Zero Energy Residential Buildings Design in Hot Climate Zone

Seyed Arash Naghibi

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Approval of the Institute of Graduate Studies and Research

Prof. Dr. Mustafa Tümer
Acting Director

I certify that this thesis satisfies the requirements of thesis for the degree of Master of Science in Architecture.

Prof. Dr. Özgür Dinçyürek
Chair, Department of Architecture

We 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 in Architecture.

Asst. Prof. Dr. Polat Hancer
Supervisor

Examining Committee

1. Asst. Prof. Dr. Halil Zafer Alibaba
2. Asst. Prof. Dr. Polat Hancer
3. Asst. Prof. Dr. Pınar Uluçay

ABSTRACT

Buildings consume a significant proportion of the total energy used worldwide and consequently emit masses of green gases. Therefore, energy management in the buildings plays an important role in formulating sustainable development strategies. There is a growing interest in zero energy buildings (ZEBs) in recent years. Several countries have adopted or considered establishing ZEBs as their future building energy targets to address the problems concerning the depletion of energy resources and the environmental issues. In general, ZEBs involve two design strategies. Firstly, to minimize the need for energy consumption in buildings (especially for heating and cooling) through energy efficient measures and secondly to adapt renewable energy technologies to fulfil the remaining energy needs. The aim of this thesis is to do a comprehensive investigation of design strategies in order to select proper solution applied in buildings and proposed solutions to attain Net Zero Energy Buildings (Net ZEBs) in hot climates.

For the undertaken subject of this study, firstly the concept of 'Zero Energy/Emission Building' (ZEB) is to be analyzed in detail. For this purpose, ZEB building strategies in terms of energy production and consumption for hot climate areas have been considered. The thesis contains three chapters. The first chapter focuses on the review and analysis of main design principles, technologies and solutions. The objective is to reach an energy balance in residential building in hot climate zone by selecting the proper methods for reducing energy in terms of thermal and visual comfort and producing energy from renewable energy sources.

In the third chapter the factors discussed in chapter 2 are evaluated by selecting case studies in hot and arid and hot and humid climates. Finally, chapter 3 concludes the study by comparing the reported data. The result shows similar patterns, the designer aims to minimize energy by understanding the best local passive systems and optimizing them by recent technologies such as sufficient materials and most effective insulation. Similar to the literature findings, most of the energy for the case studies is produced by solar radiation in hot climate regions. Nevertheless, attention should be paid about heat gain by radiation using proper insulation and envelope design, while Occupants of the modern buildings expect comfortable conditions combined with balance in energy consumption to reduce environmental effects as well as energy cost.

Keywords: Net Zero Energy Building Design, Residential building, Renewable Energy, Energy Efficient Buildings Envelope; Passive systems, Mechanical systems consumption Energy, Low energy, Hot climate Zone

ÖZ

Binalarda harcanan enerji ve çevreye olumsuz etkisi global ölçekte kayda değer seviyededir. Dolayısıyla, binalarda enerji yönetimi stratejileri, surdürülebilir gelişim için önem taşımaktadır. Günümüzde Sıfır Enerji Bina (ZEBs) uygulamalarına olan ilgi giderek artmaktadır. Enerji kaynaklarının azalması ve yüksek enerji kullanımının çevreye olan olumsuz etkisini dikkate alan birçok ülke, bu kavramı gelecek planlarına dahil etmeye başlamıştır. Sıfır Enerji Bina (ZEBs) tasarım stratejisi temel olarak iki adımdan oluşur. Öncelikli olarak, özellikle ısısal konfor ve aydınlarma için harcanan enerjinin azaltılması hedeflenir. İkinci adımda ise, yenilenebilir enerji kullanımının bina enerji sistemine adapte edilmesine çalışılır. Bu tez kapsamında amaçlanan, sıcak iklimlerde uygulanmış tasarım stratejilerinin, seçilen örneklemlerle mukayeseli olarak karşılatırılması ve bunun sonucunda Sıfır Enerji Bina (ZEBs) tasarımı için uygun çözümler önerilmektir. Üç bölümden oluşan tez kurgusunda öncelikle, sıcak iklimlerde Sıfır Enerji Bina (ZEBs) kavramı, binalarda enerji ihtiyacı ve enerjinin etkin kullanımı açısından tüm detaylarıyla irdelenmiş, temel tasarım stratejileri, teknolojileri ve uygulamaları tanıtılmıştır. İkinci bölümde sıcak iklim bölgelerinde, konutlarda, ısısal ve görsel (ışık) konforun sağlanabilmesi için harcanan enerjinin azaltıması ve yenilenebilir enerji kaynakları kullanımı ile bina enerji sisteminin dengelenmesi için gerekli yöntemlerin tanıtılması ve tartışılması yapılmıştır. Üçüncü bölümde, ikinci bölüm kapsamında tartışılan tasarım stratejileri ışığında, seçilen bina uygulamaları tartışılmış, sonuç bölümünde ise araştırma neticesinde sıcak iklim bölgelerinde yer alan Sıfır Enerji Bina tasarım stratejileri özetlenmiştir. Tasarımcılar, sonuç olarak benzer tasarım stratejileriyle, binalarda enerji kullanımını azaltmak amacıyla yerel iklim koşullarına en uygun edilgen (passive) bina sistemlerini günümüz teknolojisine uygun yapım ve yalıtım malzemeleri kullanarak hedeflerine ulaşmaya çalışmaktadır. Literatür araştırmasında elde edilen bilgilere parallel olarak, tez kapsamında, sıcak iklim bölgelerinde yer alan örneklem binalarda da enerji üretimi çoğunluka güneşten sağlanmaktadır. Bununla birlikte, iç mekanda ısıl konfor koşullarının oluşması, ihtiyaç duyulan enerji miktarının azaltılması ve enerji maliyetinin düşürülmesi için, güneş ışınımlarından oluşan aşırı ısı kazancının, gerek yalıtım yapılarak, gerekse bina kabuğu tasarımında önlemler alınarak kontrol edilmesi gerekmektedir.

Anahtar Kelimeler: Sıfır Enerji Binalar, Konut binaları, Yenilenebilir Enerji Kaynakları, Enerji Etkin Bina Kabuğu, Edilgen Bina Tasarımı, Mekanik Servis Sistemleri, Enerji Tüketimi, Sıcak İklim Bölgeleri.

I Dedicate This Manuscript to My Parents Who Supports Me in All Circumstances.

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INTRODUCTION

Buildings are responsible for up to 40% of the total energy usage and 24% of the CO_2 emissions worldwide. Depending on the geographical location, population, climate condition, and the standards of energy production and consumption standards this proportion may vary from one country to the other. The use of fossil fuels in buildings can be direct or indirect as in the sites equipped with electricity grids. In addition, energy is also used in the process of production of the materials utilized for construction (Marszal et al., 2011).

During the past decades, sustainability in the building sector has been one the main concerns of the designers, energy engineers, and environmental scientists. The concept of passive ventilation has been initially introduced in late 80s when the idea of low energy usage was represented. Later on, innovative ideas for decreasing energy consumption and renewable energy resources improve the concept to zero greenhouse gas emission and zero energy building or ZEB.

The ZEB is defined as a building that consumes as much energy as it produces from sustainable resources and it emits almost zero greenhouse gas. It is achieved by means of modern energy saving characteristics as well as renewable energy resources with zero CO_2 emission. According to (Ferrantea & Cascellab, 2011), zero energy buildings are "*The residential building with greatly reduced energy needs through efficiency* *gains such that the balance of energy needs can be supplied with renewable technologies*". However, ZEB is not achievable if the technology is not accompanying by innovative passive strategies and renewable resources. Some examples of passive strategies include highly reflective materials, shading mechanisms, passive ventilation implemented in the design, thermally isolated walls and other methods evolved from vernacular architecture of the region or innovative ideas. On the other hand, different forms of renewable energies such as wind power, solar power and geothermal power may be used separately or in combination with each other in a ZEB. Considering these factors in hot climate, ZEB design with low greenhouse emission is practically achievable and can provide high quality comfort for the residents.

Since 1990s, the electricity demand in cities have grown five times as much as a result of modernization and the fast pace of population growth (Al-Iriani, 2005). Today, a great proportion of the electricity power is produced by the systems based on fossil fuels. In addition to the shortage of these energy resources, CO_2 emission is a problematic consequence considering environmental issues such as global warming. Accordingly, the solutions that lead to less energy consumption are currently at a high priority in building design.

Particularly, providing thermal comfort for the residents (heating/cooling) is the major reason for energy consumption in the building. During the seasons witch high temperature in hot regions, approximately 30% of the electricity demand goes for air conditioning (Rehman, 2016). This demand reaches its peak in the hot season starting from June to August.

In architecture, the design should be sustainable considering all these energy issues and environmental problems in the building sector. In year 2008, 18% of greenhouse emission was produced by the buildings as the large cities were growing. Actually, around 11% of this is emitted by heating/cooling systems, home appliances and lighting. Therefore, energy efficiency is a crucial matter in designing the Heating and Ventilation Air Conditioning (HVAC) and lighting systems in the modern houses (Chávez & Melchor, 2014).

Buildings are not only important energy consumers, but they are the places where we spent most of our time. Therefore, comfort conditions cannot be compromised to save energy. Those facts affect the design of ZEH, which has a general aim to contribute to the reduction of carbon footprint in residential sector. (Rehman, 2016).

The Net ZEB can be a local building which is adaptive to proper passive systems and construction to reduce energy use. In peak time the use of sufficient renewable energy systems fulfil the energy needs and the energy production over a year balances out the energy usage.

This research will focus on the review and analysis of existing ZEB definitions and already constructed Zero Energy Buildings, main design principles, passive design strategies, technologies and solutions in order to select the best methods for saving and producing energy from renewable energy sources in a building. Afterwards, based on previous studies working definitions will be developed for ‘zero energy’ concepts.

1.2 Methodology of Research

Methodology used in this study is the literature review for data collection. The data have been collected from books, articles, reports of the conferences, and scientific journals in this specific field. After data collection stage, data analysis is performed in order to find out design strategies of zero energy residential buildings in hot climates. Also, case study approach is chosen to find the answers of the research questions asked in this study. Finally, all of the findings have been analyzed in case studies.

1.2. Problem Background

The world faces a string of serious energy and environmental challenges. The global energy and environmental scenarios are closely interlinked – the problems with the supply and use of energy are related to wider environmental issues including global warming, air pollution, deforestation, ozone depletion and radioactive waste. As the buildings account for the major energy consumers in the cities, renewable energy becomes an essential domain for the design of low energy or even zero energy buildings. Although in different processes of design, construction, and maintenance of the buildings, we can reduce building energy consumption between 30-50% with current affordable technologies, but higher cuts in energy consumption needs the integration of passive strategies, high performance systems and technologies in design process to bring down energy consumption to the near zero energy or zero energy range. This study tries to answer to this question that how could be reach to Zero energy residential houses in hot climate regions and which solutions are more proper for this regions?

1.3Aim of The Study

This research aims to create a practical design guide to help architects design energy-neutral homes in hot climate zone. The study's primary emphasis is on reducing building energy demand by implementing core principles of building physics(science) into the design process throughout a case study project. What makes this process unique compared to other existing green design programs is its focus on architect's knowledge to implement core energy saving design strategies into design and evaluate their performance with a normative simulation tool. Selection and analysis of building systems, financial evaluation of cost effective systems and materials, uncertainty analysis of building systems, construction cost estimating of the case study project, demonstrate simple strategies for designers to use in projects with higher sensitivity.

1.4. Scope of The Study

In this study, general definition of zero energy residential buildings in hot climates will be taken into consideration. In order to reach this aim, first of all factors which effect building design to reach energy efficiency such as energy use for thermal comfort, visual comfort and building envelope, etc. will be reviewed. After these phases design strategies will be categorized as following:

- Reducing energy consumption in building with supporting passive systems
- Efficiency of service systems
- Renewable energy strategies

In order to find out residential building strategies during design process to reach zero building, factors which affect building efficient during three different stage, reducing energy consumption in Passive building, Renewable energy strategies stage and mechanical efficiency will be taken into consideration, which in first stage, passive elements will be mentioned to reach maximum energy efficiency and reducing energy consumption. After the design strategies analysis, the best proposal will be selected to reach for zero energy homes in hot climate zone. Figure 1 show structure of this thesis.

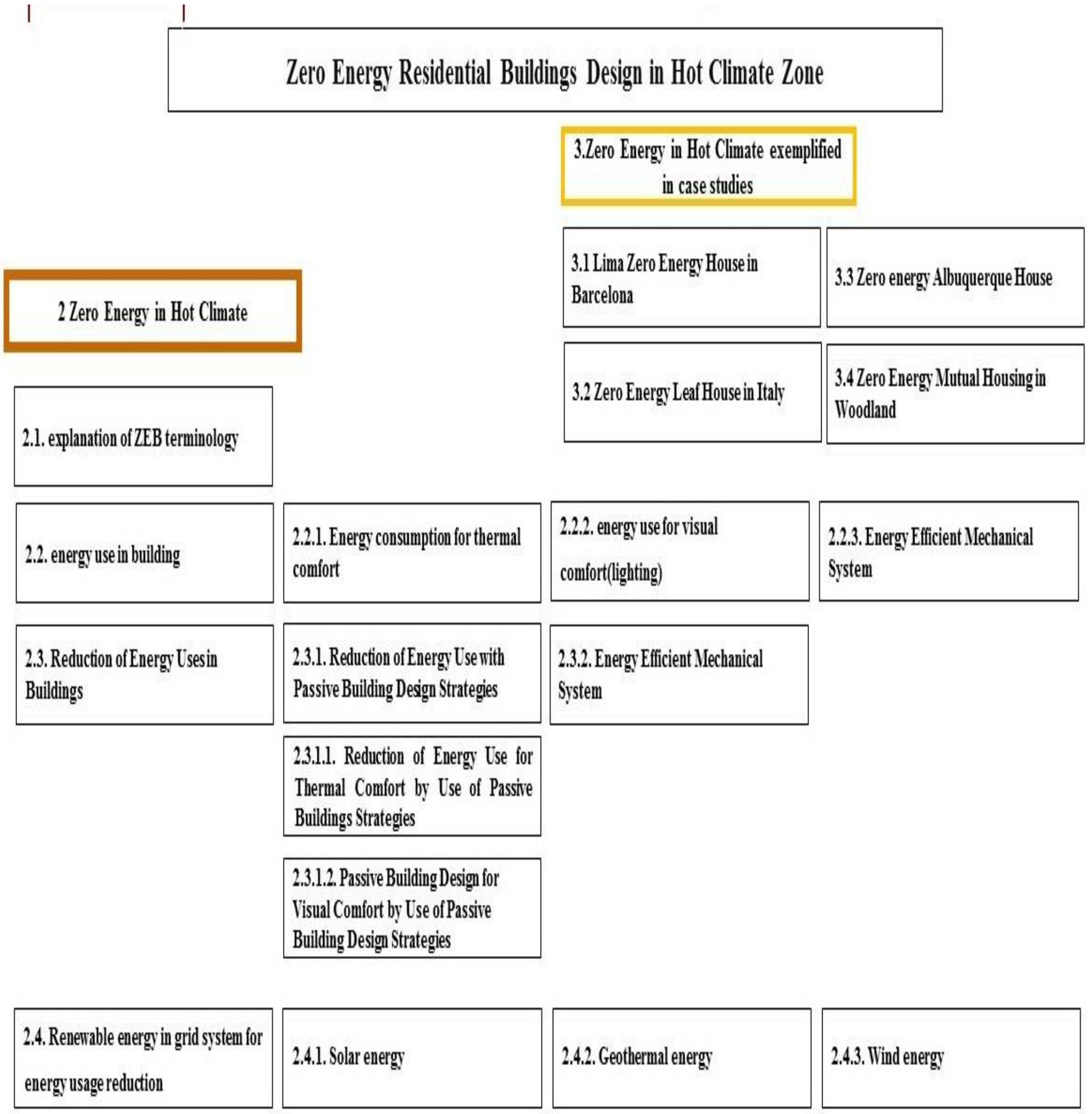


Figure 1 : Show Structure of This Thesis

Chapter 2

ZERO ENERGY BUILDINGS IN HOT CLIMATES

The notion of sustainability in energy consumption is firstly introduced in 1970s using the term ‘net energy’. This concept has been the concern of many studies in the field of fossil fuels consumption reduction (Crawford et al., 2006) and net zero energy buildings. A net zero energy house is defined as the one in which the amount of consumed energy is almost equal to the amount of energy produced by renewable resources. In such a building, a combination of traditional passive cooling strategies, thermal mass such as thick walls made of stone, reflective surfaces, and shading layouts is implemented besides small wind and solar energy plants.

As stated in (Ferrantea & Cascellab, 2011), in hot regions energy sustainable construction with low greenhouse gas emission is achieved by utilizing local material and traditional architecture. Availability of the appropriate construction materials and the feasibility of the vernacular design result in buildings providing high standards of thermal comfort with low net energy consumption. The patterns used by people in hot climate although differ in form, originated from similar concepts. Thus, regardless of political boundaries and religious beliefs that are mainly responsible for variations in traditions, vernacular architecture in different arid climates are aimed at solving extreme weather discomfort problems (Khalili & Amindeldar, 2014). It also notable that in addition to the architectural patterns, in hot regions, the life style of the inhabitants including their food choices, costumes, and even activities is to consume less energy and provide more relief (Khalili & Amindeldar, 2014).

Referring to previous studies, on average approximately 75% of the energy is consumed to perform mechanical ventilation for cooling in hot regions (Nielsen, 2002). Achieving net zero energy in buildings is a more crucial issue nowadays considering the global warming and shortage of non-renewable energy resources. Studies have shown that even in marginally hot regions of southern Europe where the hot season is not that extreme, the energy consumed for cooling is increasing (Dabaieh et al., 2015).

Climate Classification

Climate classification systems are ways of classifying the world's climates. A climate classification may correlate closely with a biome category, as climate is a major influence on biological life in a region. The most popular classification scheme is probably the Köppen climate classification scheme (URL 21).

KÖPPEN CLIMATE CLASSIFICATION

Köppen climate classification is one of the most widely used climate classification systems. It was first published by Russian German climatologist Wladimir Köppen in 1884, with several later modifications by Köppen, notably in 1918 and 1936. Later, German climatologist Rudolf Geiger collaborated with Köppen on changes to the classification system, which is thus sometimes called the Köppen–Geiger climate classification system (URL 22).

In the 1960s, the Trewartha climate classification system was considered a modified Köppen system that addressed some of the deficiencies (mostly that the middle latitude climate zone was too broad) of the Köppen system.

The system is based on the concept that native vegetation is the best expression of climate. Thus, climate zone boundaries have been selected with vegetation distribution in mind. It combines average annual and monthly temperatures and precipitation, and the seasonality of precipitation (URL 21).

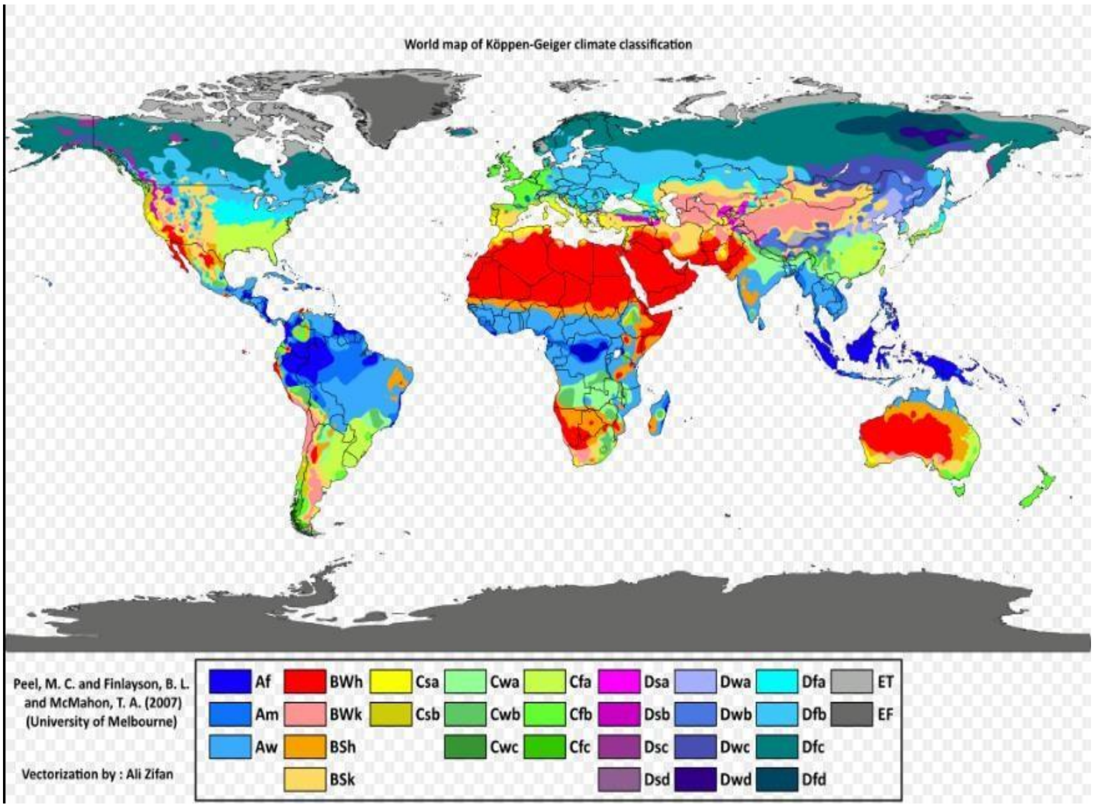


Figure 2 : world map of the Köppen-Geiger climate classification (URL 21).

