2013).

Moderation: 90 °- Latitude

Summer Solstice: moderation + 23.5 °

Winter Solstice: moderation- 23.5 °

Eaves need a correct design. Some designers may avoid sizing of the eaves properly and think that it is difficult to process. Generally, the width of the eaves should be 45% as compared to the height of the windowsill (McGee, 2013; Insulation Council, 2007).

The selection of the suitable shading reduces the exposure to the harmful UV rays and reduces the energy needs for creating the shade that acts like a pollutant filter. The selection of suitable shading modes allows adequate quantities of the daylight to enter the building while prohibiting unwanted temperatures. Moreover, the plants should allow the filtering of the light entering the building. The design of the glass allows the temperature gain and light to enter the building. The external colored surfaces or the shading means reflecting more of the sunlight in the building, which may be beneficial or it may create unwanted glare. In order to protect the building envelope from the solar radiation in the summer season, shading is helpful because it reduces the transfer of temperature across the walls, windows, and doors. It reduces or eliminates the need for mechanical cooling.

3.2.5. Material and Surface colors

All the building materials that used in the construction are associated with specific environmental cost. Some concepts may help in orienting the choice of construction systems with sustainable materials. The optimal analysis for selecting the construction materials and the way to collect each of them can improve the interior efficiency and comfort of the building and its life cycle significantly, which reduces the environmental effects.

The first step is sustainable materials strategy, which means reducing the demand of new materials. Instead of reconstructing, the structure or knocking it down, it is good to reuse the materials from the existing building wherever possible. While designing the building, it is necessary to design it with a smaller area. The wastage needs reduction by using readymade-items, and without the use of unnecessary lining and finishing. During the design and construction, it is necessary to choose materials, which are easy-to-fix, easy-to-disassemble, low-maintenance, and durable. The second step is choosing materials with low environmental impact. Sustainable materials have almost no environmental impact while the non-sustainable materials affect the surrounding environment and even human health. Most of the materials have a specific negative impact on the surrounding environment. Nevertheless, it is necessary to minimize the negative effects of the materials chosen (Taleb, 2014).

Scientific analyses are available, which explain the materials' environmental impact and the most important is the Life Cycle Assessment (LCA), which is helpful to analyze the life cycle of a material in a detailed way. The LCA determines the chemical, physical and energy affects of materials and products. This analysis provides us better and more comprehensive evaluation for sustainability of the products and materials, which helps selecting better products/materials. The knowledge about how to use the construction materials can help avoiding the environmental impact of materials without additional cost. The selection of construction materials can significantly change the amount of energy that exists in the building structure. The process of evaluating the energy that exists within the components, materials or the entire building is a difficult task. The other important factor to measure the embodied energy inside the building is the design of the building (McGee, 2013).

Recycling and minimizing wastes provide many economic, social, and environmental benefits. Using recycled materials and reusing materials is necessary during the design and construction phase because it minimizes the effort.

Construction systems:

The construction systems are ways to construct the main parts of buildings such as ceilings, walls, and floors. They are varied and each one of them has characteristics and shortcomings depending on the distance, climate, budget, maintenance requirements, required mode, and appearance. There are many important factors affecting the construction system including its durability, the effect on the environmental lifecycle, cost, lifecycle, thermal performance, reuse, possibility of recycling, and necessary skills for construction (Chun, Kwok, Tamura, 2004).

Materials:

Bricks and blocks are as durable construction components. They comprise of high mass materials with a great compressive strength, which can be in units, and handled just by one worker. The user materials comprise of brick, stone (travertine, limestone, granite, and marble), stucco, concrete, glass, manufactured stone, and tile. They differ in their thermal performance, structural capability, fire resistance, sound insulation, environmental impact, moisture resistance, vermin resistance, and durability.

Cladding is a non-load-bearing skin or layer fixed on the external part of the house to shed water and protect the building from the weather impact. There are significant environmental implications on the selection of cladding. Various cladding options are available and each one of them is suitable for a specific application. The high thermal mass in the concrete slab floors can play an important role in the thermal comfort of the building occupants. The slabs can take many positions such as on ground, suspended or both of them. In order to use the thermal mass in a better way, it needs to be polished or tiled. The traditional concrete comprises of raw materials. The production of cement results in high emission of greenhouse gases. Nevertheless, this effect can be decreased by using cement extenders (e.g. silica fume, ground blast furnace slag and fly ash), new cement (e.g. geo-polymers and magnesium cement), and alternate concrete forms (hempcrete) (McGee, 2013).

Insulating concrete type (ICFs) are exclusive modular units, which take the form of panels or interlocking blocks using polystyrene or polyurethane foam and later, they concrete fill is used. Substantial thermal mass and structural support exists inside the insulation. The high levels of insulation and the nature of sealed construction make these parts highly suitable for projects, which need high thermal mass levels to meet the passive design criteria.

Autoclaved Aerated Concrete (AAC) is a concrete, which has been made to comprise various closed air pockets(Marco, 1988).It is characterized with light weight, embodied energy, good sound insulation and thermal insulation according to the structure of the material, its irreplaceable combination of thermal mass and thermal insulation. AAC is capable of bearing loads and it is not combustible. AAC is easy to handle and easy-to-shape by using simple hand-held tools. The precast concrete has significant benefits including construction speed, flexibility to build the walls, floors and even the ceilings for different types of dwellings including cottages and apartments with multiple floors. The embodied initial energy can be offset by extended life cycle, which may reach up to 100 years with possibility to relocate and reuse (Mc Gee, 2013).Corporate production approaches include tilt-up (poured on site) and precast (poured off-site and transported to the site) approaches.

These approaches have advantages and disadvantages, and their selection depends on many factors including availability of local recasting facilities, easy access to the site and the design. The optimal construction materials, borrowed from the environment, replace after use. The raw materials are either barely processed or not at all and all of the energy inputs are taken from the sun in direct or indirect ways. Moreover, this optimal material is cheap and its acoustic and thermal performance is good. Straw or other solid fiber add-ons help reducing cracks. Mud bricks along with a mud mortar are helpful in the construction of vaults, walls, and sand domes. Despite the low energy of mud bricks, it was popular. Rammed earth walls consist of gravel, sand, silt and a small amount of clay, into place between flat panels called formwork. Stabilized rammed earth is different from the conventional rammed earth that adds a small quantity of cement to increase the durability and strength. The uses of these materials increase convenience in the construction process. Rammed earth offers an efficient thermal mass with limited insulation. For centuries, the straw has been a building material for thatch roofing in addition to mixing with earth in cob, wattle and daub walls. In addition, the straw is a renewable construction material and derived from gasses. It is resisting surprisingly to fire, vermin, and decay.

Color:

The environmental sustainability of cities is facing negative effect of increased temperature of urban cities (Zambonini, Giuseppe).

High urban temperatures lead to higher consumption of energy for thermal conditioning in buildings during summers, decrease the habitability (the comfort degree) of open areas in the city (streets, squares, sidewalks, etc.). In addition, decrease the potential cooling by natural convection in the evening there is a scientific fact that the black color absorbs radiant energy from the sun while other colors reflect it. Exterior walls and ceilings have high impact on the internal environment of the building. The hot ceilings increase heat in the rooms and thus, it is advisable to use light or white colors to reflect the falling radiant energy. Light gray color is better than the green or blue colors. Unfortunately, most of the buildings have less than optimal conditions for passive comfort. A study conducted in Florida revealed that through heat reflectivity, the owners of the houses saved on average 23% of their cooling costs Moreover, another study conducted by Lawrence Berkeley Laboratory revealed that raising the rooftop reflectivity and other surfaces in metropolitan areas substantially reduces energy costs. The dark wall absorbs more heat and light and reflects less. Therefore, we need more lights in the rooms with dark walls as compared with the rooms with light walls. Moreover, it is necessary to keep the ceilings bright and light for good reflection. The higher level of lighting with very light walls is not preferred if it creates brightness or glare on the wall. This leads to excessive stimulation of the eyes, which causes eyestrain. The color of the room affects psyche of the people and the temperature, and it may affect cooling and heating costs as well (Gupta, 1993).

The colors play a significant role in the energy consumption. There is a mutual dependence between light and materials. In the architecture, the materials play a significant role in the process of understanding the light because it directly affects the type and the quantity of the used light. The finishing type and its color are very important. Glossy finishes reflect the light like a mirror that results in reflected images of the light source being visible ‘on’ the surface. Matte surfaces such as wood, plaster and natural stone reflect the light equally in all the directions. The aspects of color including hue, value, and intensity determine the quantity of the absorbed or reflected light. A white wall reflects about 82% of the light, a light yellow wall 78 %, and a dark green or blue wall just 7 % Colored surface lends some of their hues to light that is reflected. Painting the walls with white color is one of the simplest and cheapest ways to increase light in the room. On the other hand, a room can become dark either by using a little light in a white room or by painting the surfaces with dark color (Gupta, 1993).

3.3. Passive Ventilation

Across the world, there are many naturally ventilated buildings. In the past, this type of ventilation was dependent on a random mix of opening windows. Currently, the ventilation requirements are very different and the modern systems provide control and dependability.

The natural ventilation can provide satisfactory environment even in the complex buildings. The natural ventilation can be the optimal selection especially in the buildings, which are located outside the city experiencing moderate climate. The natural ventilation systems, which widely work in different buildings, highly depend on the situations and requirements. Limp (1994) produced the bibliography of natural ventilation and its applications (Hughes, Calautit & Ghani, 2012).

Driving Forces:

The natural ventilation, which is driven by the wind and thermally (stack) produced pressures. The natural ventilation harnesses these forces through good design and opening positions.

Wind Pressure:

The Wind, which strikes a rectangular building, exerts positive pressure on the windward parts and negative pressure on the opposite parts. This allows the air to penetrate the building from the high-pressure areas to the low-pressure areas.

Stack Pressure:

The effect of the stack develops because of the differences in the outdoor and indoor air temperature and air density. This will result in differences in the gradients of pressure between the internal and external air masses, which lead to differences in the vertical pressure. When the outer air temperature is less than the inner one, this makes air enter through the openings in the lower parts of the building and exit from the openings in the upper parts of the building. This operation reverses when the outer air temperature is higher. The stack pressure calculation relies on the vertical spaces of the openings and the air temperature between the two air masses.

In order to get good natural ventilation, the following aspects need consideration for building design (Korjenic, Teblick & Bednar, 2010).

Building Air tightness:

The building must contain openings placed for airflow only for good ventilation performance. This allows more precise design solutions and inhibits air infiltration from interfering with ventilation performance (Stavridou, 2015).

The Space as an "Air Quality" Reservoir:

The time that the pollutant takes to reach the steady state concentration depends on the enclosed space size. Therefore, during definite conditions, the building becomes an air quality reservoir where the effect of a pollution transient source primarily accommodates by the mass of enclosed air itself. This compensates the variable nature of natural ventilation process and it is the main part of natural ventilation. This method may not be efficient if the ventilation is suitable for the emissions of fittings and furniture inside the building.

Ventilation Openings:

The ventilation openings must be enough to fulfill all the needs. The overall ventilation depends on local speed of wind and the number and sizes of the ventilation openings. Since the variable driving forces determine the ventilation rate, occupant can modify the openings and meet the demands. The good ventilation design must contain a set of permanently open ventilations in order to provide background ventilation and manageable openings to meet the demands. Occasionally, automatic controls and dampers control the ventilation openings. In the following sections, some of the natural ventilation methods will be described (Hughes, Calautit & Ghani, 2012).

3.3.1. Operable windows

The operable window is one of the passive ventilation strategies because its use gives the building's occupants perfect control over the internal temperature of the building. The functions of the windows are ventilation and cooling and these windows help providing the backup ventilation during the times of inactive ventilation systems or in case of power outage. Many windows can exist in a building and this depends on the needs of the design and on its size. The operable windows provide cooling in the summer season when opened to get the natural air. This is a characteristic to reduce the need for mechanical energy and cooling costs, and enjoy the natural, good, and healthy ventilation. Despite the fact that these windows depend on additional cost, they are mainly for comfort of the user, they reduce the energy needs for cooling in the long-term, and they are healthy for their users. This functional window can be washed from inside, which reduces the cost of cleaning and maintenance, and it is an effective investment in terms of cost. The additional cost is one of its shortcomings because it is more expensive than fixed windows. In addition, it always depends on the user's behavior and correct opening and closing process but still, they provide substantial comfort in the work and living areas (Edwards& Torcellini, 2002)

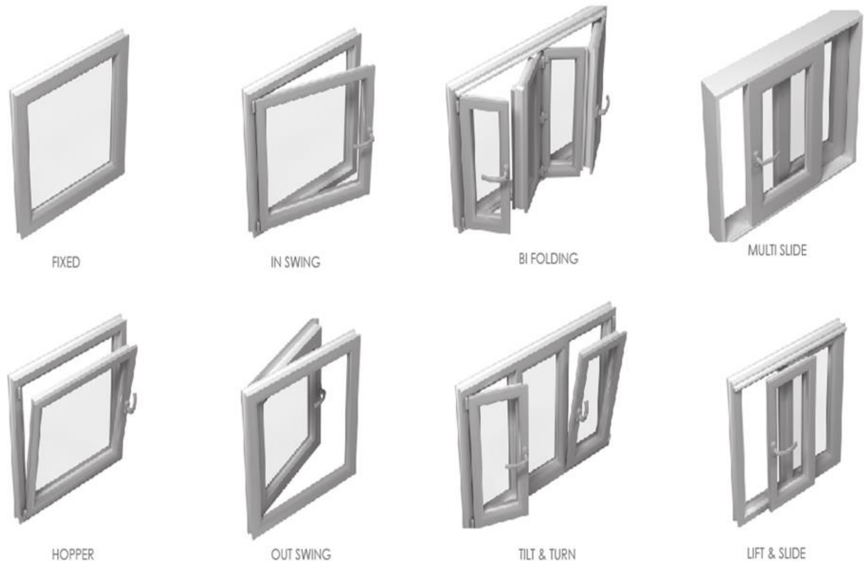


Figure 3. 17: Types of Operable Windows (tiltco.net)

These windows require multiple areas of HVAC and users should shut them when the cooling systems are not working. These windows are open during warm weather;

otherwise, the use of energy might increase up to 30%. In that case, the passive cooling and ventilation strategy will not work. Sometimes the air speed is very high in the upper floors of the high-rise buildings and in that case, it may not be necessary for use

The operable windows are as energy savers but some of the managers and officials think that the operable windows waste energy but this applies only in case of misuse. The building occupants need additional windows to vent out the indoor air and control indoor heating of the building because they need fresh air inside the building. Therefore, it is possible to make the operable windows work without energy waste through integration of the air conditioning system with the window key.

The use of computer simulation has shown engineers that the natural ventilation besides the existing air conditioning system will help reducing the energy waste and if the air conditioning system has not disabled with increasing the operable windows, this will increase the energy waste up to 30% (Limb, 1994).

In an optimal system designed both with windows and with skylights having option of a dimmer/lighting control helps users, when the daylight is not enough. It allows the designers to configure windows and skylights correctly to provide the greatest amount of daylight. The daylight is more useful when it gets in the building structure in the early stages. It allows the designers to choose the most suitable glass and allows the visual light to enter the space reducing the solar heat.

One of the environmental problems that managers face when the matter is either to keep or replace the windows in the old buildings as the existing paint contains lead or the windows are more than 30 years old especially if there are multiple quotes of paint on them. The unique way to know is that the paint needs testing and the best strategy is the replacement of windows instead of replacing the paint. This means that the managers need safe disposal because the paint containing lead is a dangerous waste and the government should dispose it of (Martin, 1995).

Atria Ventilation:

An atrium is a glass-covered courtyard, which provides an all-weather space for building occupants. They are "passive" low-energy building designs and commonly placed in shopping malls and offices. They allow natural ventilation. The atrium is prolonged overhead the employed zone by numerous meters to assure that the neutral pressure plane is overtop the topmost occupied level. The preliminary size of openings can be calculated by simple calculations and approaches. The thermal calculations are important to find the overall heat gain. Many designers to forecast the pattern of airflow within the structure use computational fluid dynamics. Fig 3.18 displays the basic natural atrium ventilation. In order to control the high speed and uncontrolled air change, the building's joints must be sealed carefully. Wind pressures can disrupt the flow patterns. Holmes (1985) and Guntermann (1994) described the successful experiments in the large buildings, which use natural ventilation in the atrium space.

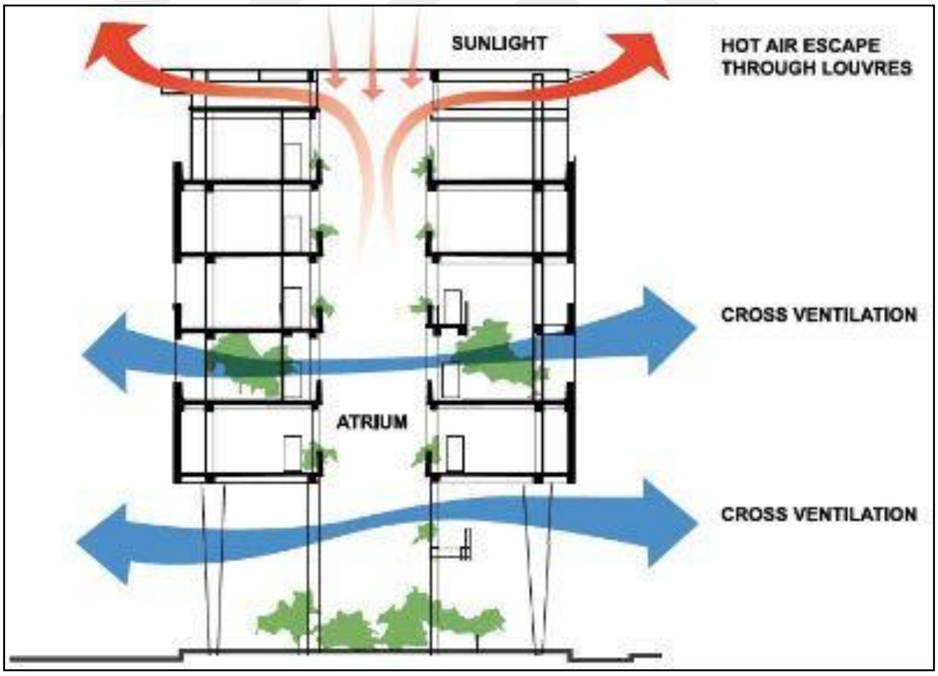


Figure 3. 18: Natural atrium ventilation (Norton, 2014)

Passive ventilation by the atrium circulates cool air around the atrium bottom and the surrounding spaces while hot air rises to the top of the atrium and expels through the louvers. It is successful because once implemented, it will provide the desired cooling without energy use. Although natural ventilation is very beneficial, as to energy savings and health concerns, there may also be some disadvantages due to incorrect design or misuse (Norton, 2014).

Disadvantages of natural ventilation:

1. Insufficient control of ventilation may lead to many problems including problems in the indoor environment and the excessive loss of heat and the mode and flow are not constant .
2. Sometimes it is not possible to distribute the fresh air carefully especially in larger and deeper buildings
3. The high gains of heat might make users get dependent on mechanical cooling rather than natural ventilation.
4. The polluted and noisy locations may not be the optimal options for using the natural ventilation system.
5. The use of natural ventilation designs may cause security risks.
6. The process of heat recovery from the exhaust is possible from the technical viewpoint but it rarely happens in practical.
7. In extremely cold areas, the natural ventilation may not be appropriate.
8. The building occupants may have to adjust the openings in order to get suitable cooling.
9. The process of cleaning or filtering air is hardly practical.

   Ducted systems need large-diameter ducts and there are constraints in their routing.

3.3.2. Double facades

The double facade is one of the most effective options to preserve and control the air, heat, and light temporarily through the envelope of the building. It requires premium cost as compared to traditional facade systems. Thus, justifications for inclusion in buildings include energy efficiency and saving overhead costs. Qualitative benefits include solar control, noise reduction, moderated access to fresh air, moderated surface temperatures, aesthetic purity, increased delightfulness and reduced glare, which are intangible ‘bonus’ benefits (Prianto, Bonneaud, Depecker, & Peneau, 2000).

The double skin facade principle is an extra layer of glass offset from the traditional curtained wall that creates an interstitial space, which acts as a thermal buffer. Usually, the blinds have a specified a space to prevent the solar heat gains from entering the occupied spaces. The blinds placement is usually normal. The operable vents and glazing in the outer surface placement is above and below in order to inhibit the void from the summer heat. In general, the windows are not open during the winter season in order to trap the internal heat and not to lose it through windows. In order to adapt with the weather conditions during the mid-season, the interior curtain wall has operable windows for natural ventilation. Moreover, other benefits of the modification of the external openings include temperature control and extending the duration of natural ventilation. In spite of this, energy saving analyses infrequently conclude double skin facades because they have reasonable paybacks keeping in view the current energy prices and there is no doubt that they do deliver better energy efficiency.

A widespread systematic investigation in a study has proved the cost versus payback profits of double skin facades with respect to their energy saving capacities (Holmes, 1985).

Findings of this study are as follows:

1. The double facades in the south and southwest provide maximum energy savings.
2. Extreme climates provide more chances for energy conservation because they need more HVAC energy and so, they have better potential for savings through developed building envelope.
3. The energy saving can range from 10% to 50% of HVAC energy, and cost of payback duration can range from 30 to 200 years based on local energy prices. Double facades have their individual merits in different climates, orientation, energy costs, and construction cost (Auger, 1996).

4. The economic viability of the double facade in a specific location is not only the climate because the energy prices and the construction cost play a more important role.
5. Another matter taken into consideration is the energy price that differs during the life of the building.
6. The energy saving of today may not be significant because currently, fuel prices are low but we should consider tomorrow's energy prices, which will definitely be higher.

In the current time, double facades can serve multiple purposes; however, they are highly suitable in temperate climates. The double facades provide many benefits including better natural ventilation, create aesthetic and delighting internal atmosphere, decrease cooling loads, decrease energy consumption, and improve noise control (Auger, 1996).

Double facades and ventilation

The double facades provide many openings for natural ventilation but there is no connection between natural ventilation and double facades; however, natural ventilation and double facade can be possible in an integrated manner. The artificial cooling combines with natural ventilation through careful and accurate design of some buildings and residences. The space that exists between the glazing of the two facades works as a buffer, which controls the comfort and utility problems inside the building. The natural ventilation is not limited to airflow through the windows, as it must control dust, noise, snow, rain, and insects. Moreover, in the past there were many tall buildings, which used the operable windows combined with air conditioning systems without any real difficulties, such as the RCA building, Chrysler Building and Empire State Building. Thus, it can be said that the double facades are not necessary, and sometimes, they can act as a handicap (when the temperature is too high), in the buildings with natural ventilation (Auger, 1996).

Delighting effects of double facades:

The facades contain a large area of glasswork allowing large daylight exposure in the building/s. In general, occupants should control the artificial lights. Moreover, the double facades and daylight are not strongly connected factors. Most of the façade designs provide the daylight as figure 3.19 shows. Many factors determine the amount of daylight that can enter a specific building. In addition, the double facade is not as good to bring a suitable amount of daylight to commercial buildings. In order to get suitable daylight exposure, windows and suitable shelves placement is necessary (Straube & van Straaten, 2001).

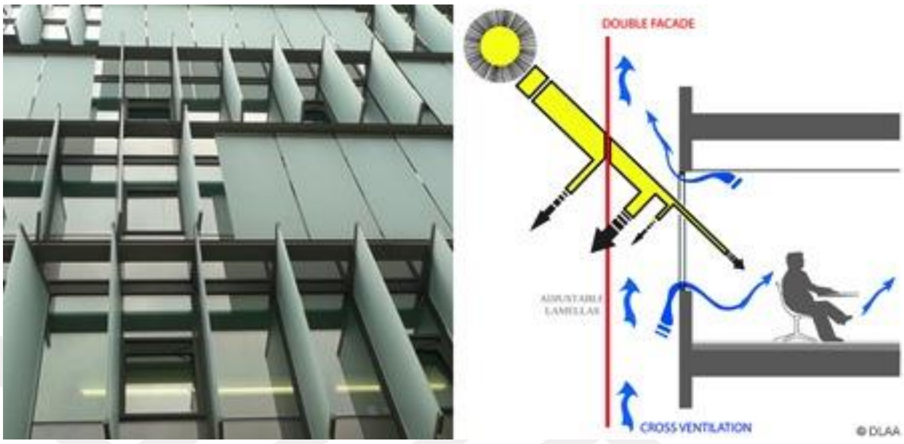


Figure 3. 19: Double facades and Day lighting

The figure displays decrease in the warm sunrays, natural ventilation, and the daylight entry in the building (Stribling &Stigge, 2003).

Double facades and Sound Control:

Adding the third glass pane to a facade having asymmetrical airspaces result in condensed sound transmission, which further reduces by double-glazed sealed units, the sound transmission of sealed triple-glazed units with asymmetrical airspace sizes is nearly always superior to a double facade because there is no direct air connection between the external and internal atmospheres. If the windows are the main sources of ventilation, the double facade provides better sound control. The best sound performance depends on using specifically designed windows (Stribling, & Stigge, 2003).

3.3.3. Transitional spaces

The transition is the space that connects between any two confined spaces. If there is lack of transition space, the architectural space will not exist. The transition space is an interesting topic. A good exterior allows larger spaces for conspicuous design through shade and light. While designing most of the non-domestic spaces, the inclusion of transitional and circulation spaces such as corridors, atriums, lobbies, and stairways is inevitable. The sizes of these spaces vary between 10 to 40 percent of the total size of the building (Rodeghiero & Bassanese, n.d).

The transitional spaces are a physical link and buffer space located between the exterior and interior environments. Despite that, they are as circulation sources inside the building and designers give them importance because they bring comfort and health for the occupants in addition to providing emergency routes in case of fire. Moreover, the optimum energy consumption in non-domestic transitional spaces is important because these areas do not provide income and besides, any consumption associated with higher energy is economically complex to defend before investors.

The transitional spaces have a significant role in the environmental behavior. It is a study, which covers the relationships between the human behavior and the characteristics of urban places, mutual interaction, social grouping, culture, and physical environment on holistic level from interior architecture to regional planning, with applications to develop the life quality by upgraded environmental policy, planning, and design. The sustainability in the building design is one of the most important functions of the transition spaces. The optimal use of these spaces may increase the effectiveness of energy use to a higher extent. This space is sometimes a constraint during the design phase. The transition space design should include special care for the type of building, site organization, orientation, landscape, and topography. The peripheral corridors provide cooling in the interior spaces because they reduce the solar radiation and glare (Pitts, Bin, 2007).

The availability of the water bodies lets in the cool breeze, which gives cool feeling in the interior spaces. If the designs of buildings with wrapped-around circulation space, with internal corridor, with wrapped around circulation space, and with courtyard is compared, it is seen that the design with space for external circulation and courtyard is the most effective design in terms of energy saving and pays back in the form of change in temperature. Transition spaces have great importance while designing a building because it is suitable to all types of climates. For instance, in the climates characterized by warm and humid temperatures, the space of building must allow the airflow (Araji, 2004).

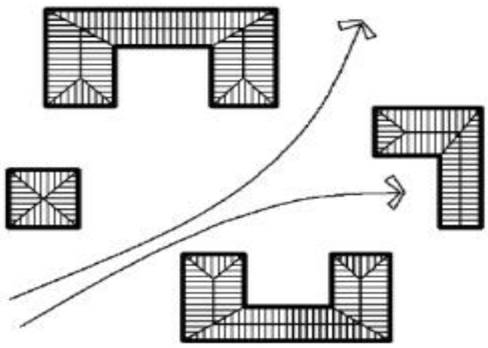


Figure 3. 20: Transitional spaces

The transition spaces are highly affected by the design elements. They include water bodies, pathways, colonnades, pergolas, openings like doorways, grounds, foyers, aisles, gardens, courtyards, patios, trellis, and lobbies, etc.