The Köppen climate classification scheme divides climates into five main groups (A, B, C, D, E), each having several types and subtypes. Each particular climate type is represented by a two- to four-letter symbol.

- Group A: Tropical/megathermal climates
- Group B: Dry (arid and semiarid) climates
- Group C: Temperate/mesothermal climates
- Group D: Continental/microthermal climates

ASHRAE RP-884 database was classifying each data file supplied into one of three climate groups including hot–humid, hot–dry, and moderate according to survey location and season (The University of Sydney, 2010).

The widely Köppen–Geiger climate classification map updated by Peel et al. (2007) was used to define the three groups. In this classification system, five climates including tropical (A), arid (B), temperate (C), cold (D), and polar (E) are categorized into 30 climate types on the basis of quantitative criteria for temperature and precipitation (Peel et al.,2007).

As see the classification of climates are varying and widely, to reach better result in this thesis investigated in zero energy building in hot-dry and hot-humid climate zone.

2.1 Explanation of ZEB Terminology

The zero energy building standards has increased in percentage over the past year. As USA and Europe have established energy ZEB standard. Among the various strategies for reducing energy consumption in the building sector, ZEBs have the potential to significantly reduce energy consumption and gives hope to increase the overall share of renewable energy (Marszal et al., 2011).

The publications from the 1970s and 80s' (Gilijamse, 1995, Saitoh et al., 1985) can be perceived as one of the first attempts towards zero energy buildings. At that time, when the biggest part of energy use in the buildings was mostly due to the thermal energy (space heating and/or domestic hot water (DHW) and/or cooling), the zero energy buildings were actually zero thermal buildings. An example could be the Zero Energy House in Denmark (Gilijamse, 1995) where the authors state ‘Zero Energy House is dimensioned to be self-sufficient in space heating and hot-water supply during normal climatic conditions in Denmark.’ (Iqbal, 2004) and (Gilijamse, 1995) provide another method where the definition ZEB focuses only on electricity. (Hernandez & Kenny, 2010) state that energy balance should not only focus on the energy used by buildings in the exploitation phase, but also include the energy construction of buildings and systems.

Several countries such as Europe and the United States of America performance standards to creating ZEBs as future energy goals and guidelines for the technology (Sartori et .al, 2012). robust calculation methodology needs attention with the growing number of ZEB projects due to the lack of agreed definition of ZEB at international level and thus the interest in how the ‘zero’ balance is computed. The complex concept on Zero energy buildings with a number of methods are currently have various aspects of ZEB. Therefore, the calculation of the energy balance of a building equipped with on-site and / or off-site renewable energy systems and / or interact with the electricity grid and trying to fulfill. the 'zero' goal is not easy to handle. Some methods like LEED or BREEAM established environmental assessment but yet there is not such an attempt for ZEBs. Therefore, if we want methods to target the zero energy building in the future, it is a key issue to develop a physically convincing and strong calculation methodology in designing ZEB to reflect the concept and facilitate the work of both architects and engineers (Marszal et al., 2011).

For example, the metric for the balance is an important issue on the ZEB agenda. The applied zero as the unit for balance number of measures is influenced; furthermore, the calculation methodology and/or definition of one unit can be used. For example, the final is also called CO2 equivalent emissions, end-use or un-weighted energy, cost of energy, delivered, exergy, the primary energy or other defined parameters by national energy policy.

mostly grid connected ZEBs relevant to some balance issue, because in this type of ZEBs there are two possible balances between (Marszal et al., 2011):

(1) the use of energy and the renewable energy generation or

(2) the delivered energy to the building and the energy feed in to the grid.

The main difference is the period of application as the result of both balances is the same in most cases. During the design phase of the building and the second to the monitoring phase the first balance is more applicable. In the off-grid ZEBs the situation is clear. The energy use has to be offset by the renewable energy generation. In order to define ZEB (Kilkis, 2007) states that metric of the balance both the quantity as well as the quality of energy should address, to assess the complete building's impact on the environment in a certain period of time. Only two units of the balance is defined by (Mertz et al., 2007) and (Laustsen, 2008): energy and emissions, however, without specifying primary energy or delivered. Hernandez and Kenny stated that the energy balance of the building to calculate the full life cycle period could be more appropriate. It means, to balance only calculating the operating energy use it is not possible, also the energy embodied in the building construction, materials and technical installations need to be calculated. Most of the building energy simulation programs as the final result give the annual energy use of a building because the Eleven out of twelve current methodologies are based on the annual balance, because the seasonal discrepancy between energy demand and renewable energy generation just there is one methodology that uses a monthly balance it is more difficult to achieve zero balance than in the case of annual balance. a year calculation period in issue of energy use of a building among the existing ZEB definitions and calculation methodologies is the popular. As the annual energy use in the building due to many reasons i.e. stronger and longer winters, warmer summers or behavior occupants can differ from year to year and over e.g. 50 years of building operation it could be a balance. Another option, i.e. seasonal or monthly not very popular within the building community is the sub yearly balance.

The unit applied in the ZEB definition according to (Torcellini et al., 2006) can be influenced by:

(1) goals` project

(2) the investor`s intentions

(3) the concerns of the greenhouse gas emissions and climate

(4) energy cost.

Therefore, four different ZEB definitions propose are: site ZEB, source ZEB, emissions ZEB and cost ZEB.

Table 1: Definition of Net ZEBs (Torcellini, et al., 2006).

Net-Zero Site Energy	A site ZEB produces at least as much energy as it uses in a year, when accounted for at the site.
Net-Zero Source Energy	A source ZEB produces at least as much energy as it uses in a year, when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site. To calculate a building's total source energy, imported, and exported energy is multiplied by the appropriate site-to-source conversion multipliers.
Net-Zero Energy Costs	In a cost ZEB, the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.
Net-Zero Energy Emissions	A net-zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources.

Generally, a ZEB is defined as a building provided with its own renewable energy system that generates as much energy as it consumes annually. (Pacheco & Lamberts, 2013)

to define energy policy aims first before defining a ZEB it is important. According to (Torcellini et al., 2006). The local balance is easier to implement and maximizes both energy efficiency and local renewable generation. Source metrics for energy balance to meet balance induce lower need for the search of energy efficiency measures and reliance of external renewable sources of energy.

Renewable Supply in ZEB

The hierarchy of renewable supply options is suggesting by Torcellini et al. (2006), see Table 2.

Table 2: ZEB renewable energy supply option hierarchy. (Torcellini et al., 2006).

Option no.	ZEB supply-side options	Examples
0	Reduce site energy use through low-energy building technologies	Daylighting, high-efficiency HVAC equipment, natural ventilation, evaporative cooling, etc.
On-site supply options		
1	Use renewable energy sources available within the building's footprint	PV, solar hot water, and wind located on the building
2	Use renewable energy sources available at the site	PV, solar hot water, low-impact hydro, and wind located on-site, but not on the building
Off-site supply options		
3	Use renewable energy sources available off site to generate energy on site	Biomass, wood pellets, ethanol, or biodiesel that can be imported from off site, or waste streams from on-site processes that can be used on-site to generate electricity and heat
4	Purchase off-site renewable energy sources	Utility-based wind, PV, emissions credits, or other "green" purchasing options. Hydroelectric is sometimes considered

Definition of Off-Grid

The building–grid interaction requirements that exchange energy with the energy infrastructure are only relevant for the grid connected ZEB (Baetens et al., 2010, Marszal et al., 2011).

The biggest attention the interaction with the electricity grid is given to the biggest attention due to only few cases of ZEB that exchange heat with the district heating grid in Austria.

Moreover, only within few European countries the possibility to exchange the heat is feasible R. (Baetens et al., 2010, Marszal et al., 2011).

Review of Off-Grid ZEB

Any utility grid is not connected to the off-grid ZEB and hence more energy needs to produce or system for periods with peak loads have some electricity storage. This type of ZEB in the literature is also named ‘self-sufficient’ (Marszal et al., 2011). according to (Baetens et al., 2010) ‘buildings are Zero Stand Alone Buildings that need no connection to the grid or only as a backup. Standalone buildings can autonomously supply themselves with energy, as for night-time or wintertime use to store energy they have the capacity

Result Conducted from Existing Definitions to Reach ZEB

A very similar path to achieve to ZEB in the existing Zero Energy Building definitions could be found out:

- Firstly, the demand of energy reduction using energy efficient measures
- secondly, the renewable energy sources utilization to supply the remaining energy demand. For the life of the building Energy efficiency is usually available.

However, efficiency measures must have good persistence and make sure they continue to save energy should be checked. To save energy than to produce energy it is almost always easier and the most logical approach to reach ZEB is the above strategy. In order to ensure that Zero Energy Buildings also are very energy efficient buildings (Marszal et al., 2011).

Energy Codes and Standards in Building

Energy codes and standards set minimum efficiency requirements for new and renovated buildings, assuring reductions in energy use and emissions over the life of the building. As a building's operation and environmental impact is largely determined by upfront decisions, energy codes present a unique opportunity to assure savings through efficient building design, technologies, and construction practices. Once a building is constructed, it can be significantly more expensive to achieve higher efficiency levels. Including energy as a fundamental part of the building construction process and making early investments in energy efficiency yields benefits for all owners and occupants for years into the future (URL 19).

Energy codes are a subset of building codes, which establish baseline requirements and govern building construction. Energy codes reference areas of construction such as wall and ceiling insulation, window and door specifications, HVAC equipment efficiency, and lighting fixtures.

Today's energy codes come in two basic formats, *prescriptive* and *performance*. A possible third format, outcome-based, has begun to pique the interest of the building community.

A **Prescriptive** path is a fast, definitive, and conservative approach to code compliance. Materials and equipment must meet a certain levels of stringency, which are quantified in tables. These tables list the minimum and maximum requirements for the R- and U-values of materials, the allowable watts per square foot of lighting systems, and the minimum energy efficiencies required of mechanical systems. This path dictates specific requirements that must be met, but does not account for potentially energy saving features like window orientation.

Performance-based codes are designed to achieve particular results, rather than meeting prescribed requirements for individual building components. Performance paths typically are based on the anticipated results from application of the prescriptive path. This path is useful when quantifying non-traditional building features such as passive solar and photovoltaic technology.

Performance-based approaches use an established baseline measurement from which certain systems must perform. This path requires more detail regarding building design, materials, and systems; however, is a more flexible approach than the prescriptive path. Such an approach is particularly desirable for larger buildings, as it provides opportunities for trade-offs across energy-influencing systems to come up with the most cost-effective means for achieving compliance. Performance-based codes are technology neutral, thus enabling quicker incorporation of energy saving technologies and practices into the marketplace.

Outcome-based codes establish a target energy use level and provide for measurement and reporting of energy use to assure that the completed building performs at the established level. Such a code can have significant flexibility to reflect variations across building types and can even cover existing or historic buildings. Most importantly, it can address all energy used in buildings and provide a metric to determine the actual quality of the building construction.

The U.S. does not have a national energy code or standard, so energy codes are adopted at the state and local levels of government. Because of this, the codes and editions in place vary widely. The Department of Energy maintains information on energy codes adopted. DOE also provides technical assistance to states and localities as they adopt and enforce energy codes.

Relevant codes and standards use in U.S:

- 10 CFR 433 and 10 CFR 435 (minimum standards for energy efficiency for the design of new federal commercial and multi-family high-rise residential buildings)
- ANSI / ASHRAE / IESNA Standard 90.1—Energy Standard for Buildings Except Low-Rise Residential Buildings
- ANSI / ASHRAE / IESNA Standard 90.1—Energy Standard for Buildings Except Low-Rise Residential Buildings; used by the U.S. Department of Navy and U.S. Department of Defense
- ANSI / ASHRAE / IESNA Standard 90.1—Energy Standard for Buildings Except Low-Rise Residential Buildings; basis for government standard 10 CFR 434
- ANSI/ASHRAE Standard 90.2—Energy Efficient Design of Low-Rise Residential Buildings
- ANSI / ASHRAE / IESNA Standard 100—Energy Conservation in Existing Buildings
- ANSI/ASHRAE Standard 100—Energy Conservation in Existing Buildings
- ANSI/ASHRAE Standard 105—Standard Methods of Measuring and Expressing Building Energy Performance
- Energy Policy Act of 2005
- Executive Order 13693, "Planning for Federal Sustainability in the Next Decade"

- International Energy Conservation Code (IECC)
- International Green Construction Code (IGCC)
- NFPA 900 Building Energy Code
- NFPA 5000 Building Construction and Safety Code
- Presidential Memorandum—Federal Leadership on Energy Management

Europeans countries improving the energy efficiency of buildings by stablish codes and standards to reduce total EU energy consumption and CO_2 emissions as mention below.

The 2010 Energy Performance of Buildings Directive and the 2012 Energy Efficiency Directive are the EU's main legislation when it comes to reducing the energy consumption of buildings (URL 20).

Under the Energy Performance of Buildings Directive:

- energy performance certificates are to be included in all advertisements for the sale or rental of buildings
- EU countries must establish inspection schemes for heating and air conditioning systems or put in place measures with equivalent effect
- all new buildings must be nearly zero energy buildings by 31 December 2020 (public buildings by 31 December 2018)
- EU countries must set minimum energy performance requirements for new buildings, for the major renovation of buildings and for the replacement or retrofit of building elements (heating and cooling systems, roofs, walls, etc.)

- EU countries have to draw up lists of national financial measures to improve the energy efficiency of buildings

Under the Energy Efficiency Directive:

- EU countries make energy efficient renovations to at least 3% of buildings owned and occupied by central government
- EU governments should only purchase buildings which are highly energy efficient
- EU countries must draw-up long-term national building renovation strategies which can be included in their National Energy Efficiency Action Plans
- Buildings under the Energy Efficiency Directive (EED)

In this thesis review some information from different standards and codes that used in literatures, most of these information's come out from EU and US standards.

2.2 Energy Use in Building

The building sector accounts for approximately 40% of total global energy usage. Energy consumption for space heating and cooling makes up 60% of the total consumed energy in buildings highlighted by (Baetens et al, 2010). It is also stated that building-related carbon emissions are more than 30% of total emissions in most developed countries. A significant portion of the total primary energy is consumed by today's buildings in developed countries in HVAC systems. In many of these buildings, the energy consumption can be significantly reduced by adopting energy efficiency strategies. Due to environmental concerns, climate changes and the high cost of energy in recent years there has been a renewed interest in building energy efficiency. as well Future predictions regarding environmental health are also not promising as reported by (Bolaji & Huan, 2013). In this respect, intensive efforts are made on both energy saving and clean energy generation (renewable energy technologies. However, recent works reveal that renewables can supply only about 14% of total world energy demand. Cost can be considered one of the most dominant parameters which decelerates the renewables to become widespread as reported by (Cuce , 2016).

There are several reasons that could increase the among primary energy consumption and primary energy load:

daily or seasonal overstate period for cooling and heating and systems use;

- high use of independent equipment, which provide a very localized heating or cooling.
- Adaptive people to mechanical systems that they feel uncomfortable in small changes in temperature.

Furthermore, the equipment for heating and cooling, such as the electric heater, heat pump for heating or cooling, gas boiler or gas heater, wood fireplace, air conditioning, elevators for apartments resulted effected primary energy load in building.

According to (EN ISO 13790, 2008) The other factors that effected on energy consumption for heating and cooling energy in building are include:

- transmission heat transfer;
- ventilation heat transfer;
- internal heat gains from people, appliances, lighting and others;
- solar heat gains through windows and opaque building elements;

- annual and seasonal energy needs for heating and cooling to maintain set point temperatures in the building.

2.2.1 Energy Consumption for Thermal Comfort

Proving thermal comfort for the residents is a necessary element in the design and it also important in terms of energy (Nicol et al., 2012). There are some well-defined standards for indoor spaces that need to be considered in the architecture of the buildings in order to reduce the energy consumption and provide a thermally comfortable interior environment. Considering the environmental issues and lack of fuels, the standards aim at reducing required energy for cooling and heating the building (Toea & kubota, 2013).

In the hot seasons of hot regions, providing the residents with thermal comfort is a challenge. Most of vernacular buildings constructed in hot climate are designed based on the passive and mechanical strategies that rely on natural ventilation (Cellura, 2014). Generally speaking, the criteria for evaluating the quality of thermal comfort play an active role in sustainability in the buildings since they define the ventilation strategies and standards (Mirrahimi et.al, 2016).

Considering energy consumption, thermal comfort can be standardized by the strategies that result in less energy usage. Actually, thermal comfort is defined in two fundamental ways namely static approach and adaptive approach. In the conventional approach, data is extracted from experiments conducted in a climate chamber. More precisely, the residents of the building are considered as passive or static objects feeling thermal comfort or discomfort (Pacheco & lamberts, 2013). The latter however, takes into account interactions between the inhabitants and the building thermal conditions. In other words, comfortable state for the occupants is affected by the environment and history of the thermal condition. According to Candido et al. (2011) and ASHARAE (2010), the adaptive approach facilitates thermal comfort by reduced energy consumption using strategies like swift air draft. These predictions are made based on more than 2000 records for comfortable thermal conditions considering a broad range of temperatures.

From the energy consumption and heat gain perspective, occupants' activities in addition to ventilation, lighting and home appliances increase the temperature inside the building (Choi et al., 2010). On the other hand, thermal comfort is essential for the residents to perform their daily tasks efficiently. Therefore, in a resident a great deal of energy is also consumed for providing thermal comfort (cooling and heating) (Mohammed Abdul Fasi,2015). As a matter of fact, Building's Indoor Climate and Environment or briefly BICE constitutes a considerable proportion (ranges from 30% to 40%) of the global energy usage . Depending on the country and its conditions this percentage may vary. The influencing factors include economic condition, social and cultural situation, architectural patterns, available energy resources, climatology, and energy consumption standards. For instance, in the European countries and in the US, 40% and 41% of the total national energy is utilized for house ventilation (Omrany et al., 2016). As a result of global warming issue and lack of fossil fuels, the European Energy Performance of Buildings Directive has implied that by year 2020, all the buildings constructed in the European Union should be nearly ZEB. To reach this standard it is necessary that '*the coherent application of passive and active design* strategies *in order to reduce the heating and cooling loads*', '*raising equipment energy efficiency*', and '*the use of renewable energies*' (Stevanović, 2013).

In Asia, China is one the countries that has established an analogous trend in architectural design. They ratified an inclusive standard as Building Energy Codes (BEC) which defines design conditions and energy consumption regulations. The issues that are considered by the existing BEC comprise HVAC including heating/cooling and air conditioning as well as coating (Nejat et al., 2015) . Moreover, some regulations for efficient energy consumption are ratified by Chinese Ministry of Housing and Urban/Rural Development. As an example, energy consumption in the newly constructed buildings should be decreased by 50% or for the already in use buildings located in small towns, medium cities and big cities, energy consumption needs to reduce by 10%, 15% and 25% respectively. (Omrany et al., 2016).

As mentioned before, efficient design of the building coat is one of the basic factors in energy consumption reduction for providing thermal comfort. Moreover, passive ventilation strategies are recognized as effective solutions to improve thermal comfort without consuming more energy. A well designed ventilation system is an optimum combination of innovative passive strategies with active air conditioning system.
Building envelope plays a vital role in sustainability in the construction sector. The coating of a building is the intermediary that connects interior microclimate to ambient climate. The main features of an envelope include being sound proof, providing natural light, passive ventilation and thermal isolation. Thus, the building envelope influences the degree of thermal comfort as well as energy consumption. In designing the envelope there should be a trade-off between the amount of natural lighting and the energy needs for cooling/heating. For instance, in a building with several glazed openings, energy demand for cooling will be high. Consequently, the building envelope should be designed in an efficient way. (Omrany et al., 2016).

As introduced before, there is an adaptive standard for improving thermal comfort. Considering the envelope design, adaptive model is more effective in providing high quality thermal comfort at different seasons, specifically, in low energy buildings benefiting from passive ventilation strategies adaptive model is more proper (Nicol et al., 2012).

On the other hand, in a study by Nguyen et al. (2012), it is stated that ignoring humidity and air draft in thermal comfort resulted in increased energy consumption in large cities located in developing countries. The relative effect of thermal comfort with humidity is inspected by Nicol. He has shown that in the climate conditions when ambient humidity increases to 75% and above, comfortable temperature decreases by at least 1°C.

Thermal comfort conditions in three different climates including hot and humid, hot and arid and moderate weather regions are also addressed in the literature (Toe & Kubota, 2013). Particularly the effect of air speed and humidity level on thermal comfort are explored in hot weather. The research is conducted on a refined data set consisted of 7662 records of the average ambient temperature during the day as well as indoor operative temperature and relative humidity. Figure 3 shows the scatter diagram of the indoor conditions for the refined data set in three climate conditions. It is notable that in the records for hot and humid regions are clearly observable.

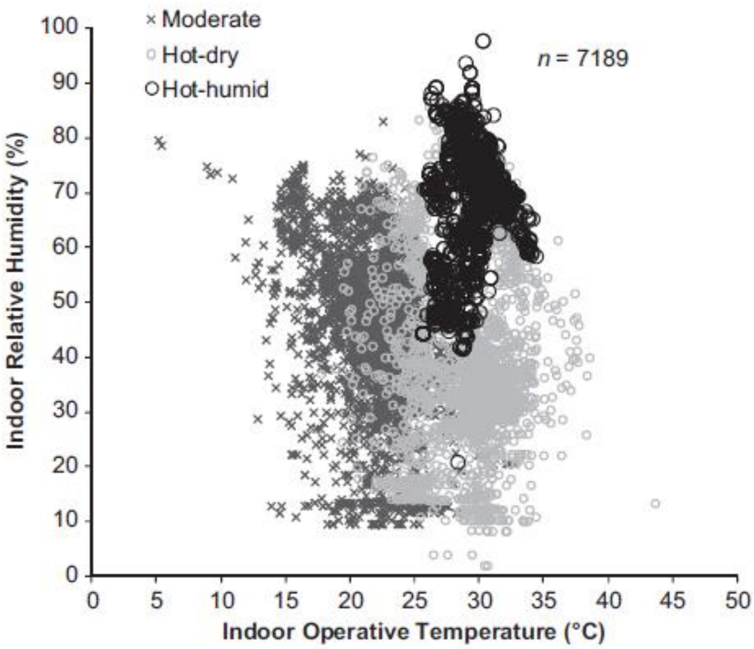


Figure 3 : Scatter diagram of indoor thermal conditions in refined data set (Toe & Kubota, 2013).

Acceptable Comfort Limits in Hot and Arid Versus Hot and Humid Climates

As discussed before, comfortable temperature level depends on the outdoor humidity. In Figure 4, proportions of thermal sensation votes and occupants' neutral votes are plotted versus the degree of deviation from comfortable temperature. Referring to Figure 4a, in hot and humid climates, 80% of thermal comfortable votes are given to the temperatures approximately 0.7ºC lower than that of neutral votes. In hot and arid climate, 80% of the occupants' comfortable votes are observed at temperatures deviations range from -6 ºC to +2 ºC (Figure 3b). In the regions with moderate climate as illustrated in Figure 4c, the 80% comfortable votes lie at deviation of 2.5 ºC below to 1.5 ºC above the neutral operative temperature. It is also notable that in arid regions the range of comfortable temperature is larger than that of humid climate since humidity decreases the range of tolerable indoor temperature (Zhao et al., 2015).

The Concept of Adaptive Thermal Comfort

On the other hand, in (Nicol, 2004).it has proved that the occupants are behaviorally adapted to the indoor thermal conditions. It means that thermal comfort conditions may vary from one person to another one living in the same climate region because of the ways people get used to that make their living spaces thermally comfortable. Thermal comfort is necessary for the occupants to perform their daily tasks productively. However, the conditions at which the people feel comfortable is also affected by the cultural and social standards. In addition, the duration of the time that people reside in a specific climate condition, can change their thermal feeling and preferences because of adaptation as mentioned before (Rattanongphisat & Rordprapat, 2014).

Thermal comfort is defined in (Hensen, 1991) as ‘a state where no driving impulses exist so as to modify the environments by the behavior’. There is another definition made by ASHRAE (The American Society of Heating, Refrigerating and Air-Conditioning Engineers) (ASHRAE) as the situation at which the occupant is satisfied with the indoor thermal condition. Therefore, people desires can easily influence thermal comfort standards. In fact, culture, mood, personal preferences and social factors have impact on this condition.

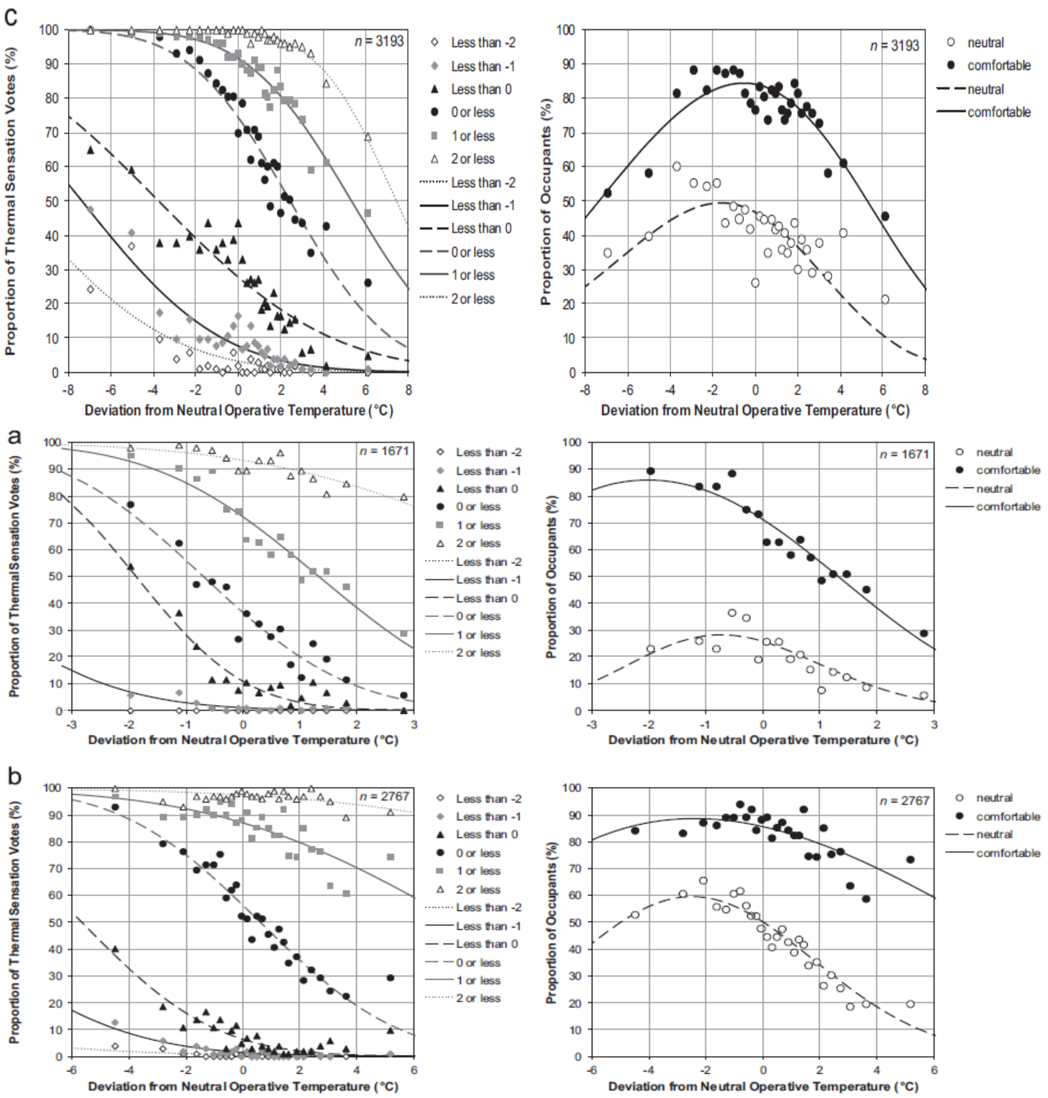


Figure 4 : Thermal comfort conditions in (a) Hot and humid region (b) hot and arid region; (c) (Toe & Kubota, 2013).

Thermal comfort conditions in (a) Hot and humid region (b) hot and arid region; (c) moderate climate region. In the left hand side plots, proportion of thermal sensation votes are illustrated versus temperature deviation from neutral operative condition. On the right, proportion of occupants is plotted versus the deviation. Neutral vote or ‘0’ is plotted by dashed lines and black points, filled lines and grey points are related with “comfortable” votes or ‘±1’ (Toe & Kubota, 2013).

Humidity Effect On Thermal Comfort and Energy Consumption

Estimating the impact of humidity on thermal comfort and consequently the energy usage is not straightforward because humidity cannot be easily evaluated. Generally, at higher humidity levels the body loses less heat by evaporation and thus the comfortable temperature for occupant's decreases. In Nicol (2004), it is also confirmed that comfortable temperature in hot and humid climate is less than that in hot and arid climate. It means that more energy is consumed to maintain indoor air quality at an acceptable condition.

In addition, the discomfort caused by daily activities is more sensible in hot and humid climate compared to hot and arid regions. The deviation in comfortable temperature is also smaller at higher humidity levels. However, it is not easy to predict a precise comfortable temperature for tropical regions. It has been suggested that deviation of approximately 2ºC to 3ºC from general optimum temperature is considered as acceptable. When air movement is provided for instance by fans, comfortable level can be increased by 2 ºC. As a matter of fact, besides the comfortable temperature that is generally 1ºC lower in high humidity, it has been concluded that at tropical climate conditions, the zone of comfortable temperature shrinks.

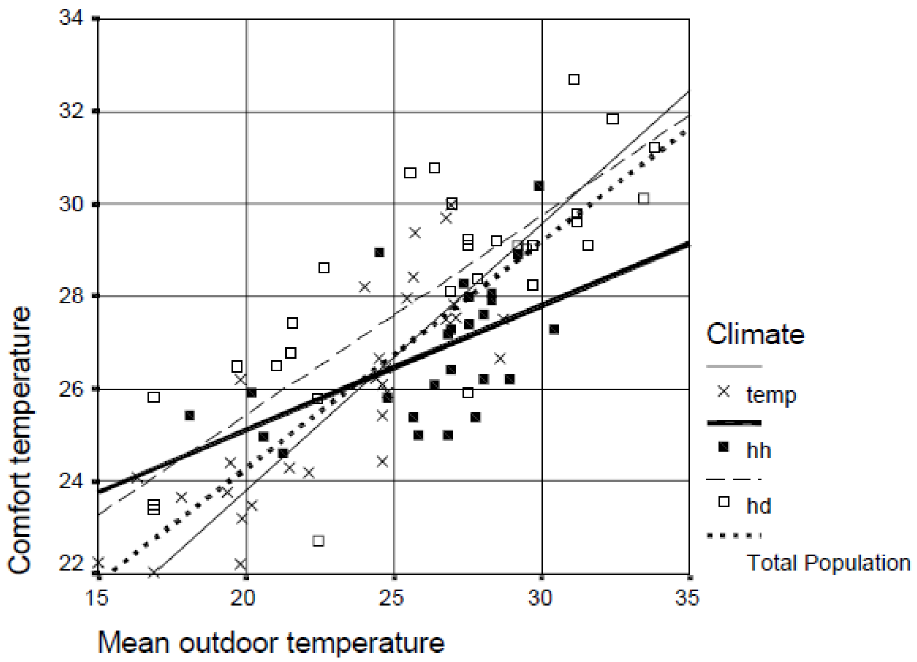


Figure 5 : Comfort temperature against average ambient temperature in different climate conditions (Nicol, 2004).

Comfort temperature against average ambient temperature in different climate conditions including moderate (temp), hot and humid (hh), and hot and dry (hd) in typical residential buildings (Nicol, 2004).

2.2.2 Energy Use for Visual Comfort(Lighting)

One important influential factor in the amount of energy consumed in the building for ventilation is the envelope of the building faces outdoor. Replacing the daylight enters through the windows by artificial lighting reduces the heat that enters the building but it has a main drawback as it causes an increase in energy consumption in the building. Natural lighting on the other hand, gives the residents less visual comfort as they lose the control over the light. Besides (Fasi & Budaiwi, 2015) Investigations reveal the amount of electrical energy usage for artificial lighting as well as the equal green gas emission for the process. According to International Energy Agency (IEA, 2014), approximately 20% of the domestic electrical energy consumption is related with lighting. This energy is responsible for an equivalent 5% green gas production. In developed countries such as United Kingdom the proportion is even more (up to 25%).

A simulation based on Design Builder performed by Fasi and Budaiwi (2015) has studied three different forms of windows with glass in a typical building constructed in hot climate. The building models are investigated from the visual performance perspective and the energy consumption. They commented that in all three models the amount of energy usage is decreased. For windows glazed with doubled pane the ratio of total energy reduction is reported to be 14% while for low emission double pane type energy consumption is reduced by 16%. Without implementing an indoor shading mechanism, these windows cause visual discomfort. However, by interior shading mechanism it is possible provide visual comfort without a substantial change in total energy consumption.

In that study, the impact of daylight integration on visual comfort and energy usage for lighting and cooling are also investigated. The experimental results based on the typical house model with double-glazed windows in hot climate have revealed that the lighting energy consumption is deceased by a factor of 70% in comparison with the same model with no daylight. Annual cooling energy consumption is also declined by 8%.

In the first steps of designing a building, saving energy should be considered as one the main concerns. More specifically, cooling, heating and lighting are the major reasons for energy consumption in a residential construction._According to the statistics published by IEA, lighting is the main energy consuming purpose in the building. Cooling and then heating are the next ones (International Energy Agency, 2014). However, by implementing properly positioned windows with efficient heat isolation and controllable shading, energy usage for artificial lighting can be significantly reduced using daylight. This trend is recognized as an efficient, cost effective and simple strategy for improving visual comfort and saving energy.

A similar pattern is also observed in the designs with windows having tinted glass when daylight is used as a lighting source. In fact, tinted glazed windows and Low-E glazed windows decrease the total energy consumption in a year by 15% and 16% respectively, but the latter do not offer a glare-free interior space. Stare value can be controlled automatic blinds which improve visual comfort as well. Researcher have found that in buildings, automatic venetian blinds enhance visual comfort and decrease lighting energy usage to some extent (Fasi & Budaiwi, 2015).

Effect of day light on improve visual comfort

A proper utilization of the natural daylight in building design affects the feeling of visual comfort. In contrary to thermal comfort, visual comfort is not well defined and does not have implicit quantitative and qualitative standard. It is influenced by several factors including the available daylight time in the region, optical characteristics of the interior space, and the features of glazes that filter the light before entering the building. According to the (EN Standard 12464-1, 2002) there are some standard criteria for lighting and glare index. However, the matter of daylight intensity and the appropriate luminance level has not been answered. The only available approach is a qualitative one established for the proportion of daylight and artificial lighting combination.

On the other hand, in the most recent (EN standard numbered 15193, 2007) daylight integration is also included in the procedure for estimating the energy usage for lighting indoor spaces. This method despite the innovative assessment of the contribution of daylight into the energy consumption, has an important deficiency. Particularly, accessibility of natural lighting is evaluated by a stationary method based on daylight factor. Thus, the actual impact of daylight integration and interactive shading technologies are not taken into account. This drawback is a confusing one because the design of windows, their dimensions, locations and glazing as well as shading elements requires an accurate assessment of the daylight and at the same time influences the energy usage for artificial lighting and cooling systems (Nguyen et al., 2012).

In conclusion, there is a need for including all these elements of lighting into the design strategy of the buildings just like it has already performed for thermal comfort. Windows are the vital elements for integrating daylight and improving visual comfort. During the hot seasons, this approach is doubtfully important since limiting the heat gain due to sun exposure and proper air movement are important matters for energy saving in ventilation (Sicurella et al., 2012).

2.2.3 Energy Use for Mechanical Systems

Approximately 40% of total building energy consumption is attributed to HVAC (heating, ventilation, and air conditioning) systems that aim to maintain healthy and comfortable indoor environments. An HVAC system is a network with several subsystems, and there exist heat transfer and balance among the zones of a building, as well as heat gains and losses through a building's envelope. Diverse occupancy (diversity in terms of when and how occupants occupy a building) in spaces could result in increase of loads that are not actual demands for an HVAC system, leading into inefficiencies (Yang et al., 2016).

In the United States, people spend more than 90% of their time indoors_and approximately 40% of all energy consumption is attributed to the 120 million buildings. Sustainability and energy conservation have become increasingly important topics, as nearly 50% of the energy consumed by buildings is wasted, and the total energy consumption by the building sector is projected to increase by 15.7% between 2013 and 2035.as well In commercial buildings, nearly 40% of the energy is used by HVAC (Heating, Ventilation, and Air Conditioning) systems to maintain comfortable and healthy indoor thermal environments (U.S. Department of Energy, 2016).

2.3 Reduction of Energy Uses in Buildings

The request for energy has been increasing ceaselessly and is potentially to continue also in the future time. British Petroleum released a report about the world current status of energy that demonstrates a rise about 2.3% in the global preliminary energy consumption. Population development and the building services growth and comfort rates have led to rise of the energy consumption of a house. The decrease of energy consumption in the houses can make a considerable cooperation to decrease the global request for energy (International Energy Agency, 2014).

The planning of the houses and structures with energy efficacy based on the appropriate election of good methods that accompany the local climate and could decrease the energy utilization in the building sectors. The two main factors to be considered in hot climate areas are referred to the cooling technology and the electrical appliances (containing the lighting system).the good primary architectural planning decisions (passive design techniques) and election of effective mechanical devices (active specifications) to decrease the consumption rate then by adapting renewable systems produce based on the hot climate areas influence on the energy consumption rate and also the user comfort (Rattanongphisat & Rordprapat, 2014).

According Carlos Ernesto on the performance of individual active specifications to apply one or more climatic design methods cause energy saving issues that vary from 8% up to 40%, related to the integration method that was applied. Passive design methods and strategies that utilized low-sophistication devices gained between 20% to 60% energy savings, but some of these methods might not be appropriate for all the conditions (for instance, depending on the facing to the south directions or climatic area).

However, integration of active specifications and correct passive design methods brings steady savings about 50–55% for most of the cases in compare to an ordinary condition. (Ochoa & Capeluto, 2008).

The following trend is presented to decrease the energy requirements:

- constructing a proper house coverage by optimization of the sizes of heat insulation with the wall and roof structures to bring an overall heat transfer
- election of the right direction for the house to maximize the passive solar design utilizing the energy-efficient appliances and light equipment.
- Utilizing effective water fixtures.
- Utilizing effective mechanical systems.
- Maximizing the application of solar power cooling systems and heating techniques.

- Providing the space and water heating system by solar heat systems, thermal storage methods and thermal pumps.
- Providing hot water by the systems equipped with the solar energy.
- Balancing the electrical network use via an integrated system of photovoltaic, wind turbine, battery bank and diesel generator.

2.3.1 Reduction of Energy Use with Passive Building Design Strategies

Passive design is considered as a design method that utilizes the natural factors same as the sunlight for the aim of heating, cooling or lighting a house or construction. Passive solar or passive cooling design methods benefit from the energy from the sun to maximize the heating or cooling based on a building's sun facing. Systems that use passive design need very little maintenance methods and decrease a building's consumed energy by minimizing or removing the mechanical systems utilized to adjust the inside temperature and lighting conditions.

The passive design method can contain also the building structure same as the orientation, window setting, skylight installation, insulation equipment and building materials, or sometimes the main components of a house or structure same as the windows and window shades. For instance, mounting functioning windows or some kind of windows that can be manually and easily opened and closed, permit occupants to control the volume of air entering a space or by utilizing the passive system same as wind catcher solar chimneys and so on to provide natural ventilation (Roslan et al., 2016).

Rise in the interior temperature in compare to the outside temperature is a great issue to concern in modern house design methods. Residents suffer from such uncomfortable conditions due to the over- heating conditions inside temperature. Poor passive designing methods result in heat to be trapped that effects on the increase in inside temperature. Moreover, passive design methods may assist in keeping the indoor temperature around the comfortable temperature limits. The heat transferred via the coverage building and the poor passive design of the construction are the main points for the discomfort conditions of the occupants in an on- air conditioned house or structure (Vijaykumar et al., 2007).

The hot climate is one of the main energy consumption methods in the world mainly in developing countries located in the middle east, the houses in such areas demonstrate high amount of energy consumption principles because of their high dependency to the air conditioning (AC) to provide comfort conditions for the residents of the building that in turns stimulates the emission of high amounts of greenhouse gasses (GHG) to the atmosphere, influencing the environment at regional global levels (Sarier & Onder, 2007). it demonstrates some various barriers to technologies to decrease the energy consumption rate. The passive design method is reliable generally for all the hot climates in the word. A major share has been referred to the building sector with main focus on the important role of the building productivity and green materials play in decreasing the energy consumption and CO2 emissions (Rehman, 2016).

2.3.1.1 Reduction of Energy Use for Thermal Comfort by Use of Passive Buildings Strategies

Thermal balance in the buildings with passive design method pertains to three main elements:

- solar gains,
- indoor loads

- their relevance to the Environmental Heat Sink on the outer area

The success of a building with passive design method maintaining thermal comfort is the consequence of a fine tuned balance between these three elements. If one of these three elements performs outside of the expected conditions, then thermal comfort is not gained. Passive buildings depend on natural heat flux (Pacheco & lamberts, 2013).

Regarding the very low external temperatures for the building′s insulation, indoor heat loads will not be appropriate to provide an indoor temperature at comfort levels based on (Feist et al., 2011). Unlike, if the outside temperature is higher than the expected rate, then the heat flux towards the outside area decreases, lead to overheating of the building as the heat stacks inside and producing internal temperatures higher than the comfort conditions, as the results of Passive On (2011). Overheating of highly-insulated houses can occur in hot climate areas (Jelle et al., 2010). Feist et al. (2011) demonstrated a new description that as being effective in that a house with passive design is referred to a building in which thermal comfort conditions (as defined by the ISO 7730) is gained merely by utilizing the post-heating or post-cooling methods of the fresh air mass requested to obtain the appropriate inside air quality conditions (DIN 1946)—without any need to the circulation the again. This new description contains both the need for cooling and heating methods and also does not propose specific objectives for the energy consumption or air infiltration.