Because of global warming, days are becoming warmer, which causes thermal discomfort. People living in hot and moderate humid climates spend most of their time in the unconditional transitional spaces depending on natural or mechanical ventilation ((Pitts, Bin, 2007).

3.3.4. Wind towers

Increasing awareness about energy efficiency and eco-friendly environment has renewed interest in the natural ventilation devices inside the building. Air Conditioning ventilation and heating (HVAC), account for substantial use of savable energy in the buildings.

The natural ventilation does not use the mechanical intervention and thus, it is free of cost. In order to reduce the energy consumption and carbon emissions in the buildings, sustainable ventilation technology is the solution. The wind tower is an example of such inventive ventilation devices as figure 3.21 shows. Montazeri and Azizian (2011) defined the wind tower as a device that simplifies the natural ventilation's actual use in a wide range of buildings for improving ventilation. In the Middle East, the wind towers were popular for many centuries in order to offer passive cooling and to achieve thermal comfort especially in dry and warm areas (Hughes, Calautit, Ghani, 2012).

Fathy (1986) proposed that the conventional solution lies in the local architecture integrated or adapted with modern technologies, which make them possible to use with the new requirements.

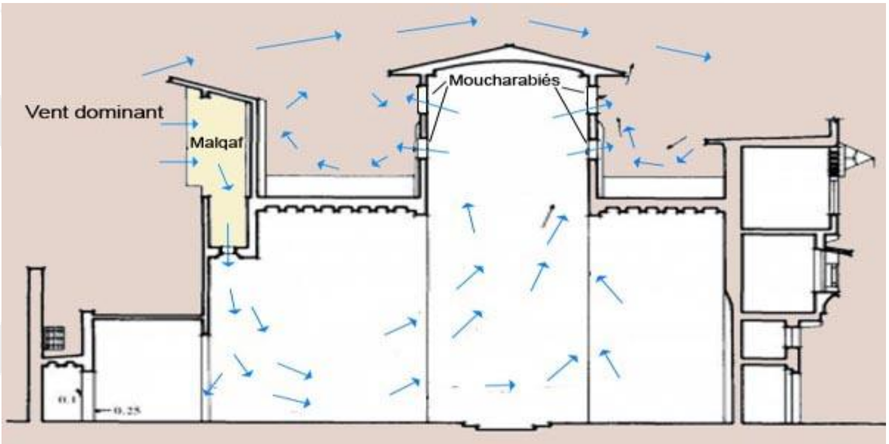


Figure 3. 21: Wind Towers (Hughes, Calautit, Ghani, 2012)

The traditional wind towers used increasingly in order to decrease the use of non-renewable energy. The ventilation principles and passive ventilation combine in the same design in the modern wind towers. In some modern buildings, mechanical ventilation can possibly alter wind towers. Nevertheless, before adopting new techniques, it is essential to search for the functions and design parameters of the conventional and modern wind towers, and to determine how they apply to actual natural ventilation (Hughes, Calautit, Ghani, 2012).

The architectural design of buildings emphasized the possible benefits of natural ventilation systems for creating comfort. Currently, the natural ventilation is an attractive solution to provide comfort and luxury for the building occupants while reducing the use of energy and cost of operating cooling and heating systems. The natural ventilation, to direct the flow of air towards the building, uses the wind and temperature surrounding the building. The wind tower is one of the low carbon ventilation systems.

Elmualim (2006) specified that ventilation through wind towers offer more control and reliability as compared to cross-flow ventilation. The natural ventilation provides fresh air to the building occupants as it preserves acceptable temperature without the use of mechanical systems (McCarthy, 1999).

Allard (1998) defined the optimal quality of air as the air free of harmful substances and contaminants, which may cause a health hazard for occupants of the building. The flow of air decreases the level of pollution. Therefore, in order to get into the indoor environment with fresh air, it is necessary to enhance the airflow with adequate amount while limiting the ventilation rates within a certain range (McCarthy, 1999).

Temperature differences, wind direction, and wind velocity are the three important factors, which depended on natural ventilation. The direction and the speed of wind create a field of pressure around the building as explained in Figure 3.22.

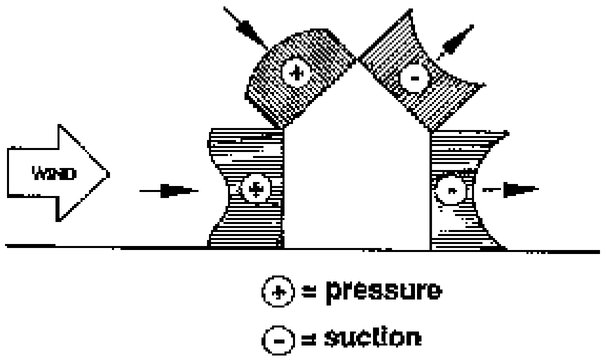


Figure 3. 22: Wind creates a positive pressure on the windward side of a structure and a negative pressure on the leeward side (McCarthy, 1999).

The utilization of pressure differences surrounding the building is possible for natural ventilation using wind towers. Consequently, it is necessary to position the device in order to maximize the inlet-outlet differences of pressure. The main driving force for the wind tower is the outdoor wind, positive pressure on the windward side, and the negative pressure on the leeward side, which extracts the stale and warm air.

Hughes and Ghani (2010) stated that simple changes in the air pressure could generate enough airflow, which can create thermal comfort for the building occupants. The openings of wind towers can change positive pressure into negative on day-to-day basis and in this case, the opening works as the exhaust ventilator. Most of the forces, which influence natural ventilation, are wind-based. The succeeding variation between the air mass and the pressure gradient of the indoor and outdoor air masses makes the warm (less dense) air to escape through the exhaust of the wind tower; therefore, the new air replaces the escaped air. Hughes and Cheuk-Ming (2011) investigated the wind pressure and buoyancy-driven flows through a natural ventilation system by using experimental and computational fluid dynamic (CFD) modeling. The study found the relationship between the forces involved in passive wind tower system. The experimental and numerical results presented that wind power is the main driving force for the wind tower device providing 76% more indoor ventilation than buoyancy driven forces (McCarthy, 1999).

To sum up, the strategies to consider for an effective passive design are as follows:

1. In order to preserve energy, building finishing's should be selected and applied accurately.
2. The orientation of the building must be selected properly at the beginning it should be modified during the planning phase
3. Sufficient insulation should be provided to reduce the air infiltration
4. Proper sealing should be provided for the doors and windows to reduce the air infiltration
5. The selection of the glazing and windows are important to reduce the values of thermal infiltration (U – value)
6. Providing shading during the summer has the same importance as providing sufficient heat during the winter season
7. The selection of proper window size for a specific direction is important as large glazing's increase the temperature if the windows are not effectively shaded

8. The applications for natural ventilation should be designed by focusing on summers with operable windows for ventilation
9. The building form needs extension towards the East in order to increase the Southern façade. The least used areas such as corridors and storage must be located at the Northern side, while the important spaces such as the living room must be placed in the Southern side
10. Obstacles such as fences or landscapes should allow the optimal exposure for solar radiation from 9 am to 3 pm, during the winter season. In order to get shading during summers, trees or trellises must be included

CHAPTER 4

ANALYSIS OF RESIDENTIAL BUILDING IN TRIPOLI REGARDING TO PASSIVE DESIGN STRATEGIES

4.1. Aim of the Study

The study aims to provide thermal comfort for the user inside the building. In addition, access the suitable orientation of residential buildings in Tripoli – Libya. Moreover, analyze the PMV value in the building, with the analysis of the passive gains and losses in fabric of the building, in addition to analysis the heating and cooling loads to access suitable materials for the Mediterranean climate, Moreover measure and analyze the suitable window size to wall.

4.2. Research Questions

This research will seek answers to the following questions in the context of the case study:

- What is the optimum orientation for residential building in Tripoli - Libya?
- Is it possible to improve the materials contributing to the construction of residential buildings to provide comfort and energy in the Mediterranean climate?
- What are the thermal comfort people feel about their homes, and whether any improvement is possible or not?
- Does the size of windows affect the internal environment of the building negatively?
- Can this work help people to save energy in the general context and particularly in residential buildings in Libya?

4.3. Description of the Site

4.3.1. Location of Libya

Libya is located in Africa between the latitudes of 19° and 34° North and the longitude of 9° and 26 degrees East. It has Mediterranean Sea in the North, borders with Tunisia and Algeria in the West, with Egypt in the East, with Chad and Sudan in the South and with Niger in the Southwest. The area of Libya is 1.759.540 km2 and the Libyan coastal line is the longest for any African country overlooking the Mediterranean Sea with a total length of 1,770 km (El Weft, 2007).

4.3.2. Climatic Conditions in Libya

The climate of Libya has two types:

i. Mediterranean climate: it includes the coastal line and the highlands in west and east of the country.
ii. Desert climate: Most of the country is located in the south of the northern areas and it falls under the semi-desert climate.

Rains: Rains are part of climate in the north of the country from May to September and from October to March. It is unstable and varies from year to year as they sometimes continue until November or even December and sometimes, the rainy season ends in March or April. Most of the rains are a consequence of Mediterranean winds, which pass during the winter season.

The rains vary in the desert regions and most of them are in the form of extensive thunderstorms for short periods. And the averages vary from one region to another (the annual rains range from 10-100 mm).The tropical rains fall in the summer in the Southern Libya in Ghat and its mountains and the mountains of Tibesti as a result of tropical weather of Africa and sometimes, during the summers as well.

The highest annual average of the rains in Shehata and the surrounding areas is about 586 mm annually. The level of rains is low in Kufra and Southeast Libya, which is barely 55 mm annually. The highest average monthly rain takes place in Tripoli, which is 74 mm in December (Şen &Eljadid, 1999).

Snowfall: The snowfall takes place in the mountains in the Eastern and Western Libya of the country and accumulates when the cold polar air rushes to the north of the country once every three years but snowfall happens approximately every winter. The highest annual average noticed in Sheath in 1991-1992, which was 850 mm while the highest annual average rate in Tripoli is 750 mm. Generally, it rarely happens that the temperature reaches 50 degree centigrade and this only happens in case of extreme temperature waves in the desert (El Weft, 2007).

The climate in Libya is moderate during the spring and autumn. The summer is hot and the winter is relatively cold. The climate varies dominated by the Mediterranean weather and semi-desert in the south. It is cold during the winter season, hot during the summer and the rains are rare. The cold sea currents in general vary from high to very high in the summer season except for the coastal line and the Green Mountain. The Western Mountains are moderately cold. Generally, the Libyan climate has high temperature and the desert climate, where the drought mostly exists.

The Coastal Area: Tripoli:

Tripoli, which is the Libyan capital, is located in the North-Western Libya on the coast of the Mediterranean Sea at 32º 52` N،13º 10` E؛ and its height is 9 m above the sea level. Tripoli represents the coastal area of this study as shown in Figure 4.1. The climate of Tripoli is relatively mild even in the summer season but on some days, the temperature may reach 40° C with very high humidity especially during July and August. The winters in this area always bring rain and cold nights and the average temperature is 15 °C in the spring season (El Wefati, 2007).

Climate data of the city of Tripoli provided input for the computer-modeling program, ECOTECT, which we used for the analysis phase of this study.

Figure 4.1: Geographical location of Tripoli – Libya (Libya Location, 2010)

4.4. Description of ECOTECT Program

In order to examine the thermal conditions of the case study, a building model exhibited using AutoCAD and ECOTECT. ECOTECT is a complete building design and environmental analysis software that covers a broad range of simulation and analysis functions (Marsh, 2003). This software is suitable to comply with the objectives of the current study because it is a visual building simulation tool with a wide range of performance analysis functions covering thermal, energy, lighting, shading, and resource allocation. ECOTECT is one of the few tools, which makes thermal performance analysis simple, accurate and most importantly, visually responsive (Sadafi, Salleh, Haw, & Jaafar, Z, 2011). For analyzing the input, ECOTECT uses a wide range of informative graphical methods with saving options including metafiles, bitmaps, or animations. Similarly, many researchers have used this software to evaluate the required design configurations in their studies (Wang, Shen & Barryman, 2011).

4.5. Methodology

A residential building model in the simulation program ECOTECT, with an area of 109 m2 was part of this study for analyzing the passive design strategies for Libya.

The building was according to the characteristics of typical modern residential buildings constructed in Libya (Omar, 2003). This residential unit consists of one floor containing main bedroom (4*4 m). With an area of 16 m2, another bedroom for children with an area of 16 m2 (4*4), a main bathroom with the area of 6.25 m2 (2.5*2.5 m) and a WC for guests with an area of 2.25 m2 (1.5*1.5 m) all located around a central hall that connects all the spaces of the building. The building can accommodate six or a maximum of nine users.

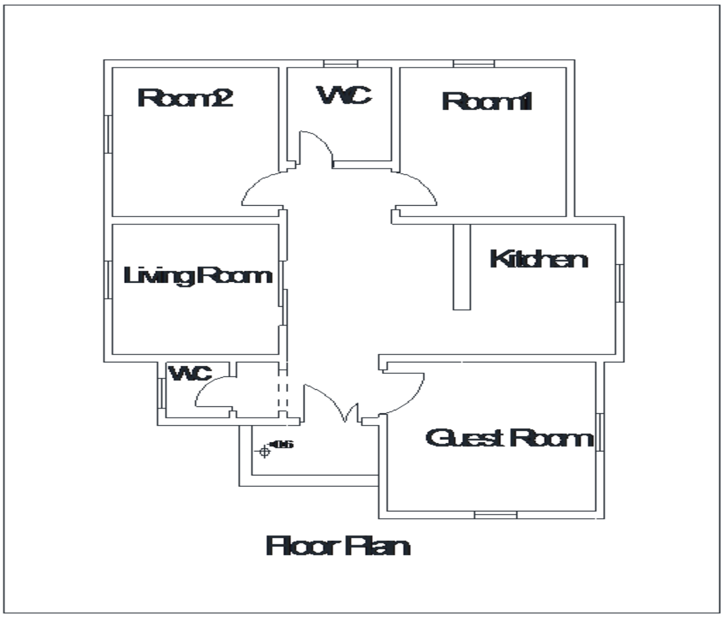


Figure 4. 2: Floor Plans of the case study (produced by the author).