(Lechner, 2009) recommended three levels of a sustainability design methods of heating, cooling and lighting building.

1) First, a primary building design should have covered with heat retention, rejection and avoidance.

2) Second, the natural energies and passive methods should be used this involve a direct solar gain for cold climate, ventilation condition and day lighting for warm climate regions.
3) Third, the mechanical and electrical equipment should be regarded as much as possible.

In summary, the building design and the application of building material as well as surrounding management are the main elements to gain an energy efficient building.

- **Energy Efficient Building Envelop Design**

The role of the envelope in a building is to provide a shield against extreme ambient conditions. It is responsible for thermal, visual and vocal comfort of the occupants. Considering the energy and environmental issues in recent decades, building envelope should also be designed in a way that reduces the load on the heat, ventilation and air conditioning (HVAC) system. The selected construction material and heat isolation features of the envelope are influencing factors in energy saving properties for HVAC (Al-Sanea et al., 2016).

It is clear that the extent of outdoor harsh conditions varies based on the geographical location of the building (Al-Tamimi et al., 2011). In hot regions, for instance, long hours of sun exposure on the envelope during the days of summer increases the HVAC load. In order to save energy, it is crucial to protect the interior space from this extreme heat gain. However, the use of natural lighting for energy efficiency in lighting sector should also be considered. Accurate design of the building orientation, material selection for the envelope, shading devices, and planting trees in the surrounding open space are some of the widely used strategies to avoid the solar heat gain.

Although these approaches are useful in different climate types, they have proved to be more essential in hot regions. By Santamouris efficiency of these heat avoidance techniques in tropical climate with extreme sun radiation has been proved. Performance of blinds for reducing heat gain through windows is also addressed in the literature (Al-Tamimi et al., 2011). A combination of different strategies is the best solution to design a promising envelope.

One of the factors which is influenced by the envelope design is thermal comfort. Standards of comfortable thermal ranges are not fixed for all the climates but depending on the people's life styles, culture, ambient weather, and humidity may vary. More precisely, the comfortable range is the temperature at which people do not feel cold or hot but comfortable doing their daily activities. As people's preferences have impact in the range, the majority voting or average range is considered to define the temperature range of comfort (Mirrahimi et.al, 2016).
As a matter of fact, building envelope constitutes of different architectural elements that maintain the interior space microclimate at an acceptable condition at any exterior climate status. These components include facade, thermal mass, heat isolation, sound proof mechanisms, roof, foundation and floor, openings and shading devices installed outside the windows (Sadineni et al., 2011).

Reducing energy consumption must urgently be sought typical in regions of harsh climatic conditions with extreme hot and cold climates that Energy requirement for cooling and heating of buildings is responsible for nearly 50% of the total electric energy consumption (Al-Sanea & Zedan, 2011). Therefore, building envelope is one of the most important design variables for effective energy conservation, building components (especially walls and roofs) must be designed to operate as passive systems over the lifetime of the building.

In general, the components of building envelope can be classified into two categories: opaque elements and transparent ones. Walls, roof, floor and door which block the light are the opaque components while glass doors, skylight and windows are transparent envelope elements. The hierarchy of the design components constructing the envelope is represented in Figure 6.

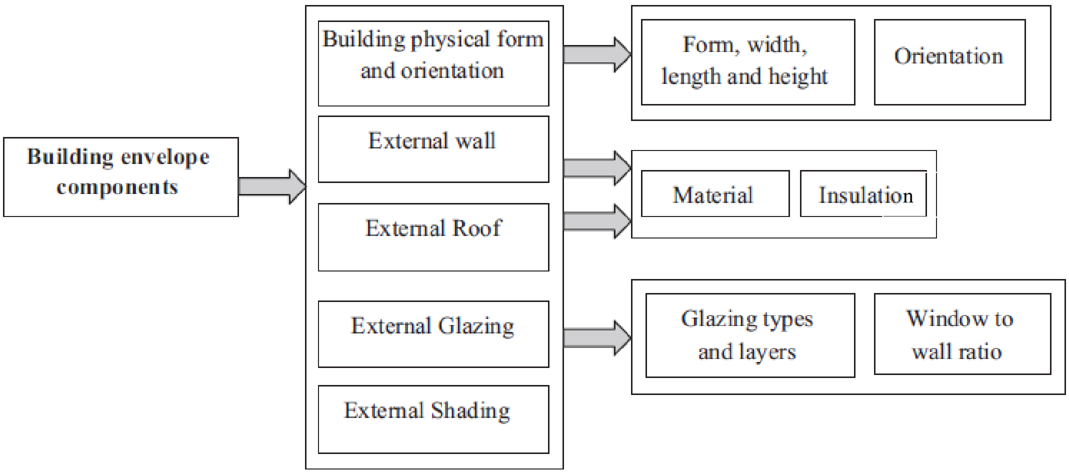


Figure 6 : The architectural components of the building (Mirrahimi et.al, 2016).

In hot climate, the opaque parts of the building absorb a significant proportion of the total heat gain. In a study conducted on a 12-story building located in Singapore (tropical climate), it has stated that roof and walls are responsible for 11% and 19% of the total heat gain in the building (Chua, 2010). These findings suggest that the opaque components of the building have a significant share in the heat gain (30%). The considerable energy consumption load induced on the cooling system by the opaque parts is also confirmed in other studies.

In another study the building envelope has been found responsible for 73% of the heating and cooling energy consumption (DoE U.Buildings energy data book, 2011). As the envelope components including windows, facade, and roof are exposed to the solar radiation, the design of this components have a considerable impact on thermal and energy efficiency

In literature, the following five different ways have been recognized as the heat and mass transmitting methods in buildings (Sabouri, 2012):

- Heat conduction and solar radiation through transparent elements
- Heat conduction over opaque components
- Incoming ambient air and air transferred between close interior spaces
- Moisture and heat generated by the occupant's activities including their bodies, home appliances, electrical equipment and artificial lighting
- The heat and moisture transferred the HVAC system

A.1 Wall (Together with Opening)

As the largest area of the building which is in touch with the exterior space, walls p-lay an important role in energy efficiency of the building. These architectural elements should be designed appropriately to provide thermal, visual and sound comfort considering aesthetic aspects. In tall buildings, walls comprise the largest proportion of the envelope and thus their thermal features influence the energy consumption level to a great extent. Thermal insulation performance of materials is evaluated by R-value or thermal resistance. The wall construction material as well as dimension define this value in the building. (Sadineni et al., 2011).

Different technologies are available in building sector for wall thermal insulation and design. The main purpose of the majority of them is to improve the functionality of the walls by decreasing heat loss during winter and heat gain during summer. This is the fundamental challenge in reducing energy consumption for the HVAC system.

Trombe Walls

Solar Heating Wall (SHW), also called storage wall is the term that was firstly introduced in 1881 by Edward S. Morse (Annamaria et.al, 2012). Later, this technology was improved in engineering domain by a French man named Felix Trombe from whom the wall had got its name. A French architect, Jacques Michel worked also on SHW to utilize it in construction sector. However, the commercial version of the Trombe wall was firstly used in 1960s when it was used in the construction industry (Omrany et al., 2016). Structure of the Trombe wall is shown in Figure 7. The wall has thick vertical structure built with concrete, stone or brick. The exterior surface is colored in black and mounted close to glazing.

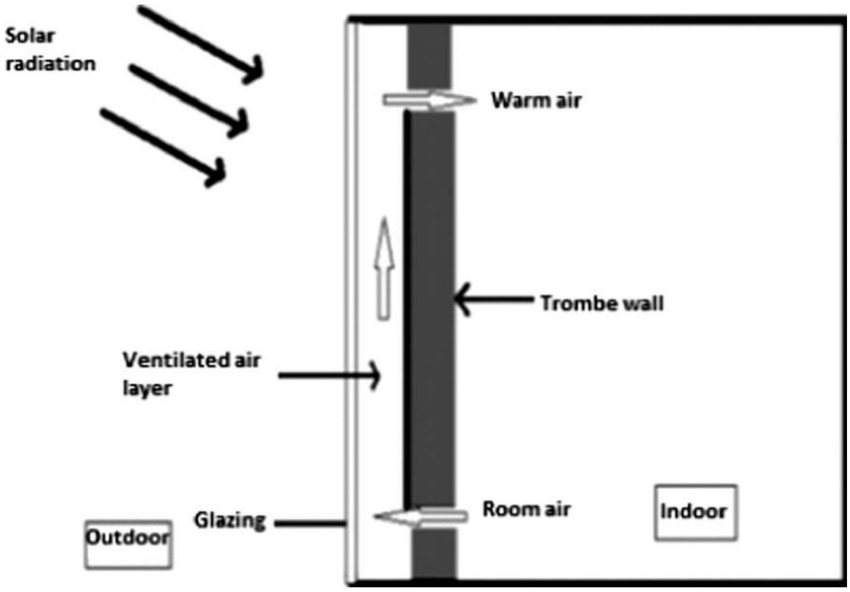


Figure 7 : Functionality of the Trombe wall (Omrany et al., 2016).

In the space between the glazing and the black surface of the wall a solar chimney is formed which transfers the heat into the building by convection. Heat is also conducted vertically by the wall mass and heats up the interior space by conduction and radiation. One of the most important benefits of the Trombe wall is that it works as a heat capacitor. Heat energy is accumulated in the wall mass during the day and then released to the building during the night. This property is crucial in hot deserts with hot days and cold nights. As shown in Figure 8, the modern design of the wall has a space between the glazing and the wall mass that absorbs heat. The two ventilation hatches produce the solar chimney effect. During summer these vents can be covered by dampers.

The design of the wall makes it an effective thermal element during winter. During the day, the wall mass absorbs the solar heat; this heat is released to the interior space gradually at night. In addition, the temperature difference causes a natural ventilation draft between the funnel and the interior space. The solar radiation energy is transmitted through the glass to the dark mass of the wall. In the hot season, the air draft can increase interior temperature and this the vents are kept closed to avoid heat gain (ESE & Matoski, 2013).

The dimensions of the Trombe wall's parts are vital in the design since they affect its thermal performance. The heat loss through the glass varies with the size of the space between the glazing and the wall mass. Moreover, the convection draft in the chimney is affected by the width of the funnel. The width for the chimney should be more than 3 cm and less than 6 cm to guaranty appropriate function (Anderson, 1985).

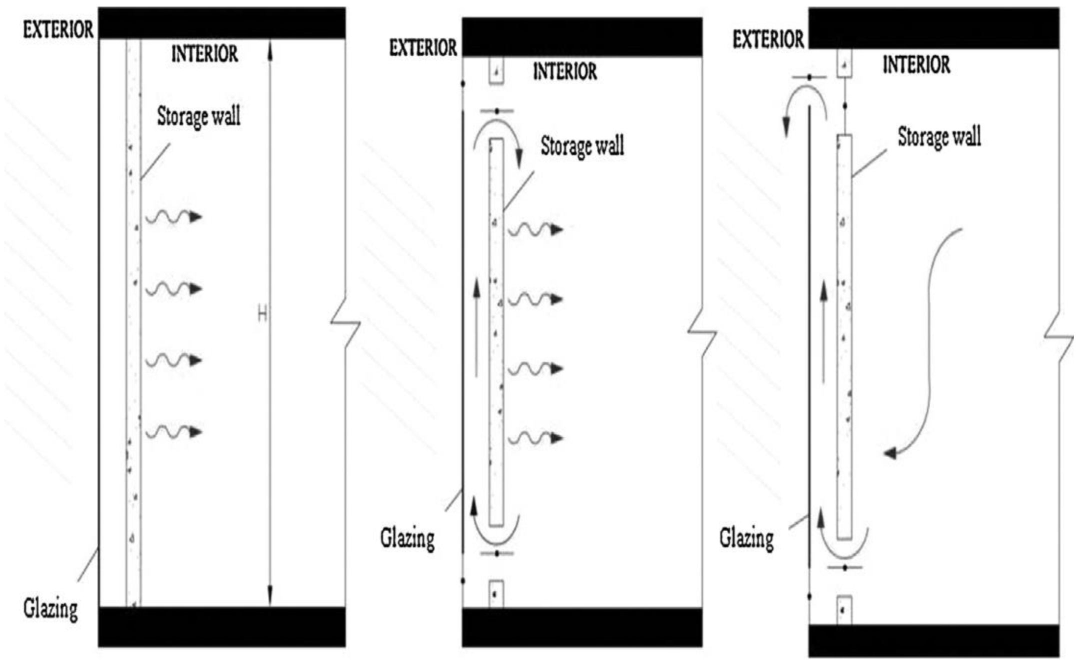


Figure 8 : Primary layout of Trombe wall (left); Trombe wall with vents in cold season (center); and in hot season (right) (ESE & Matoski, 2013).

The thermal performance of the Trombe wall during the winter is studied by (Bolaji & Huan, 2013).Two Trombe walls were constructed in the south-facing facade of the house and the energy consumption was estimated. The results have shown that Trombe wall reduces yearly energy usage by about 20% compared to conventional walls.

The subject is also investigated by Koyunbaba and Ulgen (2013) but using a photovoltaic Trombe wall. The integrated photovoltaic wall was assessed in terms of thermal performance and mean electrical energy consumption during the day. The tested building is located in the city of Izmir, Turkey. The photovoltaic Trombe wall installed in the facade of a room has decreased the electrical energy demand by 4.5% and enhances thermal performance by 27.2%.

In (Tunc & Uysal, 1991) an innovative configuration for the Trombe wall named 'fluidized' wall has been represented. As illustrated in Figure 8, the space between the glazing and the wall mass was filled with low density particles with highly absorbing characteristic. Circulating fans transfer the energy accumulated in the particles to the interior space. However, a purifying system is necessary to avoid the particles from entering the resident's interior. It has implied that this novel layout has higher thermal efficiency than conventional Trombe wall.

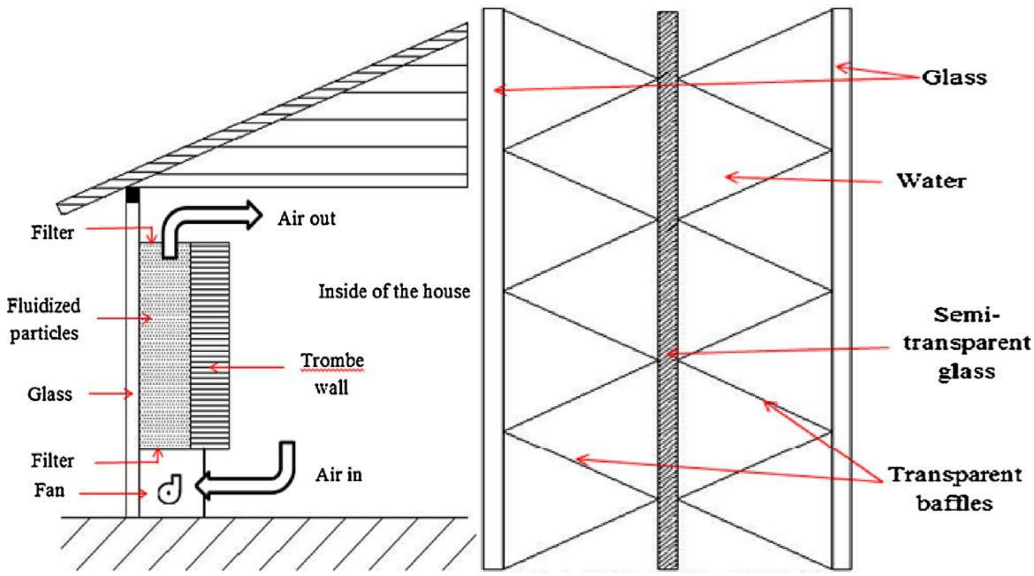


Figure 9 : A cross-sectional view of Transwall system (Nayak, 1987).

Another novel configuration for the wall is known as ‘transwall’. In Figure 9, the wall cross-section is illustrated. As shown in the figure, the wall has two glass panels with metal framework and the space between the plates is filled with water. A semi-transparent glass panel is also installed between the transparent panes to absorb part of the solar radiation and provide privacy. Hence, the wall is capable of providing heat and daylight for the building simultaneously. In fact, water and semi-transparent pane capture part of the solar energy and the rest is transferred to the interior space for heating and lighting (Nayak, 1987).

Autoclaved Aerated Concrete (AAC) Walls

The technology used in ‘Autoclaved Aerated Concrete’ wall is a noncombustible material firstly introduced in the 1920s as an alternative for cement in construction sector. This cement-based material is a combination of cement, silica, quick lime, gypsum, and aluminum powder mixed with water to form a paste (Omrany et al., 2016). Because of exceptional thermal and mechanical characteristics and great feasibility in construction process, ACC has become an essential element in modern architecture. From environmental perspective, AAC is recognized as a sustainable construction material.ACC promising features have been listed as relatively low density, low contraction, high thermal resistance, fire resistance and simplicity of application in construction process. It has also implied that ACC is easy to shape; it is light and thus easy to transport; it is sound proof and transpiring.

Energy saving properties and thermal comfort performance of ACC is widely investigated in literature. In Kuwait, Al-ajmi has studied six mosque buildings equipped with air-conditioner in hot season in terms of thermal comfort (Al-ajmi, 2010). Particularly, the performance of ACC walls is analyzed and it has stated that ACC walls provide thermal comfort as efficient as heat insulation mechanisms.

ACC walls impact of energy consumption has been evaluated by Radhi in buildings located in UAE. According to the experimental results, ACC walls reduce energy consumption by 7% compared to conventional walls. Further analysis also revealed that in the life cycle of each unit square meter of ACC wall, approximately 350 kg less greenhouse gas is emitted. In general, excellent properties of ACC make it a smart construction material for walls. Thermal comfort, sound comfort, energy efficiency and environmental sustainability are improved by utilization of this technology (Al-ajmi, 2010).

Double Skin Facades (DSF)

DSF has been defined as '*a special type of envelope, where a second skin, usually a transparent glazing is placed in front of a regular building facade*'. The space between the two skins or the 'channel' is ventilated either naturally or mechanically. Channel ventilation is necessary both in cold and hot season for energy saving in heating and cooling system respectively. Although the primary concept of DSF was represented in 1990s, till recent decade it was not widely used in building sector (Omrany et al., 2016).

Particularly, DSF is a facade with multiple glazing and a cavity space which generally has a ventilation mechanism (Chan et al., 2009). In the naturally ventilated channel, stack effect works to produce the air movement. It is also possible to use mechanical ventilation or a combination of both. The two skins differ in terms of glazing. Generally, the exterior one is a single fully glazed skin. On the other hand, the interior side skin is a double glazed and not necessarily fully glazed. The channel width can vary in the range 2 cm to 200cm (Chan et al., 2009). The advantages of utilizing DSF in buildings can be summarized as transparency (view to the exterior), visual comfort (daylight with low glare), aesthetically attractive, electrical energy saving, improved thermal comfort (natural ventilation).

Conversely, DSF technology has also some drawbacks including high weight (extra load to the design), being expensive (installment and maintenance), risk of thermal discomfort in summer (overheating), and complicated design (Omrany et al., 2016).

DSF Energy Performance

DSF effect on energy saving is investigated by Chan in an office building located in Hong Kong (Chan et al., 2009). The DSF used in the facade was consisted of a single glazed plate at the interior and a double glazed pane with reflection features at outer side. It is stated that DSF can decrease the energy demand for cooling by about 26% compared to ordinary single pane walls.

Another study by Xu and Ojima (2007) was conducted in the city of Kitakyushu, Japan on a 2-story building. A comprehensive study and measurement has performed in summer, autumn and winter in the building equipped with DSF. The stack effect in hot season, the passive air-conditioning in autumn and the CO_2 emission in winter were analyzed. Energy saving potential is also evaluated. According to the reported results, DSF cuts up to 15% of the energy demand for cooling in hot season. In cold season, up to 30% energy is saved because of the greenhouse effect produced by DSF (Xu & Ojima, 2007)

A hybrid system based on Photovoltaic DSF and automatic shading device has been proposed in Charron and Athienitis (2006). Theoretical evaluations have shown that the proposed layout saves approximately 60% of electrical energy in the building. Additionally, the motorized shading device installed in the channel improved visual comfort.

In general, DSF is widely used in today's construction industry since it provides heating and natural lighting for the building. Considering the energy saving properties of DSFs, high cost of installment and maintenance do not work as a barrier for its popularity.

Green Walls and Roofs

Green facade including green walls and green roofs are the environmental friendly strategies to improve the thermal comfort and energy efficiency in the buildings. In large cities with small implantations, these green mechanisms enhance the aesthetic features of the city, improve the air quality, moderate the acoustic artifact and increase sustainability protections. Particularly green walls can replace horizontal gardens in urban regions where the space is limited (Virtudes & Manso, 2011).

There are different names mentioned in the literature for green walls including 'Biowalls', 'vertical gardens', 'vertical greenery systems' 'vertical greening systems', or 'green vertical systems'. Although the term seems a modern concept, utilization of green walls in building is dated back to the 5th era. The very first green walls appeared in the central parts of Europe and the UK, but today everywhere around the world you can see them. In Germany and Switzerland for instance, 10% and 70% of the building roofs in cities are green respectively. Asian countries like Singapore, Japan and Hong

Kong are the leading countries for using green walls and roofs. According to the standards established in Apr. 2000 in Tokyo, the new buildings which are larger than 1000 square meters must have green roofs (Environment Preservation Bureau Tokyo Metropolitan City, 1999).

The effect of green walls on air-conditioning load has been addressed in a study by (Price ,2010). The comprehensive measurements of the temperature of the ambient air, envelope, interior air, and the air draft have shown a reduction using a green wall facing south. In addition, with an appropriate building and green wall design, energy consumption for cooling can be reduced by up to 28% (Fong & Lee, 2014).

The degree of the improvement in energy consumption by green facade depends on the building size as well as the green facade scale. In tropical climate for instance, the impact of green walls is studies by simulation (Wong & Li, 2007). Three configurations including concrete walls, seven glass windows in each wall, and full glass walls in a typical 10-story building were simulated. The findings proved the efficiency of the vertical green coverings. In opaque walls, vegetation covering reduces the heat transfer ratio. The solar heat gains of the fully glass wall also reduced by vertical green covering.

Figure 10 : Continuous green wall, Caixa Forum, Madrid (Fong & Lee, 2014).

Another interesting effect of green walls is their sound insulating feature. This characteristic has been studied by Azkorra who proved that green cover can be used as the sound proof mechanism in buildings.

In addition to the heat insulation performance of the green covering itself, the gap between the wall body and the vegetation also works as a heat insulator. It also blocks a considerable proportion of the solar radiation and the resulting heat gain. More precisely, the green wall reflects 5% to 30% of the solar light, transforms 10% to 50% into heat, and absorbs the rest for evaporation and photosynthesis. Consequently, just a small proportion is transmitted to the building facade (Fong & Lee, 2014).

The researchers also compare the effectiveness of green roofs and green walls on thermal comfort and energy saving. In fact, vertical gardens have been proved to be more effective than living roofs. However, it has been suggested that for the optimum result both strategies should be used. Simulation results have shown that this combination reduces the energy demand for cooling significantly (32% up to 100%) (Chen et al., 2013).

Briefly speaking, living facade is a mechanism that can be easily implemented for both new buildings under construction and the old ones. The effect of the green walls and roofs on the view of urban regions, wellbeing of the residents, and performance of the buildings has been recognized well. These systems are sustainable design elements to reduce energy demand and thus greenhouse gas emission.

Comparison of green facade with bare facade

In order to evaluate the performance of green walls and roof, it is essential to perform some experimental comparisons. In the hot and humid region of Wuhan, China, Chen et al. performed some experiments using 6 different types of vegetation coverings on green walls. Temperatures at two sides of the wall and the interior space are measured. The temperature of the outer skin of the wall is reduces by more than 20°C. In addition, the surface of the inner wall had a temperature 7.7°C less than bare wall. A 1.1°C reduction is also reported for the interior residential space. (Omrany et al.,2016 & Chen et al., 2013).

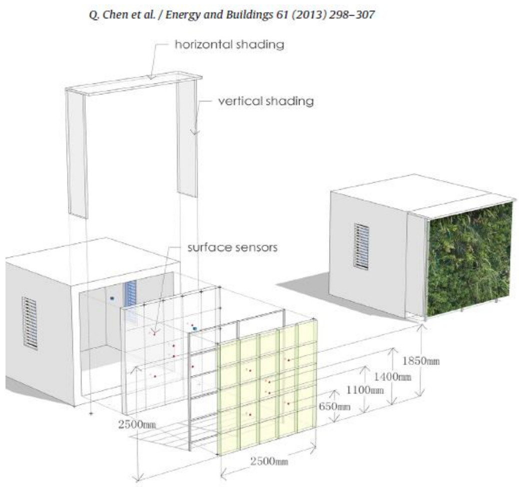


Figure 11 : A cross-sectional view of green wall (Chen et al., 2013).

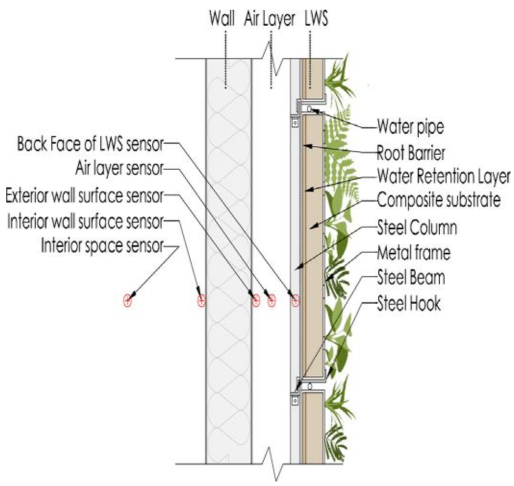


Figure 12 : The structure of the green wall and the pattern of sensors (Chen et al., 2013).

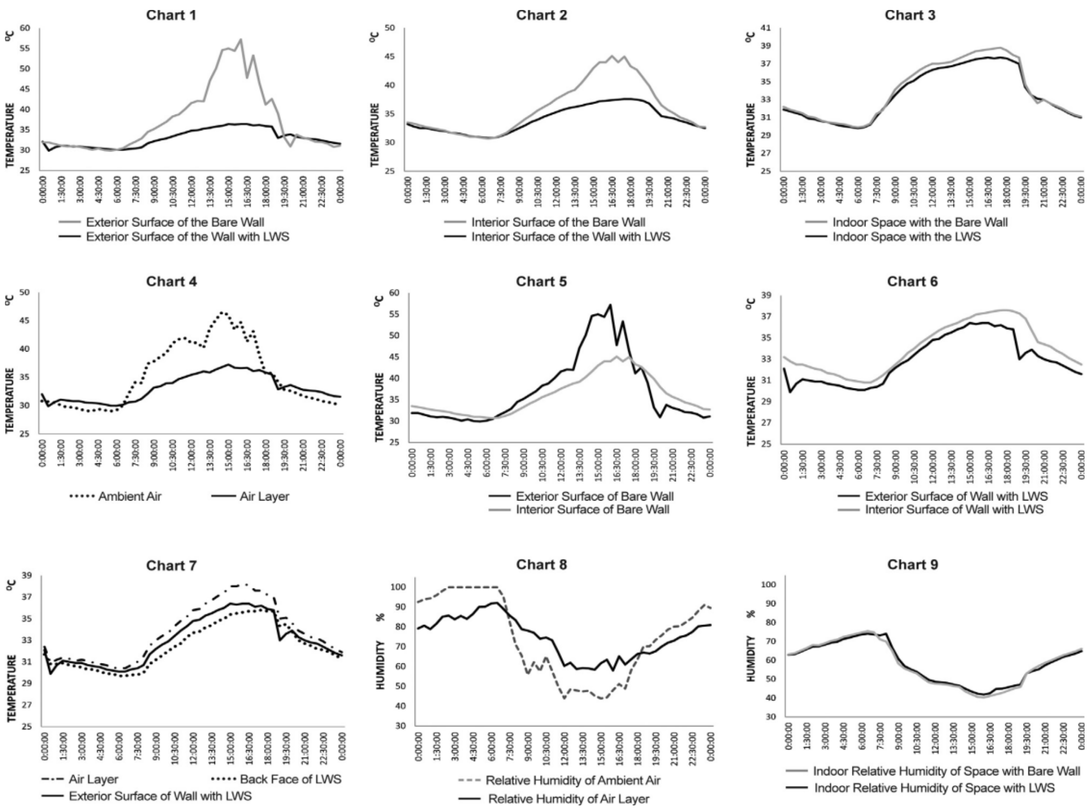


Figure 13 : Comparison between the living facade and the bare facade. (Chen et al., 2013).

In a research by Chen et al. the difference between the sealed air layer and the open air layer is investigated. According to their finding, sealed air layer reduces the temperature at external skin of the wall 1.76ºC more. For the inner surface however, the difference between two layouts is not remarkable (approximately 0.65 ºC) (Chen et al.,2013).

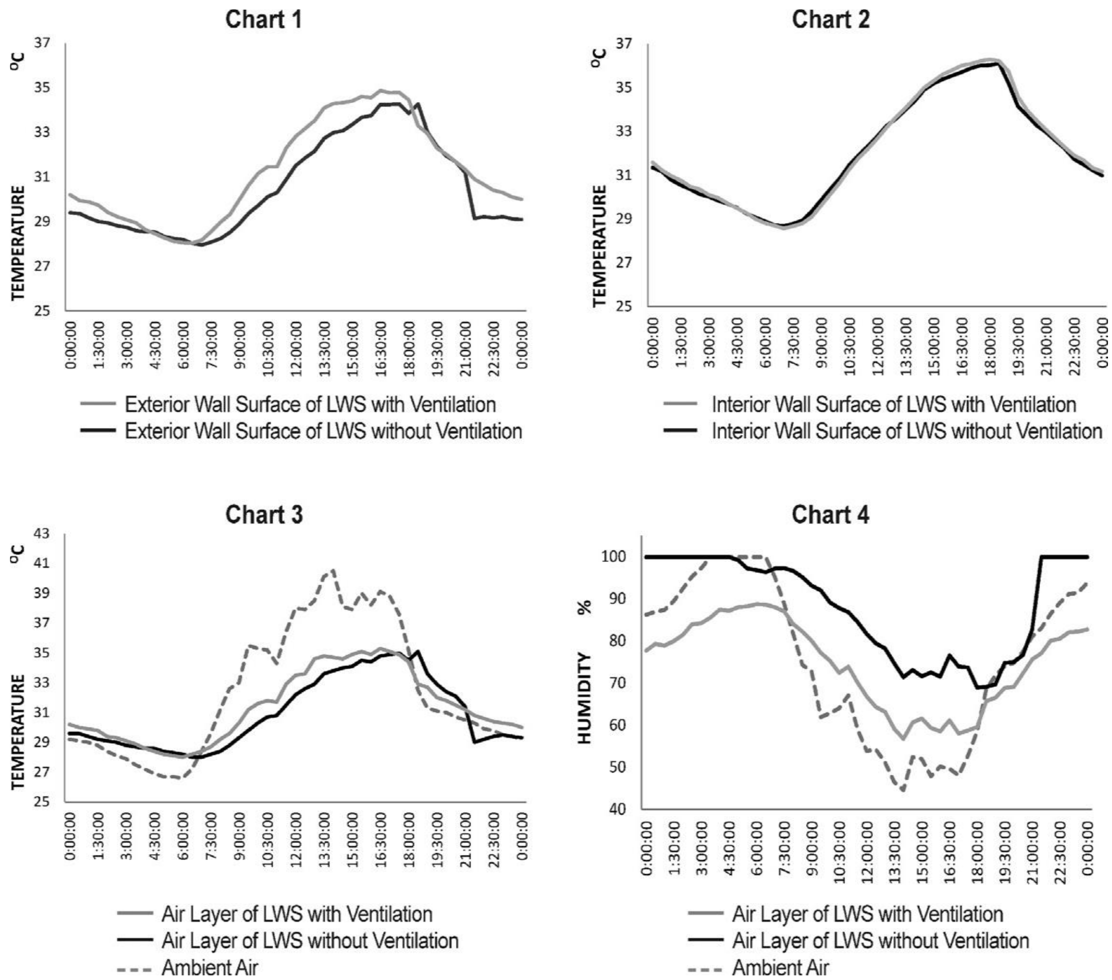


Figure 14 : Comparison between green facade with and without ventilation mechanism (Chen et al., 2013).

One of the concerns about living walls is the increased humidity because of the evaporation from leaves. As mentioned before, increased humidity affects comfortable temperature and this may induce an extra cooling load even in hot and arid region. Nevertheless, just the air layer adjacent to the wall may be affected by this phenomenon. Furthermore, the quality of the air in the gap between the living wall system (LWS) and the wall surface is of more importance as it influences the interior space air quality. In general, the relative humidity in this air layer is more steady and usually do not increase the humidity in the interior space (Chen et al., 2013).

According to the simulated experiments, unlike bare walls that absorb heat in hot season, LWS removes heat. Hence, green covering is a heat removal or cooling mechanism. Additionally, the performance of living wall with sealed air sheet is superior to that of naturally ventilated wall. The experiments on the effect of w-v-d have shown that for a smaller distance the humidity level is higher while the cooling effect is considerably stronger. Table 3 summarized the features of different passive wall layouts including LWSs in term of thermal efficiency and energy consumption reduction.

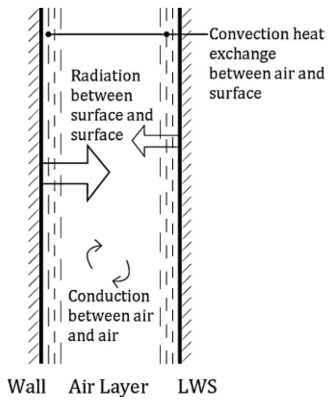


Figure 15 : Net energy flow directions among the air layer, wall surface, and the LW (Chen et al., 2013).

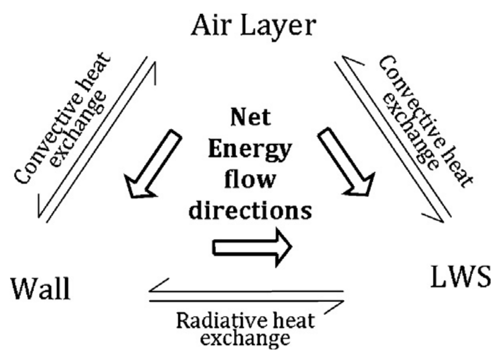


Figure 16 : The heat exchange conditions in the microclimate (Chen et al., 2013).

Table 3 : Pros and cons of different wall layouts (reference adapted from Omrany, 2016).

Typology	Advantages	Disadvantages
Trombe walls	• Capability to be integrated with new technologies such as PV systems. • Reduction of building's energy consumption, and decrease of moisture and humidity of interior spaces in humid regions. • The indoor temperatures are more stable than in most other passive systems. Prevention of excessive sunshine penetration into the inhabited space. • Installation is relatively inexpensive, where construction would normally be masonry, or for retrofitting existing buildings with uninsulated massive exterior walls. • The time delay between absorption of the solar energy, and delivery of the thermal energy to the living space can be used for night-time heating. • Trombe wall not only provides thermal comfort in the spaces connected to itself, but also contributes to the enhanced thermal comfort condition of adjacent spaces.	• In regions with mild winters and hot summers, overheating problems may outweigh the winter benefits. • In a climate with extended cloudy periods, without employing the adequate operable insulation, the wall may become heat sink. • Trombe walls have low thermal resistance causing to transfer the heat flux from the inside to the outside of a building during the night or prolonged cloudy periods. • The amount of gained heat is unpredictable due to changes occur in solar intensity. • Trombe walls are esthetically appealing.
AAC walls	• AAC walls are lightweight concrete, and fire resistance. • Reduction of energy consumption. Ease of construction, transportation and installation. Environmentally friendly. • Lower thermal conductivity, lower shrinkage; ductility; acoustic insulation properties and transpiring properties. • Porous structure resulting in lower density and compressive strength compared to normal-weight concrete. • AAC can be introduced as a green masonry material due to its properties.	• Production cost per unit for ACC is higher than other ordinary concretes. • AAC is not as strong as conventional concrete. • According to the Portland Cement Association [105], ACC has an allowable shear stress of 8–22 psi, and a compressive strength of 300–900 psi. However, conventional concrete has a shear stress closer to 40 psi, and a compressive strength of 1500 psi. • The process of autoclaving concrete requires significant energy to be consumed, by which environmental demerits will be involved in its application.
Double skin walls	• Provision of sufficient visual connection with the surroundings. • Facilitation of entering a large amount of daylight without glare. • Offering attractive esthetic values. • Promotion of natural ventilation, and thermal comfort without any electricity demand. Reduction in building energy consumption. • Acoustic insulation.	• Higher cost for designing, constructing, maintaining compared to the traditional single façade. • Increasing the weight of building's structure due to the application of this façade. • Risk of overheating during sunny days can be increased. Complicated process of designing. • Additional maintenance and operational costs. • Increased airflow velocity inside the cavity. • Potential issues associated to fire propagation.
PCMs wall systems	• *Organics*; availability in a large temperature range. • Freeze without much super cooling. • Ability to melt congruently. • Compatibility with conventional material of construction. • Chemically stable. • Recyclable.	• Low thermal conductivity. • Low volumetric latent heat storage capacity. • Flammable.
	• *Inorganics*; High volumetric latent heat storage capacity. • Low cost and easy availability. • Sharp phase change. • High thermal conductivity. • Non-flammable.	• High volume change. • Super cooling. • Segregation
Green wall systems	• Enhancing building esthetics. • Improving the acoustic properties. • Reduction of heat gains and losses. • Ability to be integrated with existing buildings.	• Providing a living environment for mosquitoes, moths, etc. Requiring significant, and consistent maintenance measures. • Water drainage can be involved in complexities, and difficulties.

Wall Implanted with Heat Pipes (WIHP)

The technology of 'Wall Implanted with Heat Pipes' (WIHP) was proposed and studied by(Zhang et al., 2005) as a novel method for using solar radiation in a passive way. WIHP is fabricated by small microgravity piped embedded in the snap of plaster outside of the insulation panel. The evaporating segment is installed in the cement plaster of the internal surface. As the implanted pipes are microgravity heat pipes, the thickness and the strength of the wall do not change with this mechanism. Figure 15 illustrates the structure of the WIHP.

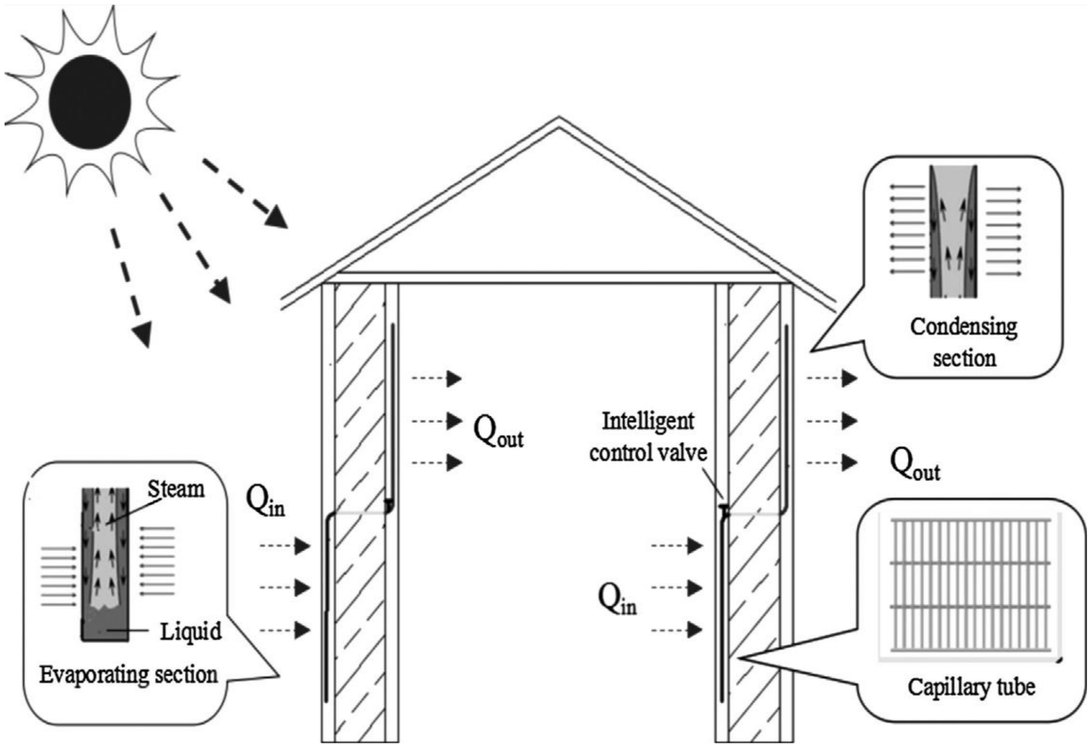


Figure 17: Structure of WIHP (Zhang et al., 2005).

According to the evaluation studies, WIHP has exceptional feasibility and energy saving performance. In (Zhang et al. ,2005), it has shown that the hating loss in cools season is reduced by about 14.5% compared to conventional walls without heat pipes. In general, WIHP enhances the heat transfer and heat capacity of the wall. Inside temperature increases using this technology which means lower energy consumption in heating system. Feasibility and efficiency of this innovative technology have been proved in previous research.

Thermal Insulation

For both cooling and heating system, efficient heat insulation is a required to save energy. In hot climate regions, the heating system consumes a significant proportion of total annual energy as a result of solar radiation heat gain. Thus, solar insulators are the most effective passive energy saving elements in buildings (Rehman, 2016).

In general thermal insulation is installed in the facade facing exterior in order to reduce the cooling load in summer and heating load in winter. The aim is to decrease the heat transfer and save energy in a cost effective way. Consequently, the optimum thickness of the insulation is defined by the total cost including the cost for installing insulations and the energy cost during the life period of the insulation system. Therefore, a thicker layer of heat insulation is not essentially the better choice (Al-Sanea &Zedan, 2002). Generally, thermal insulation is recognized as one of the most effective strategies for energy saving at reasonable cost provided that optimum design is considered.