The windows of the building exist on all facades to increase ventilation and natural lighting in the building. The areas of all the windows are 1.20 m2 except the one in the WC, which has a smaller area. By using the program ECOTECT, issues such as the best orientation of the building, thermal mass for the whole building, window to wall ratio in the living room have been analyzed, heating, and cooling loads. By using, weather data and the latitude and longitude data for the city of Tripoli, Libya.

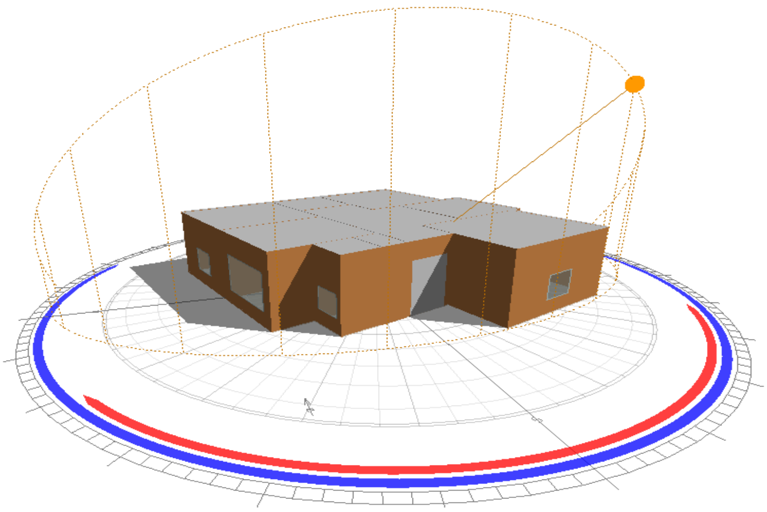


Figure 4. 3: 3D Floor Plans of the case study (produced by the author).

4.6. Findings and Discussion

The Analysis of Thermal Properties:

Weather data taken from the weather library for usage in the ECOTECT program, and materials selected from the materials library for finding the U - value. A model in ECOTECT has a series of individual spaces known as 'zones' for the purpose of thermal analysis. The thermal zones in the study model had further eight zones namely: Master Bedroom, Bedroom 1, Kitchen, Living Area, WC 1, WC 2, Guest Room, and Hall. Table 3 shows the properties of these zones.

Table 3: Properties of zones in building model

Definition	Identification
The maximum number of people who will occupy the zone	10 users
The type of passive or air-conditioning system used in the selected zone	Passive system
Highest desirable temperature	25 degree Centigrade (ELWEFATI, 2007)
Lowest desirable temperature	15 degree Centigrade (ELWEFATI, 2007)

The best orientation of the building for the location of Tripoli - Libya:

The analysis pointed out that there is a direct relationship between the orientation and the energy consumed by the building to maintain comfortable interior conditions. Givoni (1981) states that with walls sufficiently insulated at the exterior, and effectively shaded windows, changes in internal temperature orientation may be minor (Sadafi, Salleh, Haw, & Jaafar, Z, 2011). In this case, the orientation is more important in terms of wind direction, ventilation, patterns of solar radiation, and passive strategy. Therefore, before analyzing the thermal comfort data of the case study building, the site was Tripoli - Libya in ECOTECT program to show the best orientation for the building.

The entrance facade was the South facade, and then analyzed in climate analysis program ECOTECT. The latitude, and longitude data of the region Tripoli-Libya was identified. Later, the ECOTECT program found the suitable climate and the following results for optimum orientation appeared:

Optimum orientation

Location is TRIPOLI, LIBYA. The results showed that the best orientation for the building was 162.5 degrees from the North and 17.5 degrees from the South. Figure 5.2 shows the form of the best orientation for the model.

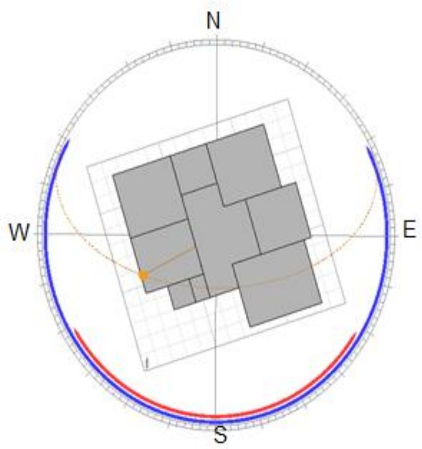


Figure 4.4: The best orientation of the building (produced by the author)

Material Choices:

To analyze the effects of used materials on thermal comfort and energy efficiency, the type of wall chosen was the traditional type of wall assembly commonly constructed in Libya. Its specifications (Alternative 1: 110 mm concrete block with 10 mm plaster either side, with U – value of 1.800 W/ m2 k) were calculated and noted down. Then, it was changed with another type, which was (Alternative 2:0.070 mm limestone, 0.130 mm concrete cinder, 0.030 mm polystyrene general purpose, 0.100 mm block, heavyweight 300 mm, 0.020 building plaster with U-value of 0.580 W/m2 k). The following tables (table 4 & table 5) show the properties of the materials used in the two alternatives.

Table 4: Material properties of Alternative 1

Material description	**U- Value (W/M2 K)**	**Admittance (W/M2 K)**
Floor: 100 mm thick concrete slab on ground plus ceramic tiles	0.880 (W/M2 K)	6.100 (W/M2 K)
Wall: 100 mm concrete block with 10 mm plaster on each side	1.800 (W/M2 K)	3.360 (W/M2 K)
Ceiling: 10 mm suspended plaster board ceiling on 200 mm joists as air gap with no insulation	4.320 (W/M2 K)	3.980 (W/M2 K)
Window: Single pane of glass with aluminum frame (No thermal break)	6.000 (W/M2 K)	6.000 (W/M2 K)
Door: 40 mm thick solid pine timber door	2.310 (W/M2 K)	3.540 (W/M2 K)

Table 5: Material properties of Alternative 2

Material description	**U- Value (W/M2 K)**	**Admittance (W/M2 K)**
Floor: 100 mm thick concrete slab on ground plus carpet and underlay	0.920(W/M2 K)	6.00(W/M2 K)
Wall: 0.070 mm limestone, 0.130 mm concrete cinder, 0.030 mm polystyrene general purpose, 0.100 mm block, heavyweight 300 mm , 0.020 plaster building.	0.580(W/M2 K)	5.920(W/M2 K)
Ceiling: 10 mm suspended plaster board ceiling, plus 50 mm insulation, with remainder [150 mm] joists as air gap	0.500(W/M2 K)	0.900(W/M2 K)
Windows: Double glazed with timber frame.	2.900(W/M2 K)	2.900(W/M2 K)
Door: 40 mm thick solid core pine timber door	2.310(W/M2 K)	3.540 (W/M2 K)

The total use of energy in the building:

The following figure 5.10 gives information about the energy that is suitable in the building during the months of the year before changing Alternative 1 to Alternative 2. In January, February and March, there is no need for cooling energy. The energy for heating is increasing succeeding, but it stabilizes during the summer months in June, July, and August and also in September. On the other hand, the need for cooling energy increases during the summer months and that exceeds the need for heating energy during winter months.

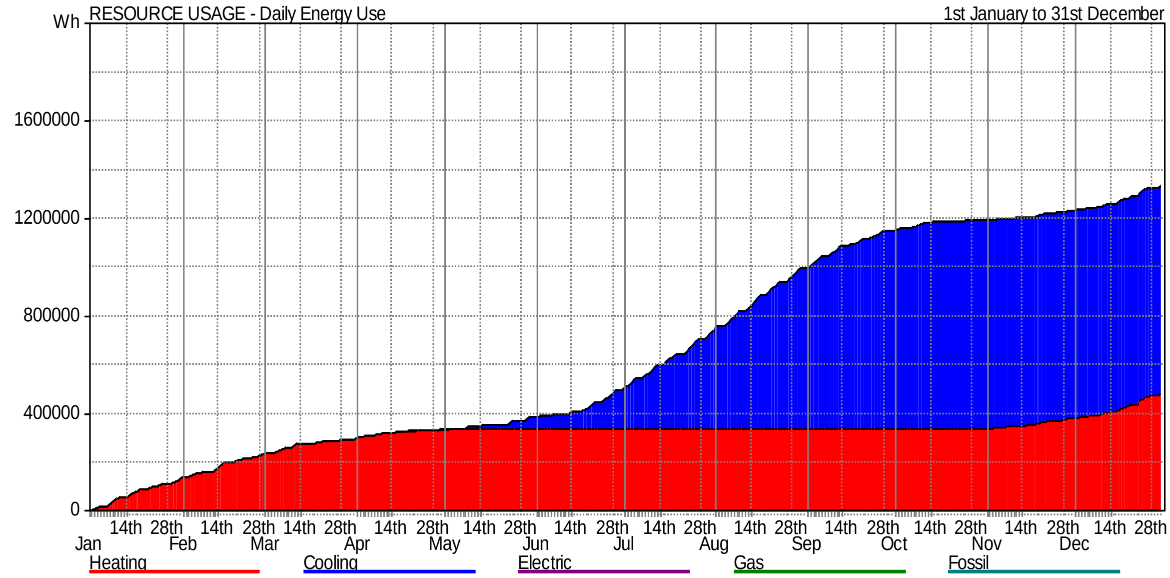


Figure 4. 5: Total energy use during the year

Thermal Conditions:

We entered the data presented in Table 4 into ECOTECT, and then changed it to Table 5. The period for the analysis includes three months: March, June, and December. These three months show some variations in climatic conditions are perceivable in these months during a year. This time span was helpful to calculate the PMV values. The major limitation of the PMV model is the explicit constraint of skin temperature and evaporation heat loss to values for comfort and (neutral) sensation at a given activity level. PMV is "scaled" to predict thermal sensation votes on a seven point scale [hot 3, warm 2, slightly warm 1, neutral 0, slightly cool -1, cool -2, cold -3]. Zero is the neutral point, representing the comfort state, the positive values indicate an uncomfortable feeling due to a hot sensation, and the negative values indicate an uncomfortable feeling due to a cold sensation.

The processing was for 4 hours. This time span included the hours: 9 am, 12 pm, 15 pm and 18 pm. The comfort indicators have three parts, which are comfortable, not comfortable, and almost comfortable. Generally, the PMV values ranged from -2.77 to +1.28 where the maximum PMV value was +1.28 observed at 3 pm in June and the minimum PMV value was -2.77 at 12 pm and 9 am in December. Table 6 shows the summary of thermal comfort conditions for the building using materials Alternative 1 and Alternative 2.

Table 6: Summary of thermal comfort condition according to PMV variations in all thermal zones by using materials mentioned in Alternative 1 and Alternative 2.

Month	Comfort condition	PMV result (Alternative 1)	PMV result (Alternative 2)
March: 9:00 am to 6:00 pm.	Almost comfortable	-1.41 / -1.75	-1.27 / -1.38
June: 9:00 am to 6:00 pm.	Comfortable	+1.28/ 0.86	0.92 / 0.99
December: 9:00 am to 6:00 pm	Uncomfortable	-2.70/ -2.77	-2.31/ -2.61

When the properties of materials entered as given in Table 6, the simulation results in ECOTECT program showed that the thermal condition of the building was inappropriate with respect to thermal comfort. The results during all the months of the year from 1 January to 31 December showed that the building gained heat during the summer months and lost in the winter season. This thermal gain is unwanted at this time of the year and the need for cooling increases during the summer. These shows the time when the materials used were not helping to provide thermal comfort inside the building. The passive gains in the simulation of ECOTECT refers that a flow through the fabric takes place because of the difference in air temperatures inside and outside the building. Moreover, the rise in passive gains reduces thermal comfort. Further were, the simulation results showed that the percentage for losses were as high as 83.3%. The simulation pointed out that the interior thermal condition is not comfortable when Alternative 1 is helpful for materials, but when the materials were changed to the referred to as Alternative 2, Table 5, the results also changed and were satisfactory because the simulation showed significant changes in the amounts of heat gain and loss in the building. Table 7 shows the heat gains and losses regarding the building's thermal comfort.

Table 7: The comparison between the passive gain and loses for Alternatives 1 and 2.

Category	Losses		Gains	
	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Fabric	83.3%	33.4%	7.3%	2.0%
Sol – Air	0.0%	0.0%	56.3%	10.0%
Solar	0.0%	0.0%	8.2%	10.9%
Ventilation	10.1%	47.0%	0.9%	2.9%
Internal	0.0%	0.0%	22.3%	71.3%
Inter – Zonal	6.6%	19.6%	5.0%	3.0%

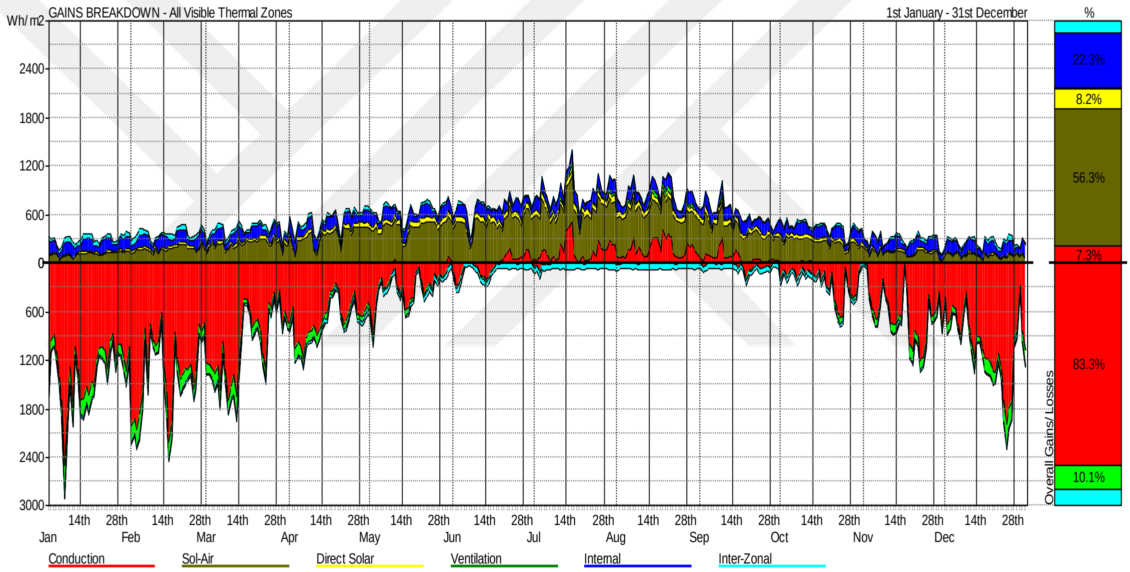


Figure 4. 6: passive gains and losses on ECOTECT simulation when using the materials mentioned as Alternative 1 (Table 4).