In a study conducted in Greece, energy saving performance of different insulation strategies were evaluated (Balaras et al., 2000). It has stated that facade with thermal insulation saves on average 30% of energy. Low penetration mechanisms on the other hand, reduce energy by 20%. Similarly, external shading devices have proved to reduce energy demand by 20% while light color exterior facade only decrease it by 3% on average. Another interesting fact was revealed in Rattanongphisat’s study that just using thermal insulation on the walls reduces 28% of the energy demand (Rattanongphisat & Rordprapat, 2014).

Thermal resistance factor (R-value)

A quantitative measure for the efficiency of the heat insulation materials is the 'thermal resistance (R-value)'. A building facade with larger thermal resistance transfers less heat. In fact, an envelope with high R-value is more expensive but more energy efficient. As mentioned before, the thicker the envelope is, the larger the thermal resistance will be. Thus, the optimum insulation thickness is designed considering the thermal comfort of the occupants in addition to the total cost including the cost of insulation and energy expense during the life period of the insulated envelope (Al-Sanea rt al., 2016).

In addition to R-value of the insulation, climate condition, interior thermal setting and the envelope configuration also affect the rate of heat transfer. Solar radiation intensity, humidity level, wind speed and temperature of the ambient air are the influential factors of climate on the heat transmission rate. The radiation properties (reflection and absorption features) of the exterior surface of the envelope also play significant role. There are some other important factors in defining the optimum thickness of the insulation panel including the age of the building, efficiency of the air-conditioning/heating system, the price of insulation materials, cost of energy and some other economic matters such as inflation rate (Al-Sanea et al., 2016).

It is notable that the function of thermal insulation differs from thermal mass which has the heat capacity properties. Insulation is a time lag mechanism that delays the rate of heat transfer unlike heat storage materials that preserve heat and release it afterwards. However, the impact of insulation on slowing down the rate of heat exchange has been proved to be similar to thermal mass. The interactive performance of thermal mass and thermal insulation depends on their relative positions. (Al-Sanea & Zedan, 2011).

Optimized thickness of insulation in building

As stated in the previous section, finding an optimized thickness for thermal insulation is an economical procedure of estimating the total cost. The initial cost for insulation materials and the expenditure on energy in the building during the life time of the insulation are estimated for this purpose. In order to find the best thickness firstly, the annual transmission load is investigated. Then, the cost analysis is performed considering the local climate conditions. Generally, the type of material utilized in insulation is more crucial for annual transmission load than the layout of the wall (Al-Sanea et al., 2016).

The impact of wall orientation on heat transfer load and transmission delay has been investigated in (Al- Sanea and Zedan, 2002). Wall orientation does not affect optimum width (Lopt) as remarkable as transmission load. Based on L_{opt}, the wall orientation facing south reduces annual load by 12% while western-faced wall resulted in only 5% reduction.

The yearly heating load of the walls has been investigated by the heating degree-days concept. Bolatturk conducted the study in different climate zones in Turkey and evaluated L_{opt} for different fuel types. It has been mentioned that depending on the climate condition and the frequently used fuel, the energy demand is reduced by 22%

up to 79%. The estimated duration of the payback is reported to be 1.3 to 4.5 years (Bolatturk,2006).

Configuration of Insulation Layer

As the thermal insulation and thermal mass interact during unstable thermal conditions, the thermal characteristics of the wall are profoundly affected by the relative position of these two elements. The position of insulation in mass was studied by (Al-Sanea and Zedan,2011). In their study, the optimum thickness of single-layer, double-layer and triple-layer thermal insulations have been investigated. For the single layer one, the position of insulation was changed and its effect on energy saving performance has been studied. Results revealed that changing the relative position of insulation layer in thermal mass has no effect on its optimum thickness. In addition, it has been stated that the optimum thickness of the single layer insulation is equal to the total thickness of multiple layer ones.

While the result showed that the R-value of the wall is the same at optimum thickness for all configurations, furthered measurements implied that other thermal parameters may significantly change. The transmission load, time delay, and the reduction coefficient which also define the thermal performance are influenced by the layout of the insulation. Particularly, the triple-layer insulation has been found as the most efficient layout with three 26 mm thick insulation layers. In this optimum configuration, the position of the layers is at exterior, middle, and interior surfaces of the wall. The second optimum layout was a wall with two 39 mm thick insulation layers installed at exterior surface and middle of the thermal mass. The best performing wall improves the time lag by 100% compared to a one-layer wall having a 78 mm thick insulation at interior surface. The maximum heating and cooling transfer load is reduced by 20% and there is also a reduction in annual energy demand for heating/cooling.

In a case study conducted in three different extreme climate regions of Saudi Arabia (Jeddah, Riyadh and Abha), three different insulation materials and their optimum thermal resistances have been evaluated by (Al-Sanea et al., 2016). Two different wall layouts (single and double) made of brick and concrete were studied to define the optimum width (L_{opt}). Utilized insulation materials included polyurethane panel, cast polystyrene, and rock wool. The results of economical and thermal analysis were as follows.

Firstly, climate and insulation type have a significant effect on optimal thermal resistance, heat transmission load and the expenditure while the wall layout (one or two layer) are not so influential. Particularly, regardless of the climate type, polystyrene provides the minimum total cost and payback period for both wall layouts. W_3 and W_4 wall layouts are the best wall configurations for maximizing R-value. Rock wool ranked two and polyurethane is the poorest one. The payback durations at optimum thickness vary from 3 years to 10 years depending on the configuration and climate condition. It is notable that in practical applications, thermal resistance of the wall is also affected by the thermal bridges implemented in the walls.

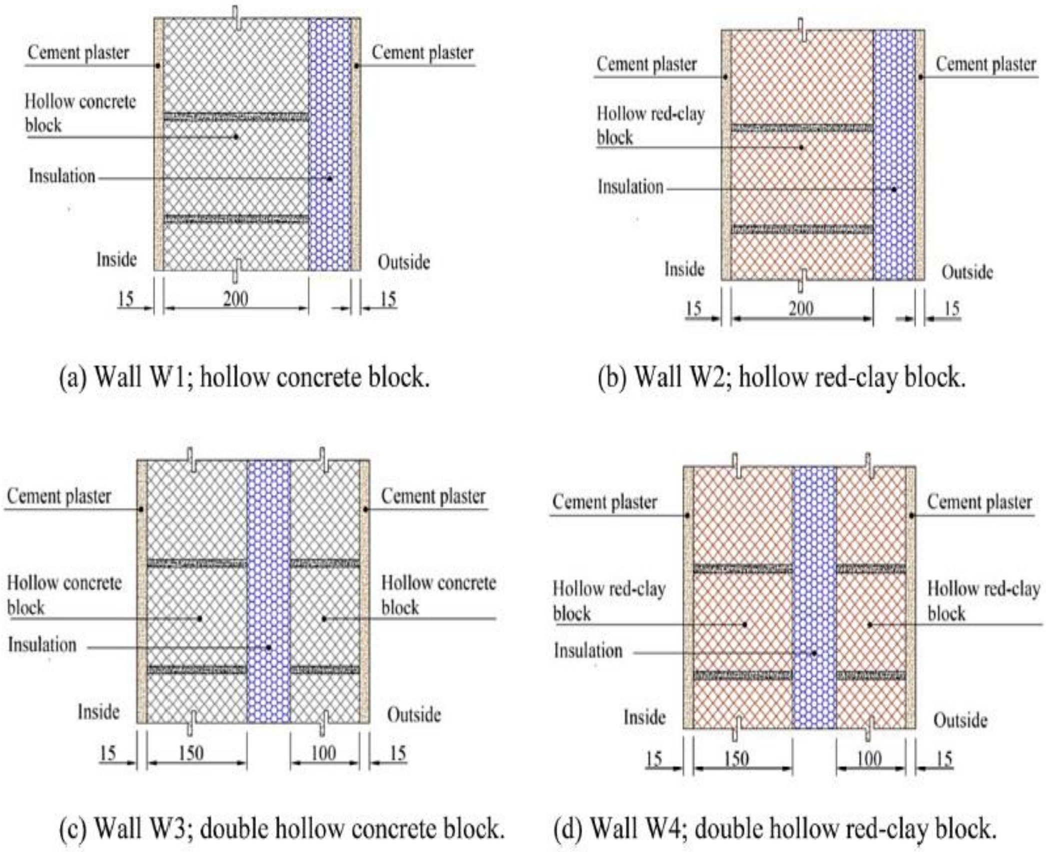


Figure 18 : Wall configurations investigated (W1 through W4, dimensions in mm); (a)Wall W1 (hollow concrete block), (b)WallW2 (hollow red-clay block), (c)Wall W3 (double hollow concrete block), and (d) Wall W4; double hollow red-clay block.S.A. (Al-Sanea et al., 2016)

Openings (windows and doors)

Openings or fenestration are the windows and doors in the building façade. Windows and doors are the influential elements of the building from thermal and visual perspective. They are also crucial for the exterior view of the occupants as well as aesthetic properties of the design. The importance of thermal and visual comfort in the building in addition to sustainability concerns have resulted in emerging technologies in glazing. Glazing for controlling Solar radiation, glass with insulation property, low emissivity (Low-E) glass, aerogels, evacuated double glazing, and double glazed windows filled with gas are the commercial modern glazing technologies (Sadineni et al., 2011).

The application of the glazing defines the characteristics of the selected technology. In cold climate where passive heating is favorable, the window should transmit solar radiation into the interior space (high solar transmittance) and have low thermal conductivity (low U-value). However, these two parameters are negatively correlated and the features of the glazing needs to be optimized considering both measures (Robinson & Hutchins, 1994).

In hot climate and for natural lighting, Low-E glazing is more appropriate since it transmits visible spectrum while stops the other wavelengths such as infrared. Consequently, the heat gain form solar radiation is reduced while daylight is integrated in the lighting system. Low-E glazing is installed in the interior surface of the external pane so that the absorbed heat is transmitted to the external space (Robinson & Hutchins, 1994).

A comprehensive study conducted in five climate regions around India, compared the energy efficiency of the 10 glazing technologies (Singh Garg, 2009). It has been concluded that in addition to the window properties such as U-value and g-value (solar heat gain coefficient), there are other factors that influence the energy efficiency of the building. Orientation of the window, climate conditions and the thermal characteristics of the design have also impact on the energy consumption.

Aerogel glazing

Aerogel glazing is a modern technology as a form of 'mesoporous solid' with a volume porousness larger than 0.5. Density of this open celled solids varies from 1 kg per square meters to 150 kg per square meter. Normally a great proportion of the volume (up to 99.8%) constitutes of air. Different materials including 'silica, alumina, lanthanide and transition metal oxides, metal chalcogenides, organic and inorganic polymers and carbon' can be utilized for fabrication of aerogels. This technology commercialized in building sector in year 2006 to use an excellent design element for roofs with daylight integration. In fact, an aerogel glazing is constituted of tow polycarbonate panes with grainy aerogel filling. This configuration is 80% lighter than conventional glass while 200 times stronger. According to this property besides light transmission feature aerogel glazing has been widely used in roof lighting systems (Bahaj et al., 2008).

Double Pane Vacuum Glazing

In vacuum glazing windows, the gap between the two plates is evacuated from air making a vacuum space with U-value smaller than 1 W/m^2 K. Thus, the heat transfer rate for vacuum glazing is very low making it a smart alternative for heating/cooling load reduction. In hot regions, one or both glass panels are coated with Low-E glazing to decrease solar radiation heat gain (Sadineni et al., 2011). Preserving zero pressure vacuum gap is not possible for a long time though. However, this technology has been being is use for energy saving in recent decade (Bahaj et al., 2008). Innovative design strategies such as using three layered vacuum glazing have been proposed that improve U-value as low as 0.2 W/m^2 K is achievable (Sadineni et al., 2011).

Switchable Reflective Glazing

The technology of variable transparency glass has been emerged to be used in hot climate regions to reduce energy demand for cooling system. Switchable reflective glazing controls solar radiation at daily peak while it is feasible for daylight integration. The core technology in switchable reflective glazing is variable optical features controlled either by hydrogen or low electrical voltage. The former is known as gasochromic glazing while the latter is called electrochromic. In some other forms, solar reflective property is controlled by switchable light helves (Bahaj et al., 2008). In (Papaefthimiou et al., 2006), energy efficiency of electrochromics glazing during its life time (25 years) has been studied. According to the reported results, this switchable reflective glazing reduces energy demand by 54%.

Thin Film Photovoltaic Glazing

Photovoltaic (PV) glazing is a technology to convert solar radiation into electrical energy and at the same time provide natural lighting for the building. Efficiency of this mechanism has been studied widely in the literature. In a theoretical study by (Bahaj et al., 2008), 40% area of the south facing wall was covered with PV glazing of 10% and 60% efficiency. From solar factor point of view, higher efficiency means lower g-value as most of the solar radiation is converted to electrical energy. Considering system energy loss in wiring, heating, inverter system and mismatch, a performance criterion is defined for PV glazing. Theoretically, 60% efficiency in PV glazing technology should result in 0.85 performance ratio. However, in today's commercially used technology it is around 0.72.

Frames and Spacers

Another component of fenestration is the frames. Frames in combination with spacers have impact on thermal load and penetration rate. Modern frames and spacers have been design to enhance energy performance of the windows. In a research by Robinson and Hutchins, the rate of heat loss (U-value) of the window with different configurations of frames and spacers have been studied (Robinson & Hutchins, 1994). It has suggested that in smaller scales, window's U-value is more affected by frames and spacers layout. A review on frames with low thermal conductivity was also performed by (Gustavsen et al., 2008) who investigated thermal properties of windows with this type of frames.

B.2 Roof

One of the main parts of a building is referred to roofs; roofs are strongly subject to solar lights and so many environmental transformations, therefore, it influences the interior easefulness state for the residents. Roofs consider high amounts of gain/loss of heat, mainly, in structures that have large area for roof. In agreement with the regulations of UK building, the upper limits pertaining to *U*-value for flat roofs in the years 1965, 1976 and 1985 were respectively as 1.42 W/m^2 K, 0.6 W/m^2 K and 0.35 W/m^2 K. At the present time, 0.25 W/m^2 K or less amount is necessary for all the new structures in the UK (Bahaj, 2005). This decrease in the *U*-value amount during the years highlights the importance of heat performance of the roofs with the aim to increase the general heat performance of the structure.

Some passive methods for cooling could be used in the environments with tropical climates as a result of some adjustments in the architecture of the roof. These actions include a compact layer of cellular roof with minimum exposure to solar radiations, vaulted and arched roofs, mechanically or naturally cooled roofs, micro ventilated roofs, high roofs and double roofs (Bahaj et al., 2008).

Some other techniques such as white washed external roof areas to decrease solar absorption, roofs coated with plants to prepare moisture and shadow, and application of high heat capacity materials same as concrete to decrease peak load requirements are also become popular. Roof shadow is one of the best methods to decrease the effect of solar light on the roof area. Low-cost roof shadow is normally gained with local materials same as terracotta tiles, dried grass, branches of date palm, upturn earthen pots and so on which can generally provide a 6 °C decrease in the interior temperature (Green, 2006).

Roof coverings are another method to decrease the effect of solar light on the roof area. Higher solar reflection and high emission are the particular daytime and nighttime elements that effect on the choice of a roof covering. Coatings with Aluminum pigments are less favorable due to their low infrared emission. A cool covering can decrease the temperature of a roof made of white concrete up to 4 °C in the hot weather of summer time and up to 2 °C at the night time (Green,2006). Most of the times, mixed roofing systems are applied to provide the favorable roof specifications based on the climatic changes of the area of the building. An extensive variety of roofing systems has appeared and several of such systems are studied in the following section (Bahaj et al., 2008).

This part studies various roof compound solutions as an instrument to decrease the effectiveness of thermal gain related to various roof systems in the areas with hot climates.

COLOR OF THE ROOF SURFACE

Regarding the point that the heat performance of a structure is directly influenced by the solar absorption of the roof, it is clear that in an area with clear sky, about 20% to 95% of solar light is generally absorbed by the roof area. The amount of this absorption based on the reflectivity factor of the roof area. The reflectivity factor differs from minimum 0.1 for very black colors to 0.8 for very white color. Usually, the refusal of solar light gain is the most important objective of passive cooling methods mainly in hot weathers. Direct solar light on a roof not only influences the interior heat comfort; heat light coming from the materials in the roof of the building influences the micro climate surrounding a building (Dabaieh et al., 2015).

Akbari in his study demonstrated in his study regarding the hot weather areas that rising the solar light reflection of a roof variation from 0.2% to 0.6% can decrease the cooling energy in a building up to 20% (Akbari et al., 2005). A numerical study conducted by Shariah about the moderate climate of Amman and Aqaba, in Jordan, demonstrated that by rising the external reflection of a roof from 0 % to 1%, the energy load was decreased up to 32% in a non-insulated structure and 26% in an insulated structure (Shariah et al, 1998).

Givoni (1994) showed that a roof that is covered with a gray or dark color achieves a higher ceiling temperature in compare to a roof covered with a lighter color. It was also stated that a roof painted with dark color has a higher interior temperature comparing to the outer climate. This research concluded that the occurrence of solar light on the roof surface area depends on the thermo-physical and color specifications of the roof (Givoni, 1994).

ROOF MATERIALS

The material utilized for construction of the roofing system is an important concern. Lau studied that the roof materials type that are used for common ordinary houses are generally made of 85% concrete tiles, but clay tiles and metal deck is made up respectively of 10% and 5%. Lau stated that most of the constructions made are influenced by high solar light transfer because of non- reflective materials applicable, which results in a high temperature in the interior parts of the building.

The roofs made of ceramic tiles would supply better performance in the decrease of heat transferred to a building. Miller et al. (2007) stated that the heat that transfers from the ceramic tiles of the roof area into the ceiling of the building, reduces up to 60% or less compare to asphalt shingles. Because the roofs made of ceramic tiles became damp in night time and dry in day time, it would effect in reducing the heat transfer from the roof area into the attic surface. The decrease of thermal transfer is a result of the capability of the materials used to reflect the heat radiated to the atmosphere. The Chinese had experienced the use of ceramic materials as a material for roofing system previously for centuries (Miller et al., 2007).

Masonry Roofs

In the development processes during the countries, masonry buildings equipped with roofs made of reinforced cement concrete (RCC) are common indebted to their pest (termite) stability, natural disaster (cyclones) stability, accessibility and cost effectiveness of concrete materials (Halwatura & Jayasinghe, 2008). During tropical climate in the summers, they incline to show some adverse heat specifications same as higher soffit temperature and extended heat keeping capacity that influence the interior air easiness conditions and rise the costs pertaining to the energy use. The interior temperatures overpass 40 °C because of higher roof temperatures of near 65 °C (Sanjay & Chand, 2008). Higher soffit temperatures make them discharge lengthy wavelength infrared lights to the residences. Worse is that it might develop into the night time because of the thermal capacity of the slab. Moreover, the heat that absorbed may result in formation of some breaks and cracks in the support structure specifically made up of brick work or block work. This issue of high roof temperatures can be reduced by usage of roof shading system, cool roof coverings or compound roof systems. A compound roof system is formed with a combination of light reflectors and heat insulation showed significant mitigation of the thermal energy conducted through a roof made of concrete (Sadineni et al., 2011).

Solar-Reflective/Cool Roof

Cool roofs are one of the cheap passive methods that are simple to install, decrease heat gain and develop interior thermal ease in hot weathers. Utilizing cool roofs with proper roof thermal specifications during the primary design stages and building the constructions, or when strengthening, are generally more cost effective regarding both the house and urban level, this can keep a high amount of the energy that is used in cooking process. Although the potential profits of cool roofs have gained high attention in the Middle East and North Africa area (Dabaieh et al., 2015).

Solar-reflective roofs or cool roofs are high solar reflectors and high infrared imitative roofs. They keep lower roof surface temperature and prevent the heat transfer into the building. Two surface specifications that influence the heat performance of these roof surfaces are solar reflective (SR) (reflectivity or albedo) and infrared propagation (or emissivity) (Sadineni et al., 2011).

To detect the effect of highly reflective roofs on cooling and peak load systems, six various types of buildings were strengthened with high reflectance white coverings or white PVC single-ply coat at three various geographical places in California (USA) (Akbari, et al. 2005). It was shown that the daily peak temperature related to the roof area for all the houses was decreased. The tests conducted on these single floor buildings stated that high reflective roofs are inexpensive for these houses achieving cooling load savings about 5–40% and the peak request savings of about 5–10%.

Reflective roof is an issue that aims to decrease the effect of heat received in to the house during a hot climate during day time (Akbari et al., 2005). The properties of cool roofs could increase interior heat comfort without demand to change the air conditioning unit. The cool roof holds up in developing the roof's life span and decreasing the imprisoned heat from the attic and some other building areas by sending back the solar lights back into the atmosphere. A cool or reflective roof also reacts as a good thermal emitter and also a reflective element of hidden short or long wave electromagnetic lights.

New approaches or methods are presented to develop the current passive design through ventilated and cool roof systems.