The passive gains in ECOTECT simulation prove that there are differences between interior and exterior air temperatures. Moreover, the reduction in the passive gains during the year shows the heat losses are through the windows. It is possible to realize that the passive gains increase by including the window. In naturally ventilated buildings, the thermal effect of cracks, ventilation openings, and infiltration in the morning hours leads to the reduction of interior temperature.

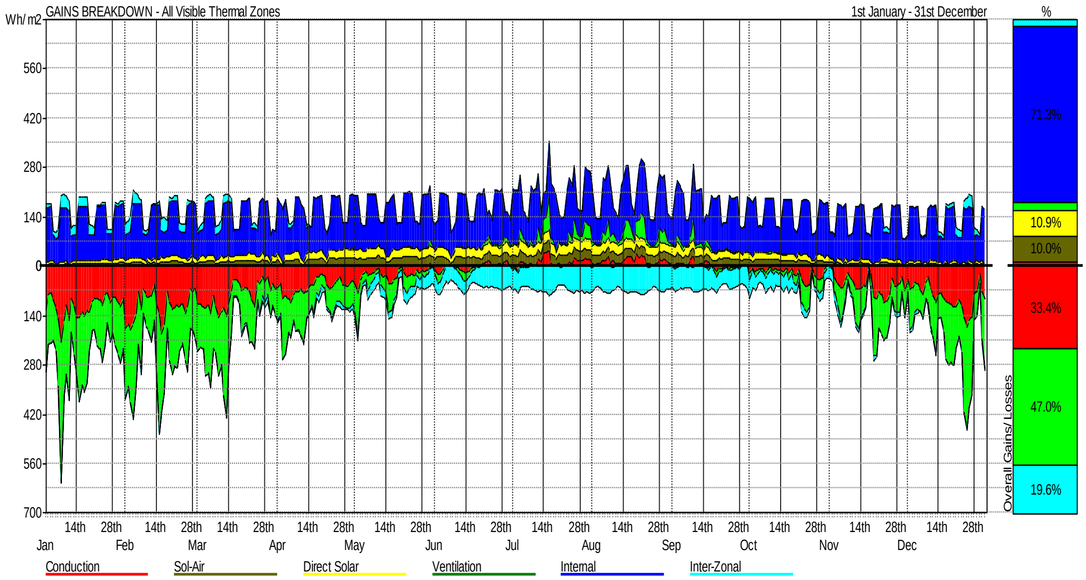


Figure 4. 7: passive gains and losses on ECOTECT simulation after changing materials to Alternative 2 (Table 5)

Measuring the loads of heating and cooling for the studied building:

When we used ECOTECT to measure the loads of heating and cooling during the whole, the results showed that when the materials changed to Alternative 2, the heating and cooling loads significantly decreased. Moreover, the results showed that there was still need for heating and cooling in some months of the year. Figure 5.6 showed that before changing the materials, the load of heating, cooling was decreased in the building, and the months of high-energy consumption reduced to just two: October and May. The overall total of the loads changed and there was a significant difference. This pointed out isolative properties of the materials, referred to as Alternative 2, and their ability to provide thermal comfort for the occupants inside the building.

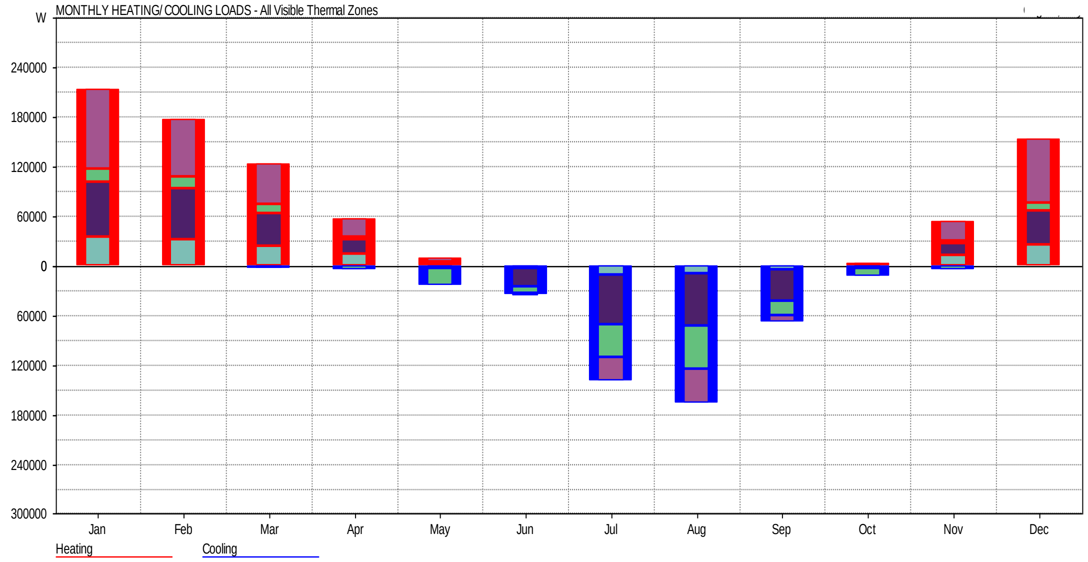


Figure 4. 8: Loads of cooling and heating for Alternative 1.

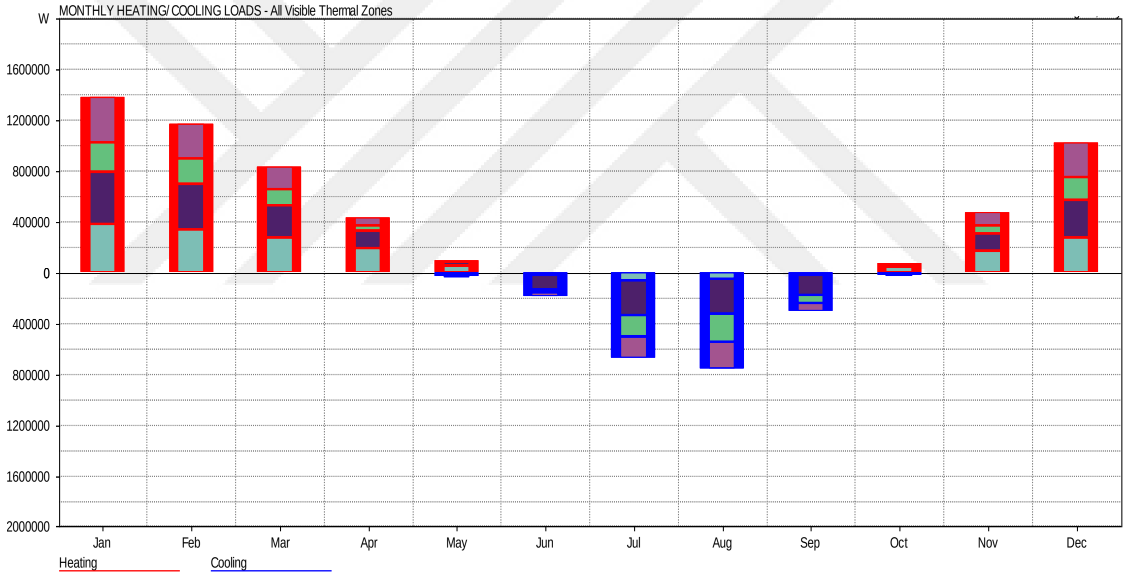


Figure 4.9: Loads of cooling and heating for Alternative 2.

Window size:

The windows are as important passive design elements as they control the amount of daylight and ventilation access to the building. Moreover, they control the solar gains in a building. Thus, the window size is an essential part for the building in passive design and whenever the window size is large, ventilation is higher but it can become a source of getting hot air and thermal gain inside the building. While deciding on the window size, the climate is important in addition to the suitable direction of the window. Large windows are preferable for use in hot climate but it must be shaded well, such as by trees or artificial covers. Therefore, relatively small windows and good orientation are as the best strategy.

The window size in the living room changed to 2*2.5 mass the living room would need good ventilation, and it is a frequently used space. When the thermal load of the building was measured the load value of heating and cooling of the living room increased from 15585 to 19615 as shown in Figure 5.9. This means that if the window size is increased, the load of heating and cooling increases as well, and this increases the heat gain. However, as stated before, in order to benefit from windows, all the associated passive design strategies must be applied such as, external shading, suitable direction of the window and internal curtains. The important period for the space function was also calculated. This means that each of the bedroom and the kitchen, which were located in the eastern part of the building were calculated. Moreover, the living room, which was located in the western part of the building, was also calculated. We took the measurements during three months of the year including March, June, and December. The results clarified that the residential unit is comfortable for the users even in the months with high-energy consumption. While the main bedroom during the sleep period was a little cold but during June, the thermal comfort was good but the temperature during December was a little higher in the kitchen. In the months of March and June, the temperature was suitable but when the window size was increased, it became relatively uncomfortable. Therefore, according to these results, the building design, in other words the space functions in the building changed to make it more comfortable, consume less energy, and get advantage of the window size in the living room.

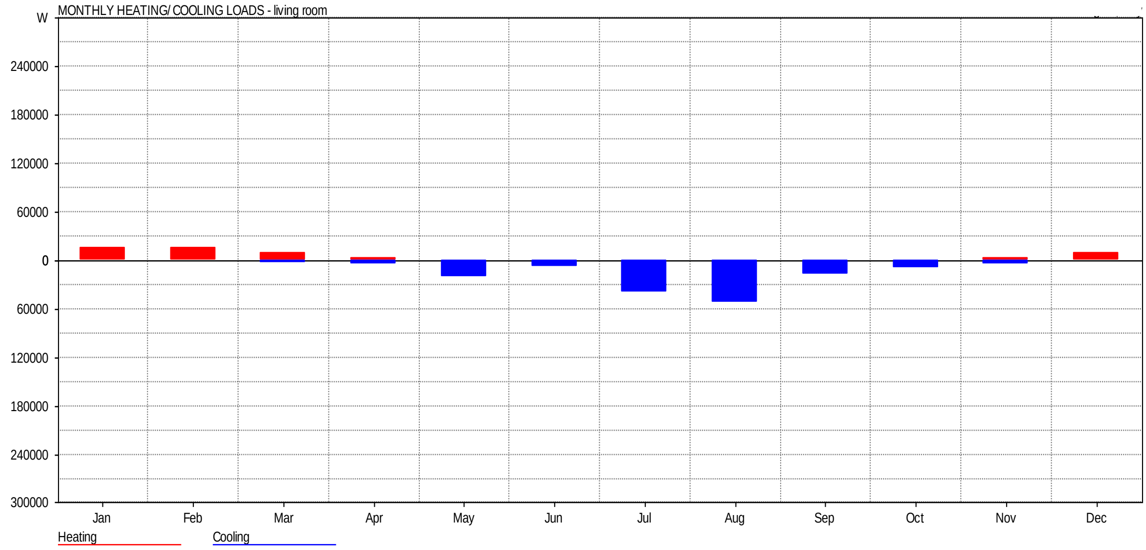


Figure 4. 9: Loads of the living room before changing the size of the window

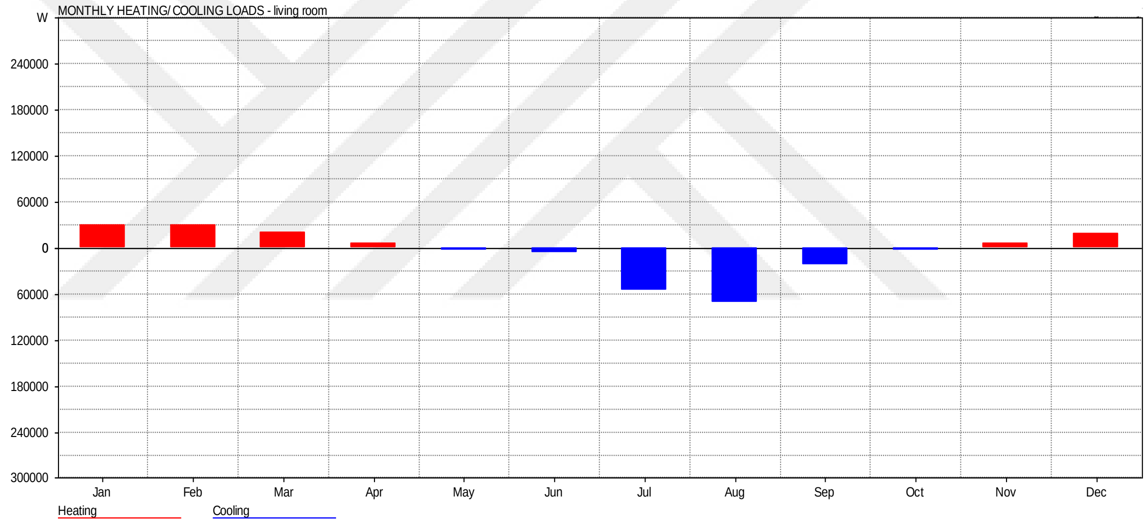


Figure 4. 10: Loads of the living room after changing the window size

Materials:

After changing the building materials, and the size of windows, including ceilings, walls and floors and the average U value have also changed and the study revealed changes in the temperature in the living room. The temperature showed thermal comfort during the summer season but it changed a little in March in the morning from 8 am to 11 am. This was not considered as a drawback, as it decreased during the sleep hours and increased until it became moderate in March from 9 am to 22 pm.