Based on the cool roof rating council (CRRC), cool roofs refer to roof areas with solar reflectance ability (ρ) of ≥0.55 and heat emittance (ε) of ≥0.75 (Zingre et al., 2015).

(Pisello et al., 2014) detected the cooling energy savings of about 34% in their experimental research performed during summer time on an air-conditioned house in Rome, Italy. In another research performed on a natural ventilated house, (Pisello et al., 2014) noticed the decrease in average roof area temperature by up to 10 °C and interior air temperature by up to 3 °C in summer time, whilst decrease in average roof area temperature about 1 °C in winter time. (Boixo et al.,2012) noticed the cooling energy savings about 30%–48 in their experimental research conducted in different areas of Spain. (Akbari et al., 1999) detected the cooling energy savings about 20%–40% for various regions in California, U.S.

The real advantages of a cool roof on every specific building will depend on many different factors, same as the type of the building, season, the load and most importantly the climatic zone. There are different environmental advantages for cool roofs. From the aspect of the urban level, cool roofs can cooperate in decreasing urban air temperatures by reducing the amount of heat that is transferred from roofs to the urban environment. This can be achieved by utilizing, for instance, retro-reflective materials and some reflective covering materials could reduce the urban heat island influence. Moreover, on the level of buildings, cool roof develops interior heat comfort. Therefore, a cool roof decreases energy receipts by decreasing the reliance on different mechanical air conditioning systems. A typical usage for a cool roof will gain a decrease near 10% to 40% in air conditioning energy used. In the long time, advantage of lower roof temperature decreases maintenance and, therefore, develop the life cycle of the roof (Dabaieh et al., 2015).

Table 4 : Solar reflectance and infrared emittance properties of typical roof types along with temperature rise (Sadineni et al., 2011).

Roof surface type	Solar reflectance	Infrared emittance	Roof surface temperature rise (°C)
Ethylene propylene diene monomer (EPDM)–black	0.06	0.86	46.1
EPDM–white	0.69	0.87	13.9
Thermoplastic polyolefin (TPO)–white	0.83	0.92	6.11
Bitumen–smooth surface	0.06	0.86	46.1
Bitumen–white granules	0.26	0.92	35
Built-up roof (BUR)–dark gravel	0.12	0.90	42.2
BUR–light gravel	0.34	0.90	31.7
Asphalt shingles–generic black granules	0.05	0.91	45.6
Asphalt shingles–generic white granules	0.25	0.91	35.6
Shingles–white elastomeric coating	0.71	0.91	12.2
Shingles–aluminum coating	0.54	0.42	28.3
Steel–new, bare, galvanized	0.61	0.04	30.6
Aluminum	0.61	0.25	26.7
Siliconized polyester–white	0.59	0.85	20.6

Cool Roof with Double-Skin Roofs in Hot Climate

One of the most important cooling solutions referred to the roofs with double skin with the aim of limiting the heat gain of buildings and cool roof is another new solution. CRHT (cool roof heat transfer) model for roofs with double skin which could model the thermal transfers for a double-skin roof mixed with cool roof. The consequence of experimental study demonstrates that the coverings in white color on a double-skin plain roof decreases the heat gain during day time about 0.21 kWh/m^2 (or 51%), lead to peak interior air temperature decrease about 2.4 °C in a shiny day (Zingre et al., 2015).

Zingre et al. studied the heat performance of cool roof in compare with double-skin roof considering the CRHT model. Double-skin roof is near 6% more impressive compare to cool roof in decrease of annual thermal gain in day time. While, the additional insulation of double-skin roof prevents the thermal loss in night time, follow by the fact that cool roof is often equally impressive in decreasing net annual heat gain (Zingre et al., 2015).

DSR (Double-skin roof) that includes two solid roofs (additive roof on the top part and the original roof at the bottom part) divided by an air gap (either open-ended or close-ended), has been a common passive roof cooling system occupied in the region (Wong & Li, 2007). The additive roof protects the original roof against direct solar light and the air gap practices as an insulation layer. Regarding the open-ended air gap, this case permits airflow to remove the heat impressively to outside area and therefore decreases heat gain into the interior environment through the original roof. (Zingre et al., 2015).

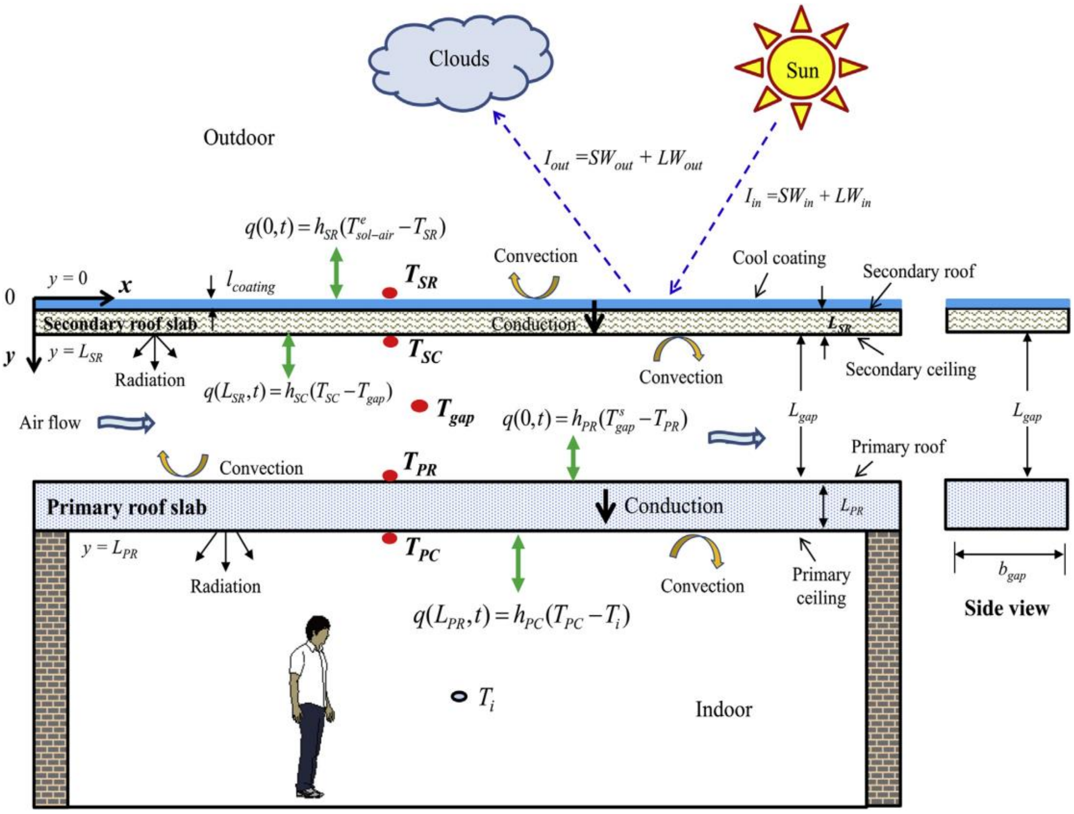


Figure 19 : Schematic diagram showing heat transfer processes at a cool double-skin roof. (Zingre et al., 2015).

The CRHT studies demonstrated that addition of a cool covering on the DSR layer decreases the peak additive roof temperature about 14.7 °C, the original roof temperature about 4.7 °C, the interior air temperature about 2.4 °C and heat gain during day time about 0.21 kWh/m^2 (or 51%) in compare to the primary equivalent on a shiny day in the tropical climate area. Because of the respective small differences in climate conditions during the year in tropical climate area, the remarks about heat gain/loss decrease during the day by cool roof or DSR are generally representative to the yearly forecast (Zingre et al., 2015).

EFFECT OF COLOR IN COOL ROOF

The color of a roof area surface is another factor that should be attended in design stage of a cool roof. A darker color would attract more thermal energy compare to lighter colors, as a light color could reflect thermal energy on its surface. (Akbari et al., 2005).

Many researches have concluded that the reflective approach may decrease the maximum solar thermal energy gain by reflecting the solar light back about 90%, therefore reducing the electricity usages for a mechanical cooling system. Under the same way, a cool roof color reports a temperature about 28 C, that is lesser in compare than the temperature of a dark roof color for about 66 C or higher degrees. A white cool roof assists to reduce the interior temperature in hot climate regions and mainly decrease the temperature around 2.3 C.

Cool Roof with Optimum Roof Pitch Approach

The mixture of a reflective cooling roof with an optimized roof pitch is a method that desires to decrease the heat transfer from the roof area surface into the building during shiny days.

Table 5 demonstrate the necessities for a minimum cool roof. These confirms that the down or steep slope of intersection or overstep both minimum solar reflectance and thermal emittance amounts. These let some roofs to have a low heat emittance with high solar reflectance amount or vice versa to characterize as a cool roof (US Department of Energy, 2016).

Table 5 : The Effect of Angle of The Roof From 0 Degree To 60 Degree in Solar Reflectance (Tashoo et al., 2014).

Roof type	Solar reflectance [3-year aged]	AND	Thermal emittance [new or aged]	OR	Solar reflectance index (SRI) [3-year aged]
Low slope	0.55		0.75		64
Steep slope	0.20		0.75		16

The rise in the angle of the roof from 0 degree to 60 degrees could decrease the interior climate about 1.5 C. Air displacement under the roof slope of about 30 degrees is quicker in compare to 15-degree roof pitch (Tashoo et al., 2014). The 30-degree optimized roof pitch is suggested for simple maintenance objectives in the future.

This research also showed that an aluminum sheet in black color with a higher pitch of about 45 degree shows the undermost temperature in compare with an aluminum sheet in white color. It also shows the relationship between the roof color and the roof pitch.

According to (Al-Obaidi, 2014) about the tropical climate regions, a plain roof is not suggested for residential houses.

Ventilated Roof Approach

Natural ventilation system is always a proper option since it depends on the natural air displacement and it is considered as a cost-effective method in design stage of a house. The ventilated air gap related to the roof surface might be sufficient to provide natural air displacement (Endriukaityte et al., 2005). The optimized height of the entrance could maximize the value of effectiveness of the ventilated roof. Although, it based on the speed of the wind at that specific region. The ventilated roof system attends at the natural way of air circulation. There are two kinds of natural ventilation systems that are driven by the wind power ventilation and pile ventilation system.

Ciampi et al. (2005) stated that a properly designed ventilated roof system upgrade the overheating circumstances at the attic, mainly in houses with average height and wide space. Natural ventilation system allows free cooling systems to its surrounding environment and makes a comfortable circumstance for the residences. It is considerable due to its significance decrease in overheating because of solar light emitting (Ciampi et al., 2005). The study show that the inside temperature might be decreased up to 8 C by adding an entrance on the roof surface area.

Al-Obaidi et al. (2014) showed that a ventilated roof would act well during the rise of air speed as the height or thickness of the air gap also increase. Also, the air gap of the roof surface area at an optimized angle of the roof might help in decreasing the heat transfer. Qasim et al. (2010) demonstrated that the rise of air gap might decrease the amount of heat that is transferred from the roof surface area. Air gap thickness of about 20 mm considerably decreases the heat achieved by the roof surface. The ventilated roof system let the house to experience the circumstances of the effects from both stacks and wind power.

Ventilated roofs might be either found in a passive type, with stack influence driving the air flow, or in an active type, with fan induced ventilation system. They are more common in areas with hot climatic circumstances and are specifically considerable in moderate height and buildings with wide roof area. Based on the duct size, the flow through it could be either laminar or turbulent (Sadineni et al., 2011).

In the time of cold winters, it is recommendable to close the air duct via some suitable dampers from one energy savings viewpoint. Such dampers services just a very little ventilation to discharge any potential sediments in the duct.

HOT_humid CLIMATE

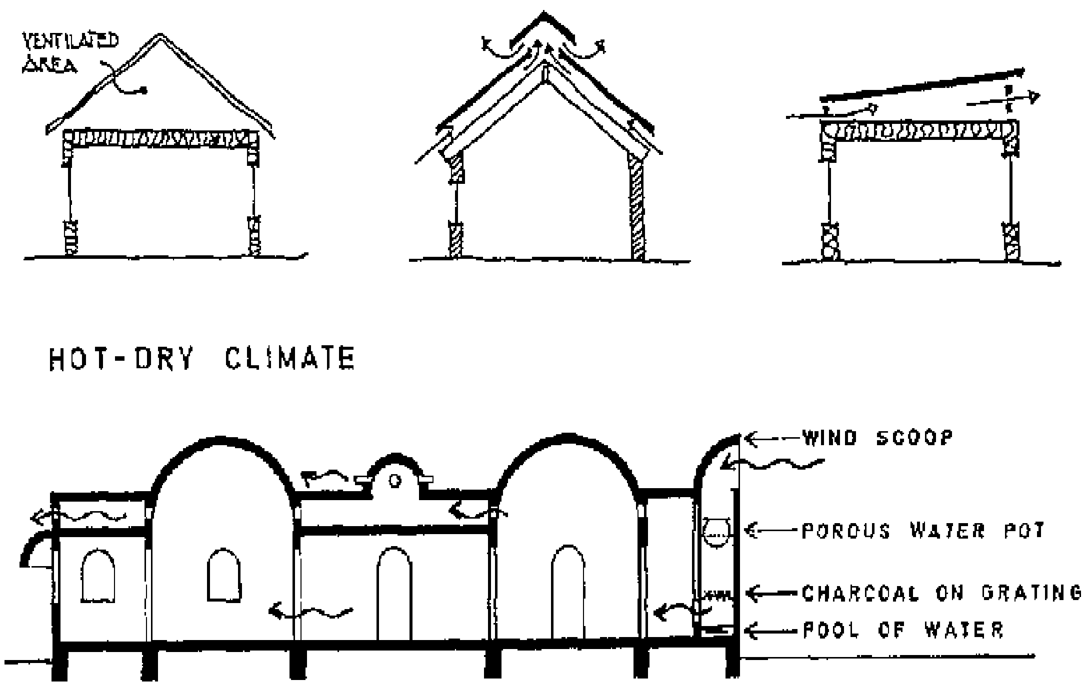


Figure 20 : natural ventilation in hot-humid and hot-dry climate (url 20).

Stack Effect

The stack influence happens due to the hot air passing from a region with low pressure to a region with high pressure

Fig. 21 explains how natural ventilation, such as openings, and stack effect could help in reducing the indoor temperature.

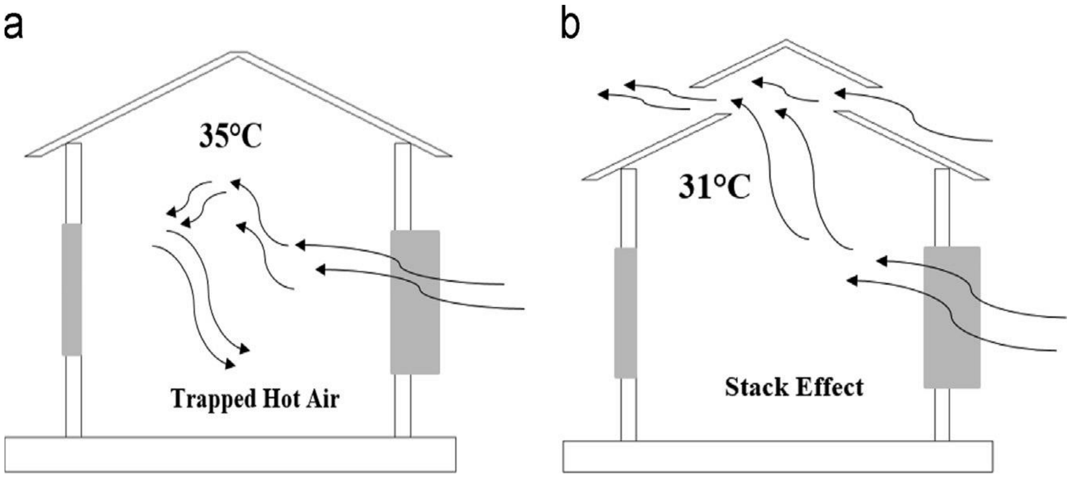


Figure 21 : natural ventilation in hot-humid and hot-dry climate (url 20).

Condition of air movement with and without stack effect. Source: Towards a low-energy building design for tropical Malaysia (Rahman, 2016).

Fig. 21(a) demonstrates that hot air will be prevented if only one entrance permits the air to move into the building. Although, no stack influence happens in such situation. Fig. 19(b) shows the productiveness of the stack influence in relieving air displacement that enters the building and over it. Fig.19 (b) also shows the situation of the entrance of the building at the top side of the building that decreases the temperature inside the house by supplying the required area for air to pass from inside to outside of the building via the opening part on there of surface. (Mathur et al., 2006).

COMBINE APPROACHES IN ROOF

Installment of reflective cooling systems with optimized roof pitch and ventilated roof methods in the current new passive design of the roofing system could help in the decrease and withdrawal of heat gained at the top side area, therefore decreasing the indoor temperature. These systems might decrease the energy requirements that minimize the cost related to generating electricity for cooling aims. (Roslan et al., 2016).

It is considerable to attend that the adjustment of such concepts into the modern passive design in the current time and future for designing a house. A reflective cool roof system with an optimized pitch might be mixed with the utilization of a ventilated roof system in the development process of the current passive designing method for modern buildings, mainly for low cost buildings. Although, the usefulness of such systems also based on the type and orientation of the building, weather condition and climate, and finally the topography. Designers should be informed about the selection of the most proper approach to stay away from unfavorable methods, which motivate the overheating of interior temperature of the building and consume the energy demands (Roslan et al., 2016).

Evaporative Cooling Through Roof in Hot-Aired Zone

Evaporative cooling systems have demonstrated to be an impressive passive cooling method for a hot arid weather. Site studies by Al-Hemiddi in the hot arid weather areas of the city of Riyadh in Saudi Arabia in August have confirmed that an average decrease about 5 °C in interior parts temperature might be gained utilizing a roof with humid soil that shadowed by 10 cm of pebbles.

Kharrufa and Yahyah utilized a roof pond cooling method with active approaches by the use of a fan to rise the productivity of the roof pond. Al-Hemiddi, in the above-mentioned study, examined a walkable roof pond with water circulation in the night time. The roof pond was charged with pebbles, with an insulation layer on the upper side of which thin tiles were set over the insulation, enacting as a roof surface in the top side available for the building's residences. Such technique decreased the inside temperature about 6 °C in compare to the outer temperature when examined in August (Dabaieh et al., 2015).

Form Roof and Shape

Dabaieh planned and examined 37 roof design potentials alternating roof shape, roof material and construction. The consequence of utilizing a vault roof equipped with high albedo covering demonstrates a fall about 53% in discomfort times and saves the energy in the summer time in compare to the fundamental case of the conventional non insulated flat roof systems in the residential buildings. The shape of the roof, domed or vaulted roofs have been greatly utilized in traditional and vernacular houses in hot climate areas (Dabaieh et al., 2015).

As Nielsen demonstrated, dislike the plain roof, a rounded or curved roof is in the shadow for part of the time during the day (Nielsen, 2002). It has yet mainly been taken for-granted that rounded or curved roofs decrease the interior temperature in compare to plain roofs but an investigation performed on the light that absorbed by the vaulted and domed roof systems in a hot weather demonstrated that domed roofs generally absorb little beam light compare to a corresponding plain roof. The research suggested the construction of domed roof systems with more than 60° of half dome angle. Other studies have recommended that a vaulted roof system with rim angles of less than 120° at night time and in the early morning time (see Fig. 20) has a lesser heat flow comparing a plain roof. In another research, Tang et al. suggested a half rim angle for vaulted roof systems of around 50° and 60° to provide the needs of both unair-conditioned and air-conditioned houses. They also suggest that the optimized orientation of the vault be north-south facing (Tang et al., 2006).

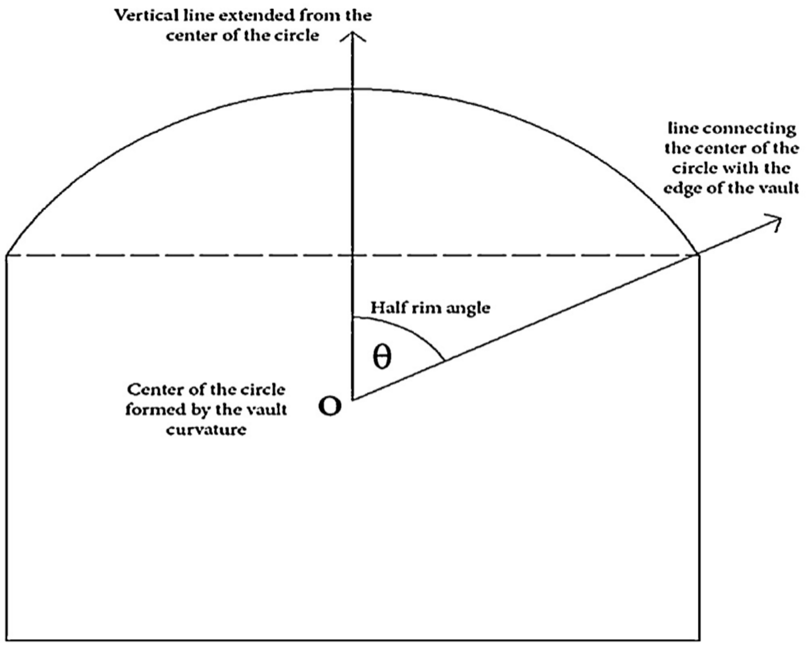


Figure 22 : Illustration for half rim angle (Tang et al., 2006).