The results were very close to the results of December. The main bedroom was moderate in March, from 12 pm to 23 pm, and the temperature decreased in the needed hours (12 am to 11 pm). In summer, it was thermally moderate and comfortable. Also in December, the results were satisfactory as during sleep hours, the temperature was thermally comfortable. This is acceptable because this area is busy during the evening hours. In case of the living room, located on the western side of the building, the thermal comfort was also satisfactory during the summer season (June). In March, the temperature decreased, but it was warm during the daylight hours and the temperature during the evening ranged to 14 degree Celsius. This condition can be acceptable as this part of the residential unit is mostly busy during the day. This condition differs when compared to December, as the temperature ranged from 22 to 25 degree Celsius. It is clear that the type and thickness of the new wall materials increased the effects of the thermal mass of the building.

Summary of results:

The results obtained from ECOTECT program show that the residential building analyzed as a case study is thermally comfortable for the building users. On the other hand, the unfavorable conditions occur during the evening in the northeastern side of the building. Therefore, it is possible to increase the value or thickness of insulation on this side (northeastern), or if possible change the functions of the rooms inside the building, according to thermal comfort. Suitable materials of the walls, ceilings, floors, and windows can reduce the effects of solar penetration. Moreover, suitable openings of the windows in the walls are able to release heat through natural ventilation, which will create the best thermal state. Moreover, as to the passive design strategies at the exterior, planting trees, shading and creating green areas will help improving the thermal comfort in the building. As to further studies, in order to analyze the effects of solar radiation on thermal comfort, there is a need for further studies.

The main aim of the study does not entail promoting a specific design for a residential building; however, according to the findings, some guidelines are necessary before mentioning the design process. They are as follows:

1. The design must be according to the climate. Thus, modifications should be done depending on climatic conditions, rather than relying on mechanical cooling or heating.
2. The interior spaces of the building must be designed in such a way to provide thermal comfort to the users
3. Builders should focus on window size and placement. Suitable and adjustable shading help avoiding extra heat gain
4. Appropriate materials with high insulation character should be selected to preserve the interior thermal comfort
5. Trees should be planted as a part of passive design strategies to reduce the heat gain caused by solar radiation
6. Placing a shaded garden overlooking to the main living area can help to provide cool air and natural ventilation during summer months.

5. CONCLUSION

This research presents an analysis of the simulation of a residential unit to achieve the thermal comfort for building occupants of in the Mediterranean climate (Tripoli - Libya), by providing energy efficiency at the same time. Moreover, this work can be a unique contribution to the literature, since there are no such studies so far in this field regarding providing energy efficiency for Tripoli - Libya construction projects. Competent bodies for the implementation of passive design strategies in the buildings of Tripoli - Libya, can benefit the results of this study in order to provide thermal comfort for building occupants and save energy.

As studies on the passive design strategy in buildings above in third chapter indicate that, the proper orientation of the building helps to reduce the internal heat of the building resulting output from direct sunlight, so this was found out the suitable orientation for the Tripoli - Libya. In addition, achieving thermal comfort in the building is irrelevant to appropriate orientation, but also to the materials suitable for the climate. Builders should also consider the window to wall ratio and shading devices appropriate as the previous studies indicated above in third chapter. Tree plantation is part of passive design strategy to reduce thermal gains from solar radiation.

Therefore, we can conclude that designers should consider implementing passive design strategies in buildings whenever possible for the benefits of building users.

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APPENDIX

1. Gains Breakdown in All Visible Thermal Zones with Alternative 1

FROM: 1 st January to 31st December

CATEGORY	LOSSES	GAINS
FABRIC	83.30%	7.30%
SOL-AIR	0.00%	56.30%
SOLAR	0.00%	8.20%
VENTILATION	10.10%	0.90%
INTERNAL	0.00%	22.30%
INTER-ZONAL	6.60%	5.00%

2. Gains Breakdown in All Visible Thermal Zones with Alternative 2

FROM: 1st January to 31st December

CATEGORY	LOSSES	GAINS
FABRIC	33.40%	2.00%
SOL-AIR	0.00%	10.00%
SOLAR	0.00%	10.90%
VENTILATION	47.00%	2.90%
INTERNAL	0.00%	71.30%
INTER-ZONAL	19.60%	3.00%

3. MONTHLY HEATING AND COOLING LOADS

3.1. Monthly Heating and Cooling Loads in All Visible Thermal Zones with Alternative 2.

Comfort: Adaptive - Average (± 1.75)

Max Heating: 2333 W at 15:00 on 7th January

Max Cooling: 3027 W at 15:00 on 15th July

Floor Area: 109.000 m2

MONTH	**HEATING(Wh)**	**COOLING (Wh)**	**TOTAL (Wh)**
Jan	214448	0	214448
Feb	176624	0	176624
Mar	123829	1966	125796
Apr	56859	4795	61653
May	9239	23727	32966
Jun	0	34751	34751
Jul	0	140096	140096
Aug	0	166506	166506
Sep	0	68372	68372
Oct	3564	12606	16170
Nov	54086	5361	59447
Dec	153325	0	153325
TOTAL	791974	458180	1250154
PER M²	7266	4203	11469

3.2.Monthly Heating and Cooling Loads in All Visible Thermal Zones with Alternative 1.

Comfort: Adaptive - Average (± 1.75)

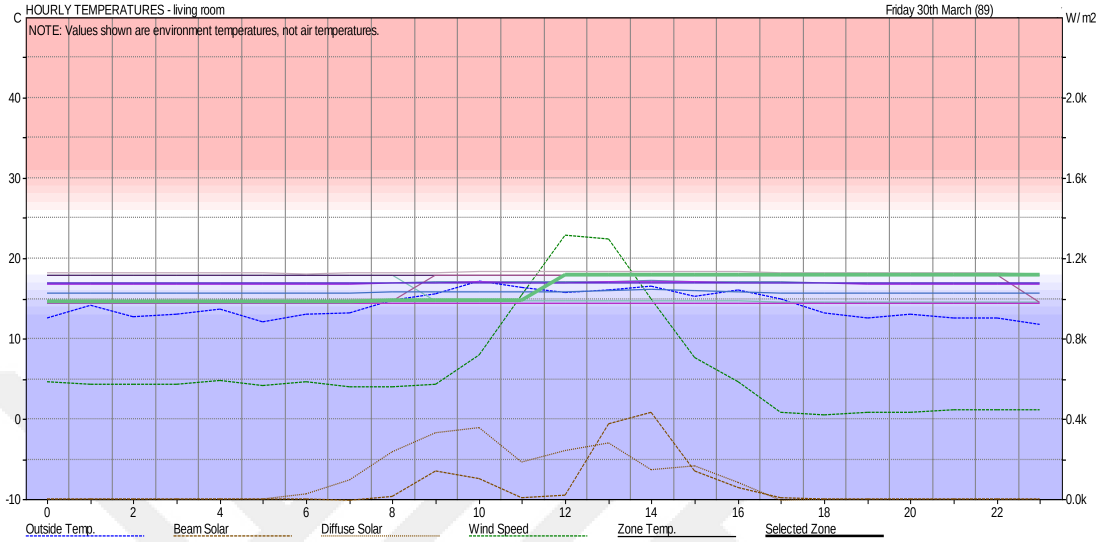
Max Heating: 6007 W at 15:00 on 7th January

Max Cooling: 6623 W at 15:00 on 15th July

Floor Area: 109.000 m2

MONTH	**HEATING(Wh)**	**COOLING (Wh)**	**TOTAL (Wh)**
Jan	1385057	0	1385057
Feb	1174052	0	1174052
Mar	838474	0	838474
Apr	437814	0	437814
May	90495	29209	119703
Jun	0	192814	192814
Jul	0	678109	678109
Aug	0	760825	760825
Sep	0	303315	303315
Oct	74891	17458	92349
Nov	473697	569	474266
Dec	1021636	0	1021636
TOTAL	5496117	1982297	7478414
PER M²	50423	18186	68609

4. HOURLY TEMPERATURES AFTER CHANGE THE MATERIAL TO ALTERNATIVE 2 IN DEFRINT ROOMS AND DAY.



4.1.Hourly Temperatures on Friday 30th March in the Living room

Avg. Temperature: 14.4 C (Ground 16.4 C)

Total Surface Area: 73.000 m2 (521.4% flr area).

Total Exposed Area: 28.961 m2 (206.9% flr area).

Total South Window: 0.000 m2 (0.0% flr area).

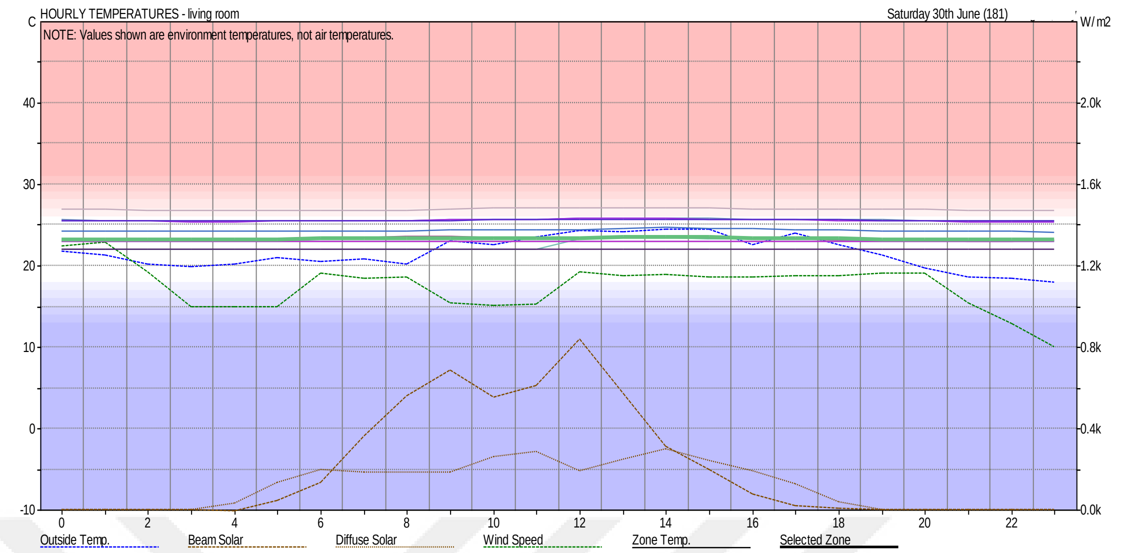
Total Window Area: 1.200 m2 (8.6% flr area).

Total Conductance (AU): 18 W/°K

Total Admittance (AY): 354 W/°K

Response Factor: 14.22

HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	14.6	12.6	2.0
01	14.7	14.2	0.5
02	14.6	12.7	1.9
03	14.7	13.1	1.6
04	14.7	13.6	1.1
05	14.6	12.1	2.5
06	14.7	13.0	1.7
07	14.7	13.2	1.5
08	14.7	14.7	0.0
09	14.8	15.5	-0.7
10	14.8	17.2	-2.4
11	14.8	16.3	-1.5
12	18.0	15.7	2.3
13	18.0	16.1	1.9
14	18.0	16.5	1.5
15	18.0	15.2	2.8
16	18.0	16.1	1.9
17	18.0	15.0	3.0
18	18.0	13.2	4.8
19	18.0	12.5	5.5
20	18.0	13.1	4.9
21	18.0	12.6	5.4
22	18.0	12.5	5.5
23	18.0	11.8	6.2



4.2.Hourly Temperatures on Saturday 30th June in the Living room

Avg. Temperature: 23.0 C (Ground 16.4 C)

Total Surface Area: 73.000 m2 (521.4% flr area).

Total Exposed Area: 28.961 m2 (206.9% flr area).

Total South Window: 0.000 m2 (0.0% flr area).

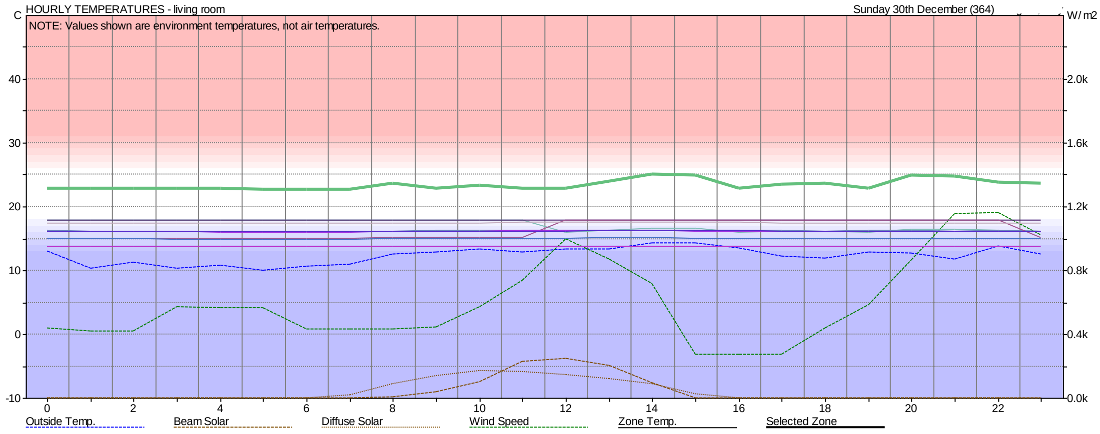
Total Window Area: 1.200 m2 (8.6% flr area).

Total Conductance (AU): 18 W/°K

Total Admittance (AY): 354 W/°K

Response Factor: 14.22

HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	23.2	21.7	1.5
01	23.2	21.2	2.0
02	23.2	20.2	3.0
03	23.2	19.8	3.4
04	23.2	20.2	3.0
05	23.2	21.0	2.2
06	23.3	20.4	2.9
07	23.3	20.8	2.5
08	23.3	20.2	3.1
09	23.3	23.0	0.3
10	23.3	22.6	0.7
11	23.4	23.5	-0.1
12	23.4	24.2	-0.8
13	23.5	24.1	-0.6
14	23.5	24.5	-1.0
15	23.5	24.5	-1.0
16	23.4	22.6	0.8
17	23.3	23.9	-0.6
18	23.3	22.5	0.8
19	23.2	21.3	1.9
20	23.2	19.7	3.5
21	23.1	18.6	4.5
22	23.1	18.4	4.7
23	23.2	17.9	5.3



4.3.Hourly Temperatures on Sunday 30th December in the Living room

Avg. Temperature: 13.8 C (Ground 16.4 C)

Total Surface Area: 73.000 m2 (521.4% flr area).

Total Exposed Area: 28.961 m2 (206.9% flr area).

Total South Window: 0.000 m2 (0.0% flr area).

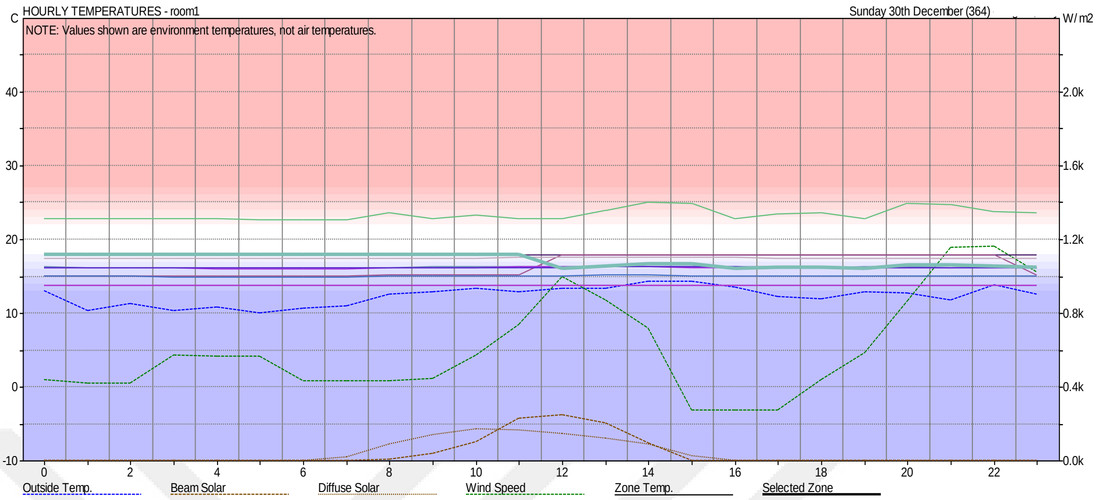
Total Window Area: 1.200 m2 (8.6% flr area).

Total Conductance (AU): 18 W/°K

Total Admittance (AY): 354 W/°K

Response Factor: 14.22

HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	22.8	13.1	9.7
01	22.8	10.3	12.5
02	22.8	11.3	11.5
03	22.8	10.4	12.4
04	22.8	10.8	12.0
05	22.8	10.1	12.7
06	22.8	10.7	12.1
07	22.8	11.0	11.8
08	23.6	12.5	11.1
09	22.8	12.8	10.0
10	23.3	13.3	10.0
11	22.9	12.8	10.1
12	22.9	13.4	9.5
13	23.9	13.4	10.5
14	25.0	14.3	10.7
15	24.9	14.3	10.6
16	22.8	13.5	9.3
17	23.4	12.2	11.2
18	23.6	11.9	11.7
19	22.8	12.9	9.9
20	24.8	12.7	12.1
21	24.8	11.7	13.1
22	23.8	13.8	10.0
23	23.6	12.6	11.0



4.4.Hourly Temperatures on Sunday 30th December in the master bedroom

Avg. Temperature: 13.8 C (Ground 16.4 C)

Total Surface Area: 80.000 m2 (500.0% flr area).

Total Exposed Area: 40.000 m2 (250.0% flr area).

Total South Window: 0.000 m2 (0.0% flr area).

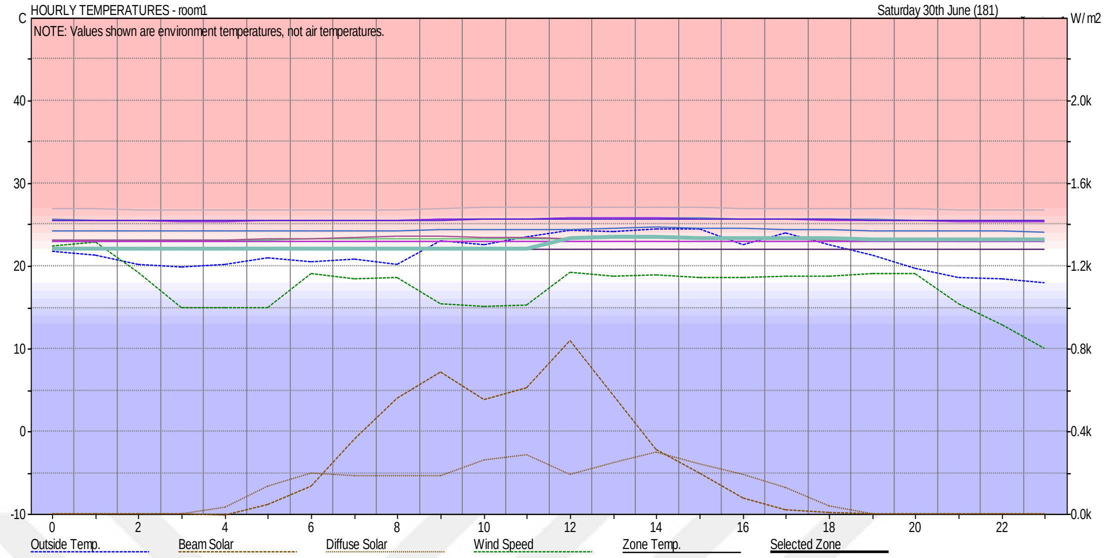
Total Window Area: 1.200 m2 (7.5% flr area).

Total Conductance (AU): 25 W/°K

Total Admittance (AY): 386 W/°K

Response Factor: 12.07

HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	18.0	13.1	4.9
01	18.0	10.3	7.7
02	18.0	11.3	6.7
03	18.0	10.4	7.6
04	18.0	10.8	7.2
05	18.0	10.1	7.9
06	18.0	10.7	7.3
07	18.0	11.0	7.0
08	18.0	12.5	5.5
09	18.0	12.8	5.2
10	18.0	13.3	4.7
11	18.0	12.8	5.2
12	16.0	13.4	2.6
13	16.3	13.4	2.9
14	16.7	14.3	2.4
15	16.7	14.3	2.4
16	16.0	13.5	2.5
17	16.2	12.2	4.0
18	16.2	11.9	4.3
19	16.0	12.9	3.1
20	16.6	12.7	3.9
21	16.5	11.7	4.8
22	16.3	13.8	2.5
23	16.2	12.6	3.6



4.5.Hourly Temperatures on Saturday 30th June in the master bedroom

Avg. Temperature: 23.0 C (Ground 16.4 C)

Total Surface Area: 80.000 m2 (500.0% flr area).

Total Exposed Area: 40.000 m2 (250.0% flr area).

Total South Window: 0.000 m2 (0.0% flr area).

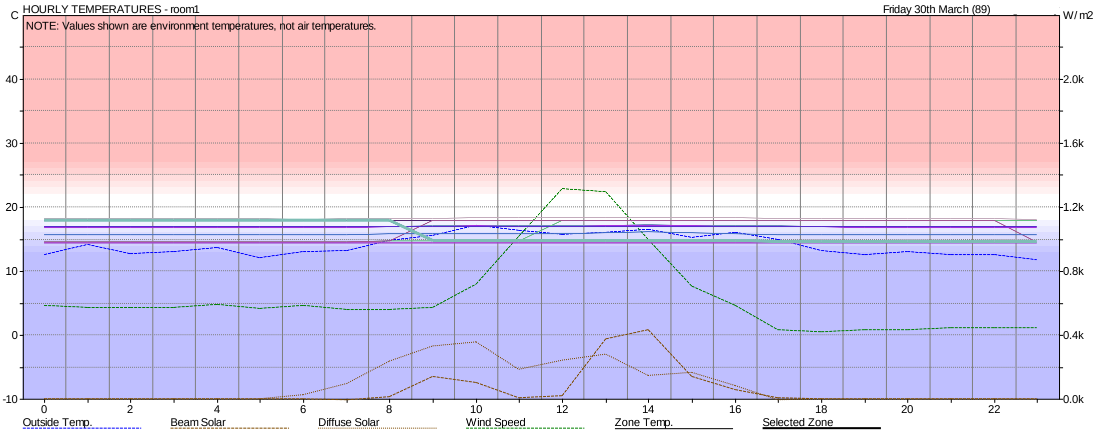
Total Window Area: 1.200 m2 (7.5% flr area).

Total Conductance (AU): 25 W/°K

Total Admittance (AY): 386 W/°K

Response Factor: 12.07

HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	22.0	21.7	0.3
01	22.0	21.2	0.8
02	22.0	20.2	1.8
03	22.0	19.8	2.2
04	22.0	20.2	1.8
05	22.0	21.0	1.0
06	22.0	20.4	1.6
07	22.0	20.8	1.2
08	22.0	20.2	1.8
09	22.0	23.0	-1.0
10	22.0	22.6	-0.6
11	22.0	23.5	-1.5
12	23.4	24.2	-0.8
13	23.4	24.1	-0.7
14	23.4	24.5	-1.1
15	23.4	24.5	-1.1
16	23.3	22.6	0.7
17	23.3	23.9	-0.6
18	23.3	22.5	0.8
19	23.2	21.3	1.9
20	23.2	19.7	3.5
21	23.2	18.6	4.6
22	23.2	18.4	4.8
23	23.2	17.9	5.3



4.6.Hourly Temperatures on Friday 30th March in the master bedroom

Avg. Temperature: 14.4 C (Ground 16.4 C)

Total Surface Area: 80.000 m2 (500.0% flr area).

Total Exposed Area: 40.000 m2 (250.0% flr area).

Total South Window: 0.000 m2 (0.0% flr area).

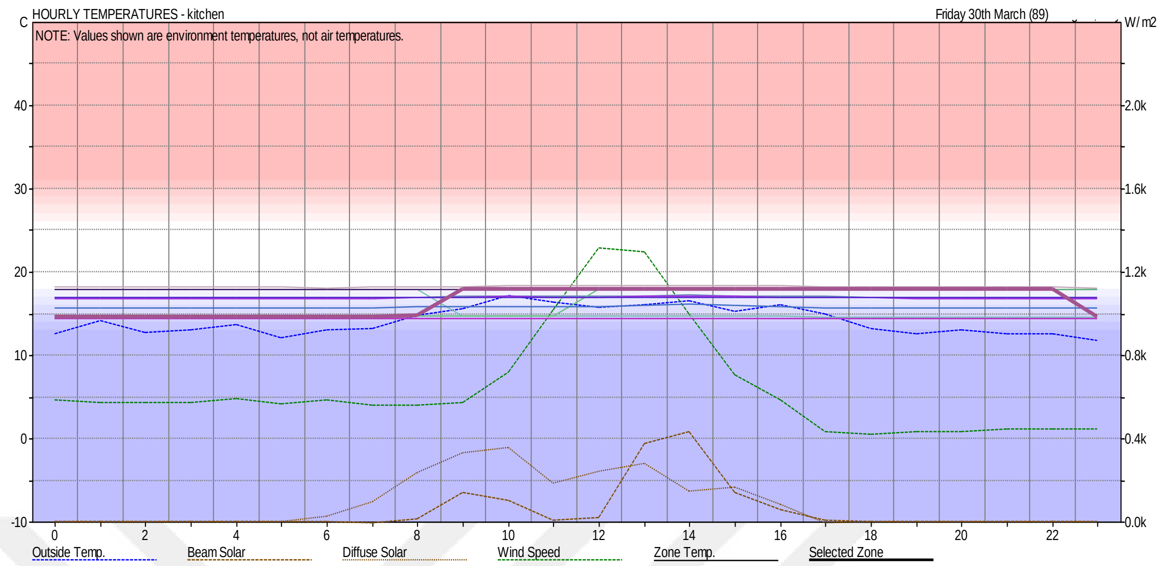
Total Window Area: 1.200 m2 (7.5% flr area).

Total Conductance (AU): 25 W/°K

Total Admittance (AY): 386 W/°K

Response Factor: 12.07

HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	18.0	12.6	5.4
01	18.0	14.2	3.8
02	18.0	12.7	5.3
03	18.0	13.1	4.9
04	18.0	13.6	4.4
05	18.0	12.1	5.9
06	18.0	13.0	5.0
07	18.0	13.2	4.8
08	18.0	14.7	3.3
09	14.8	15.5	-0.7
10	14.8	17.2	-2.4
11	14.8	16.3	-1.5
12	14.7	15.7	-1.0
13	14.8	16.1	-1.3
14	14.8	16.5	-1.7
15	14.8	15.2	-0.4
16	14.7	16.1	-1.4
17	14.7	15.0	-0.3
18	14.7	13.2	1.5
19	14.6	12.5	2.1
20	14.6	13.1	1.5
21	14.6	12.6	2.0
22	14.6	12.5	2.1
23	14.6	11.8	2.8



4.7.Hourly Temperatures on Friday 30th March in the kitchen

Avg. Temperature: 14.4 C (Ground 16.4 C)

Total Surface Area: 66.500 m2 (542.9% flr area).

Total Exposed Area: 27.259 m2 (222.5% flr area).

Total South Window: 0.000 m2 (0.0% flr area).

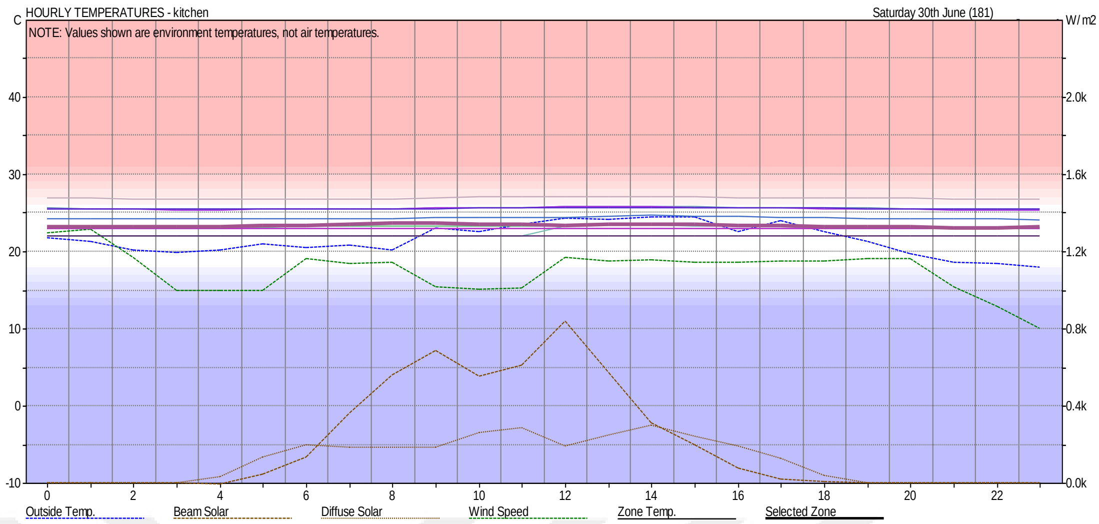
Total Window Area: 1.200 m2 (9.8% flr area).

Total Conductance (AU): 18 W/°K

Total Admittance (AY): 324 W/°K

Response Factor: 3.99

HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	14.6	12.6	2.0
01	14.6	14.2	0.4
02	14.6	12.7	1.9
03	14.6	13.1	1.5
04	14.6	13.6	1.0
05	14.6	12.1	2.5
06	14.6	13.0	1.6
07	14.7	13.2	1.5
08	14.8	14.7	0.1
09	18.0	15.5	2.5
10	18.0	17.2	0.8
11	18.0	16.3	1.7
12	18.0	15.7	2.3
13	18.0	16.1	1.9
14	18.0	16.5	1.5
15	18.0	15.2	2.8
16	18.0	16.1	1.9
17	18.0	15.0	3.0
18	18.0	13.2	4.8
19	18.0	12.5	5.5
20	18.0	13.1	4.9
21	18.0	12.6	5.4
22	18.0	12.5	5.5
23	14.6	11.8	2.8



4.8.Hourly Temperatures on Saturday 30th June in the kitchen

Avg. Temperature: 23.0 C (Ground 16.4 C)

Total Surface Area: 66.500 m2 (542.9% flr area).

Total Exposed Area: 27.259 m2 (222.5% flr area).

Total South Window: 0.000 m2 (0.0% flr area).

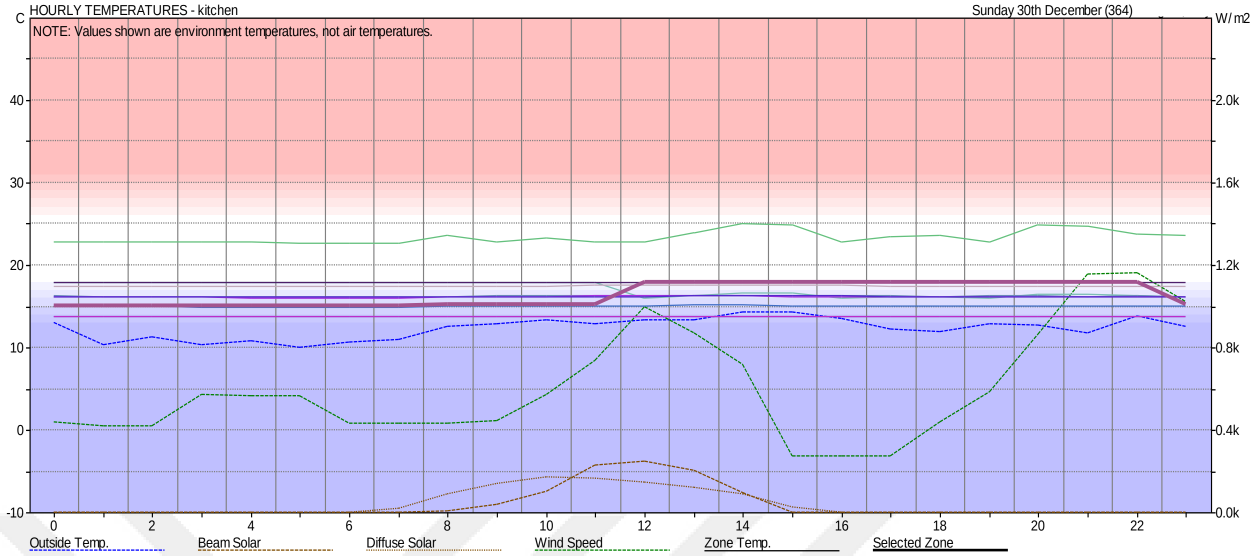
Total Window Area: 1.200 m2 (9.8% flr area).

Total Conductance (AU): 18 W/°K

Total Admittance (AY): 324 W/°K

Response Factor: 3.99

HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	23.2	21.7	1.5
01	23.2	21.2	2.0
02	23.2	20.2	3.0
03	23.2	19.8	3.4
04	23.2	20.2	3.0
05	23.3	21.0	2.3
06	23.3	20.4	2.9
07	23.5	20.8	2.7
08	23.6	20.2	3.4
09	23.6	23.0	0.6
10	23.5	22.6	0.9
11	23.4	23.5	-0.1
12	23.4	24.2	-0.8
13	23.4	24.1	-0.7
14	23.5	24.5	-1.0
15	23.4	24.5	-1.1
16	23.3	22.6	0.7
17	23.3	23.9	-0.6
18	23.2	22.5	0.7
19	23.2	21.3	1.9
20	23.1	19.7	3.4
21	23.1	18.6	4.5
22	23.1	18.4	4.7
23	23.1	17.9	5.2



4.9.Hourly Temperatures on Sunday 30th December in the kitchen

Avg. Temperature: 13.8 C (Ground 16.4 C)

Total Surface Area: 66.500 m2 (542.9% flr area).

Total Exposed Area: 27.259 m2 (222.5% flr area).

Total South Window: 0.000 m2 (0.0% flr area).

Total Window Area: 1.200 m2 (9.8% flr area).

Total Conductance (AU): 18 W/°K

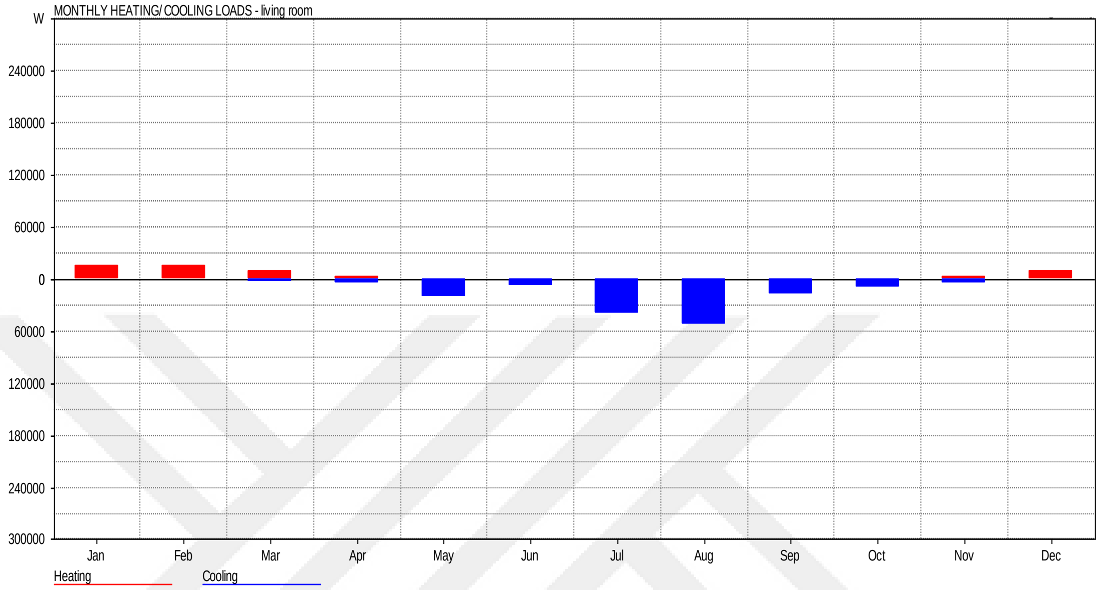
Total Admittance (AY): 324 W/°K

Response Factor: 3.99

HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	15.1	13.1	2.0
01	15.1	10.3	4.8
02	15.1	11.3	3.8
03	15.1	10.4	4.7
04	15.1	10.8	4.3
05	15.1	10.1	5.0
06	15.1	10.7	4.4
07	15.1	11.0	4.1
08	15.3	12.5	2.8
09	15.2	12.8	2.4
10	15.3	13.3	2.0
11	15.2	12.8	2.4
12	18.0	13.4	4.6
13	18.0	13.4	4.6
14	18.0	14.3	3.7
15	18.0	14.3	3.7
16	18.0	13.5	4.5
17	18.0	12.2	5.8
18	18.0	11.9	6.1
19	18.0	12.9	5.1
20	18.0	12.7	5.3
21	18.0	11.7	6.3
22	18.0	13.8	4.2
23	15.3	12.6	2.7

5. Window to Wall Ratio

5.1.Monthly heating and cooling loads before change the size of the window in the Living room.



Zone: living room, Floor Area: 14.000 m2

Operation: Weekdays 11-24, Weekends 10-24.

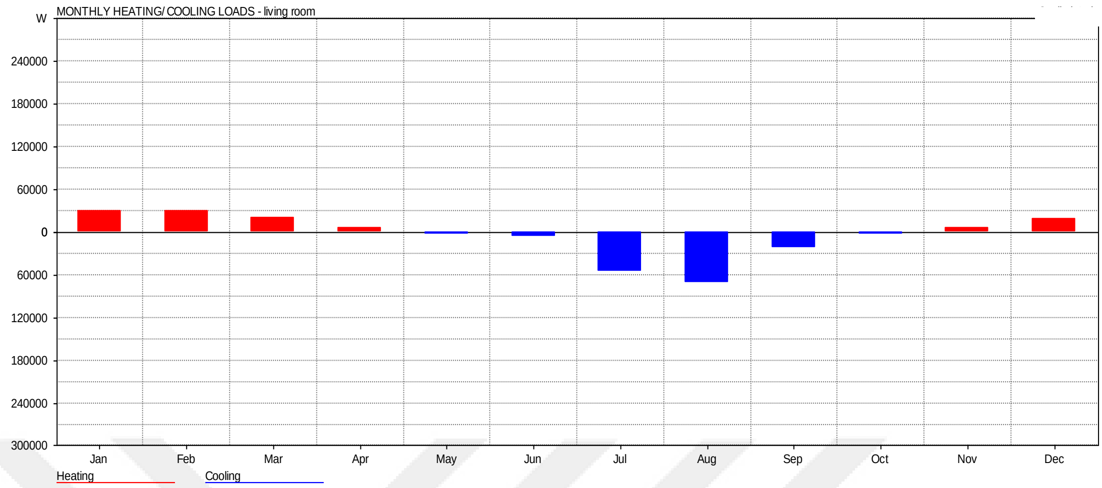
Thermostat Settings: 18.0 - 26.0 C

Max Heating: 191 W at 16:00 on 7th January

Max Cooling: 1071 W at 15:00 on 15th July

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL(Wh)
Jan	15654	0	15654
Feb	15351	0	15351
Mar	10006	1966	11972
Apr	3058	4795	7852
May	112	21159	21270
Jun	0	8088	8088
Jul	0	40126	40126
Aug	0	52671	52671
Sep	0	17120	17120
Oct	78	9903	9981
Nov	3105	5361	8467
Dec	9637	0	9637
TOTAL	**57001**	**161189**	**218190**
PER M²	4072	11513	15585

5.2.Monthly heating and cooling loads after change the size of the window in the Living room.



Zone: living room, Floor Area: 14.000 m2

Operation: Weekdays 11-24, Weekends 10-24.

Thermostat Settings: 18.0 - 26.0 C

Max Heating: 360 W at 16:00 on 7th January

Max Cooling: 1393 W at 15:00 on 15th July

MONTH	**HEATING (Wh)**	**COOLING (Wh)**	**TOTAL(Wh)**
Jan	30486	0	30486
Feb	29292	0	29292
Mar	19940	0	19940
Apr	6800	0	6800
May	417	2598	3015
Jun	0	6177	6177
Jul	0	55321	55321
Aug	0	71676	71676

Sep	0	22198	22198
Oct	508	3639	4147
Nov	6351	0	6351
Dec	19213	0	19213
TOTAL	**113007**	**161609**	**274616**
PER M²	8072	11544	19615

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: ABOUD, Nesreen

Date and Place of Birth: 30 December 1986, Tripoli – Libya

Marital Status: Married

Phone: +905445747458

Email: nesrinabood30@yahoo.com

EDUCATION

Degree	Institution	Year of Graduation
M.Sc.	Çankaya University	2017
B.Sc.	Institute 2 March	2008
High School	AL oroba	2004

WORK EXPERIENCE

Year	Place	Enrollment
2010	Center Solar Research and Studies	Architect

FOREIGN LANGUAGES

Advanced English, Beginner Turkish