Thermal Mass

In the buildings with passive design methods, thermal masses in the walls of the building and roofs play as thermal storage components that help to decrease the temperature fluctuations on the indoor surface (and therefore decrease the peak transmission load) and also assist in change time of occurrence of peak load to a later time in the day time. The decrease and shift of peak load are quite critical: (Al-Sanea & Zedan, 2011)

- firstly, it planes the large request on the electricity network during peak hours of the day;

- secondly, it rises energy productivity of AC system (as the peak load would occur later in the evening time when the outdoor air temperature is lower than that in the afternoon time)
- thirdly, by decreasing the peak load, smaller capacity AC equipment will be requested. Larger capacity AC equipment would operate most of the time at part load that makes them less energy product and would also result in higher capital and maintenance costs

The dynamic thermal specifications that are influenced by the heat storage capability of the building components are the time lag and decrement factor. Change of the peak load is a consequence of rising the time lag, while decrease of the peak load is a consequence of reducing the decrement factor both of which are developed by increasing the thermal mass (Al-Sanea &Zedan, 2011).

Thermal Storage Combines Efficiency Materials to Reduce Energy Used in Building

Therefore, decreasing the energy amount utilized in HVAC systems is considered as one of the main steps in decreasing the world total energy demand. One of the most critical methods to decrease the energy demand of a house is referred to thermal energy storage that is a rather old concept. Absorption of the thermal energy coming from the sun at daytime and releasing it back to the house at night time decreases the heating request of the houses and rise the cooling peak. There are various passive and active techniques to reserve the heat energy of the sunlight hours. Lately, utilizing the phase change materials that reserve this heat in the form of latent heat has been considered a promising method. Such materials absorb the thermal energy by melting in sunny

hours of the day and release it back by solidifying it later at the night times of the day. PCMs provide higher energy reservoir capacity and less temperature fluctuations comparing the other building materials (Baniassadi et al., 2016).
Moreover, they are lighter comparing to the materials normally utilized as thermal mass. Recently, many studies regarding the incorporation of PCMs into residential houses were conducted. Phase change materials decrease the overheating effects, indoor temperature fluctuations and the annual energy consumption of the HVAC system. Also, it was reported that the peak-load time can be shifted in order to reduce the network peak load demand (Baniassadi et al., 2016).

PCM’s can also be combined into Trombe walls that are a usual technique against for thermal storage in buildings. In such instances, the size of the Trombe wall can be decreased mainly due to the high storage capacity of PCM’s. The experimental results of Zhang et al. demonstrated that thermally enhanced frame walls with phase change materials can decrease the on-peak heat flux around 38% comparing the conventional case (Zhang et al., 2005). A detailed parametric research on space cooling systems based on night ceiling cooling with Phase Change Materials (PCM).
Phase change materials reserve and release the thermal energy to decrease the cooling and heating load conditions of a house or structure. They mainly work as a heat mass and conduct this role by liquefying as they absorb heat, preventing the heat to reach the conditioned space and releasing the heat when the outside temperature reduces (mainly at night). A recent experimental work conducted by Arizona Public Service (APS) in collaboration with Phase Change Energy Solutions (PCES) Inc. with a new class of organic-based PCM (BioPCM) demonstrated maximum energy savings near 30%, a maximum peak load, and a maximum cost savings near 30% over conventional

non PCM base-case. Moreover, unlike other organic based PCMs which are highly flammable, the BioPCM utilized in this case is less flammable and therefore is more appropriate and safe to use (Sadineni et al., 2011).

PCM-embedded piping methods recommend the appropriate values for the design parameters of such systems (Baniassadi et al., 2016). Sajadi and Baniassadi have studied the performance of phase change materials in different climatic areas of Iran besides the effect of each design factor on the PCM productivity. It was reported that about 40% of the annual energy demand related to a simple shoe-box office can be reserved in southern areas of the country (Sajadi & Baniassadi, 2015).

Implementation of PCM layer

Phase change material is set into the coverage of the building as a single layer. Previous experimental and numerical studies recommend that PCM should be set indoor regarding the insulation layer (Baniassadi et al.,2016).

In the night times of the cold season, the temperature difference between PCM and out environment is much critical than PCM and indoor zone. To prevent the heat to be released in the outer side of the building g, it is best to set the PCM layer inside regarding the insulation layer. Moreover, in research in Iran confirmed that in all the climatic areas of Iran, the building roof is associated with the highest productivity of the PCM layer. Results demonstrated that about 80% of the energy saving resulted from the PCM is because of the placement of this layer in the roof structure (Baniassadi et al.,2016).

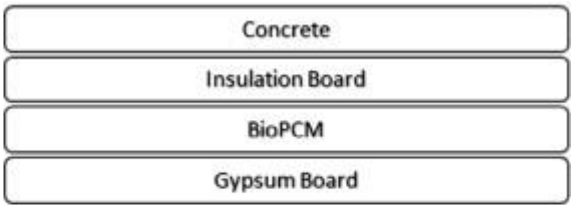


Figure 23 : shows the position of the Bio PCM layer in the roof construction. (Baniassadi et al., 2016).

By development of the insulation layer, the functionality of the phase change material spoils. In such cases, the heat that reaches the PCM rate is not enough to make the phase change process occur. On the other hand, utilizing too much phase change material, the influence of the insulation layer becomes less critical. Therefore, an economic optimization method is required to find the proper thicknesses for PCM and insulation layer thickness (Baniassadi et al., 2016).

Insulation

Buildings with insulated walls are considered as the integrated parts of a house coverage. They keep the indoor space from critical weather conditions and damp down large fluctuations in temperature. Therefore, the building coverage must provide the required thermal comfort condition for the residents as well as decrease energy consumption rates for the cooling purposes. This is normally conducted via rising the thermal resistance (R-value) of the coverage and, therefore, decreasing transmission loads. So, addition of heat insulation is critical mainly in areas with critical climates.

Heating Energy use in building

The study conducted by Schnieders on average heat loads in the hot climate areas building demonstrate that the larger part of the energy balance techniques assumes values much higher than average rate. The indoor heat loads to be partially adjusted by indoor heat sinks same as cold water in pipes and toilet cisterns, internal evaporation water from potted plants or towel drying. Additionally, the nominal electric power of appliances is usually greater than the actual heat released. This assumption was verified by monitoring passive houses in tropical humid (Roslan et al.2016).

Similar studies conducted by Mlakar and Åtrancar demonstrate some similar results. The passive building limitation also seems to be challenged by the cultural variety in the patterns of occupancy conditions and the equipment use. Dianshu stated that high consumption of equipment and electronic devices same as video game players in China is raising the internal heat loads in dwellings causing an increase in HVAC energy consumption. The increase in internal load offsets the thermal balance between the envelope and Environmental Heat Sink. In a hot climate, the outdoor air unable to work as an Environmental Heat Sink. Therefore, sheltering the inside air against the heat outside, can just work in the case that the indoor heat load can be disposed of by raised ventilation or by defining a subsidiary Environmental Heat Sink to the outside air (Roslan et al.2016).

Cooling Energy use in building

In a hot climate area, cooling methods referred to the highest share of the energy consumption in the houses. Indoor heat gains and solar gain via the outside coverage of the building are the major cooperation to the heat load in a house. Heat gain via windows specifically shows a significant element of the cooling load system and ultimately a main contributor to the energy consumption (Berger et al., 2014). Window glazing method plays a major role in energy performance and has a considerable influence on the overall energy consumption of the building. Heat flow via a glazed window addresses to the heat gain because of incident solar radiation that ultimately rises the cooling load. The net energy gain in the houses via the windows depends on the heat properties of the glazing material. Double-pane covered glass windows are utilized to decrease the heat and energy losses. They are very influential to decrease the building energy consumption by decreasing the cooling load in compare to the traditional double-glazed clear glass windows. Although, colored glazing decreases the admittance of daylight thereby hindering the chances of influential usage of daylight integration with artificial lighting methods (Fasi & Budaiwi, 2015).

In most of the countries in hot climate areas, the housing sector consumes near 40%-50% of the country's total electricity production rate. Although, the cooling system of the buildings merely consumes near 30% of the country's total electricity production rate that in most of the times is utilized by the air conditioning system (Tan et al., 2010). Passive building cooling techniques could be considered as a main solution to improve the building energy productivity and inside heat comfort in the tropical city-states (Zingre et al.,2015).

Passive cooling method is referred to a building design method that focuses on the heat gain control and heat dissipation in a house for the aim of improving the indoor heat comfort with low energy consumption. This method works either by prevention of heat to enter to the interior (heat gain prevention) or by deleting the heat from the building (natural cooling method). Natural cooling method uses some on-site energy that are available from the natural environment, integrated with the architectural design of the building elements (same as building coverage) rather than the mechanical systems to decompose the heat. So, natural cooling method depends not only on the architectural design of the house but also on the using method of them from the local site natural resources as heat sinks (same as everything that absorbs or dissipates the thermal energy). Some instances of on-site heat sinks are the upper atmosphere (night sky), the outside air (wind), and the earth/soil.

Energy use for Air Conditioning in building

To keep the indoor temperature in the limits of the comfort level, most of the building designs generally depend on mechanical means by utilizing the fans or different air conditioning systems. The dependence on a mechanical ventilation system could result in additional costs related to its installation, maintenance and operation (Ozel, 2011).

Air conditioning is the major energy consumer equipment in the houses and structures. Any decrease in such energy requirement is a decrease of diesel fuel utilization for electricity production purpose and therefore a considerable decrease in total greenhouse gas emissions. Therefore, this has to be aimed without sacrificing the quality of the indoor air and heat comfort of the building's residents. There is great scientific evidence regarding the point that the average temperature of the earth's surface is increasing. This is a result of the rised concentration of carbon dioxide and other greenhouse gases in the atmosphere released by burning fossil fuels (Ozel, 2011).

The indoor temperature of the modern low-cost building is more than the required temperature for an occupant's comfort rate. However, it could cause to high power utilization of mechanical means and rising the energy consumption rate. The highest daily electricity request which raised up to 5% from 2012. Meanwhile, the annual amount of electricity demand also rises by 3.6%, from 2012 to 2013 (Energy Commission, 2014).

With the population growth and the improvement of living standards, the percentage of constrictions with air conditioner systems have been increased considerably, cause to a high amount of energy consumption and environmental and health related negative influences, on other hand, climatic change and cultural concerns have influence to heighten air conditioning used. According to Cândido et al. (2011), climatic change increase in moderate temperature conditions, higher frequency of critical weather events, both cold and hot, and also increased discredit of weather conditions. In this context, building residents who addicted to a narrower limit of temperature, feel more discomfort regarding the outdoor conditions than those who use less air conditioning.

(Agbemabiese et al. 1996), stated that in Ghana and Thailand, air conditioning system ownership is culturally considered as a status symbol and could be applied for this reason individually. Therefore, western style clothes (same as the shirts with suits) are also considered as such status symbols, cause to the dereliction of traditional (confirming the need for air conditioning systems, as the clothes adopted are not proper and enough for hot conditions).

B. Natural Ventilation

The draft or air movement is a crucial aspect of ventilation mechanism in hot and humid climate. Air movement enhances thermal comfort by decreasing humidity and replacing humid air with dry air even if the temperatures are the same (Nicol, 2004).

Previous studies investigating the relation between humidity, draft and temperature of the air have revealed different aspects of these elements and their interactions on the temperature that human body feels (Kerslake & Mck, 1972). Particularly in hot and humid regions because of the dominating heat loss by evaporation, people need to use more energy to stablish comfort in their house. According to recent investigations conducted in this thesis, in hot and humid regions people feel hotter than actual comfort and they need more energy to decrease humidity by air conditioning or by fan (Nicol, 2004).

It has been stated that air conditioning systems established based on natural ventilation are efficient in buildings in terms of energy consumption as well as CO_2 release. In fact, implementing natural ventilation in buildings results in improved thermal comfort and enhances the quality of air in comparison with enforced mechanical air conditioning. Furthermore, residents feel a better control over ventilation system that is based on fresh air draft. Consequently, natural air conditioning systems have several benefits in residential spaces including enhanced air quality, decreased expenditure and improved thermal comfort. Either passively or actively designed, natural cooling systems are capable of soling some problems raised in artificially cooled residents (Mirrahimi, 2016).

From the historical point of view, natural ventilation systems have been a fundamental part of vernacular architecture ages before active air conditioning systems were introduced (Mirrahimi, 2016).

Construction frontages faced outdoor including surrounding walls, windows and the roof are vital elements of natural ventilation in traditional design. More precisely, in natural ventilation these are the tools that make it possible to provide thermal comfort with an appropriate mixture of ambient air with the air inside the living spaces. The relation between appropriate wall and roof design and active air conditioning usage is studied. Required air movement for thermal comfort is also achieved when sufficient openings are implemented with proper size at seemly positions. Certainly, a combination of proper facade design (materials, orientation and thickness) with enough openings located at proper position reduces the energy consumption for cooling purpose as much as 40 percent (Mirrahimi, 2016).

In a study conducted by Nicol it has been stated that effective draft or air movement is capable of providing a feeling of thermal comfort like 4ºC decrease of the indoor temperature. This phenomenon has been proved by theoretical analysis as well. As a matter of fact, heating, ventilation, and air conditioning or HVAC system is only used when natural air conditioning is not enough for the residents in the building as mentioned in (Sharma & Ali,1986). In a research investigated the usage of ceiling fans in Pakistan, it is mentioned that these air moving elements are at use during the summer in all public closed spaces giving the people a feeling of 2ºC decrease in temperature (Nicol, 2004).

On the other hand, Pacheco et al. have stated that financial growth in developing countries located in hot geographical regions increases the demand for HVAC technology. Accordingly, the people get used to a very narrow ranged temperature at which they feel thermal comfort and the usage of air conditioning system grows. This trend results in a substantial increase in the energy consumption for cooling.

natural ventilation and night ventilation reduce the cooling requirements by 30% provided that the apertures are situated in related parts of windward sides. A related study on tropical climate showed that stack effect regarded as one of the strategies for producing ventilation is inadequate due to lower range of air temperature (i.e., less than 5 °C) between outside and inside of building. Nevertheless, high amount of solar radiations may be taken as a viable alternative to make ventilation in tropical climates. (Mirrahimi, 2016).

Important factors to create building thermal comfort with use of natural ventilation are:

- air movement,
- air velocity,
- temperature and humidity.

Three ways of heat transfer, conduction convection and radiation, are involved the heat flow to the building as illustrate in Fig.1. An ambient air draws by the chimney to the ceiling and also flows into a building openings, windows and doors, this causes a movement of air and benefits the natural ventilation as shown in Fig.25 (Rattanongphisat & Rordprapat, 2014).

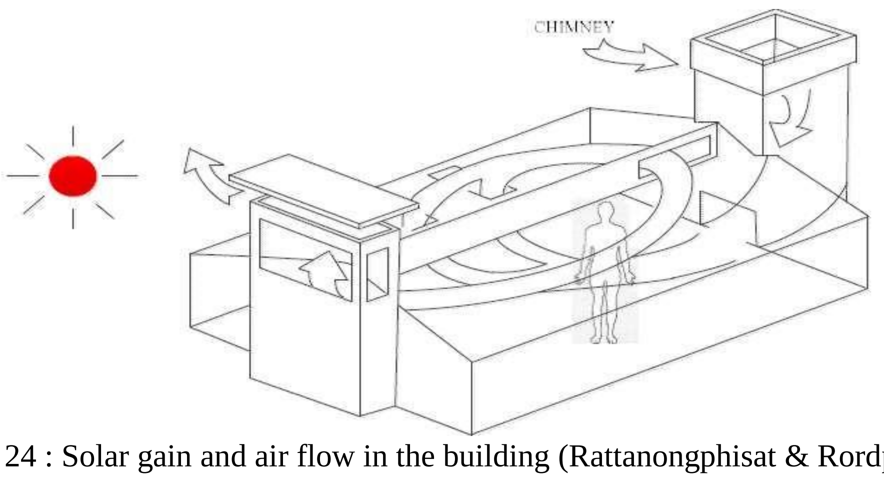


Figure 24 : Solar gain and air flow in the building (Rattanongphisat & Rordprapat, 2014).

Aziah (1994) in conclusion stated that the traditional Malay building design registers a lower indoor temperature in compare to the new terrace building design. In addition, the traditional Malay building design is the most appropriate instance of appropriate natural ventilation system, whereas it greatly is contingent to the natural cooling system via the air flow through the roofs, windows, roofs, doors and other parts Although, the utilization of the Malay traditional concept building has become avoided because of the reconstruction and modernization of the building design and the limits of woods prepared for the housing material, same as the timber and Nipa palm leaf (Nypafruticans). Fig.26 demonstrates the entrances in a traditional Malay building that could assist to ease the motion and eliminate the heat.

Although, the traditional Malay building utilizes both stack effect and wind driven concept in its building process.

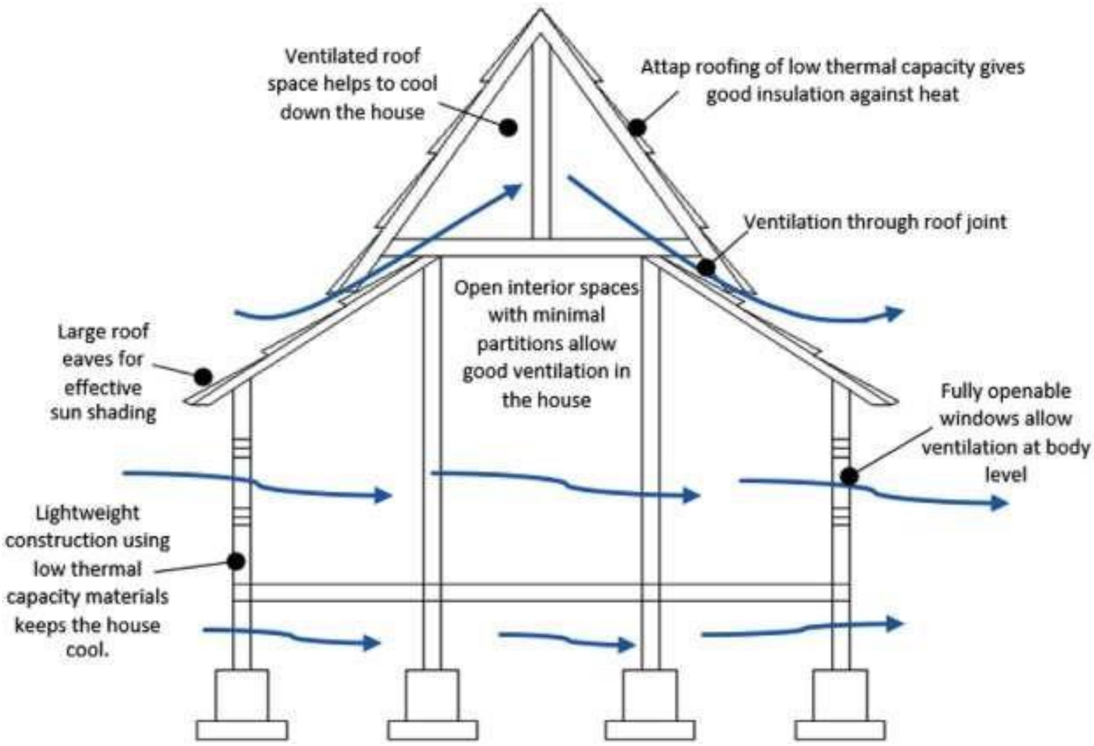


Figure 25 : Air movement for traditional Malay building. Source: The traditional Malay house, rediscovering Malaysia's indigenous shelter system (Lim, 1987).

At the present time, the residential building roofing system is organized and planned with less ventilation systems or unvented attics to preserve the costs for building, resistance against the fire, rain conservation and security improvement. The modern house made of concrete would undergo high temperature increases throughout the daytime and would gradually cool down throughout the nighttime (Rahman, 2016). The roof coverage temperature of an unvented attics and ceiling temperature conditions might respectively achieve 71 C and 66 C, whilst the outdoor temperature is just near 32 C. Although, a ventilated roof with appropriate design could develop the overheated circumstance at the attics, mainly at an average height and an extensive area of the construction (Ciampi et al., 2005).

The most influential factor resulted from the passive design is referred to the energy desire for the mechanical operation. Whereas the circumstance of the indoor temperature is higher than the comfort level, a great energy is required to create mechanical ventilation system to reach the comfort level. Thought, the condition could become awful due to weak ventilation system and the design for air circulation.

Natural Ventilation system could be implemented during the design stage of the window and door entrance to permit the air movement in the house. With appropriate design same as stack ventilation, the air speed inside the house may achieve the velocity where it utilizes from the evaporation on the human skin. This method benefits an appropriate consequence for a kind of addiction in which people are comfort at higher temperatures comparing to the stated in the standard ASHRAE 55 (Rattanongphisat & Rordprapat, 2014).

Iranian architect specialties and also the engineers have appropriate create masterworks utilizing wind flow and the temperature variation in day and night to attain thermal comfortable environment in houses in hot deserts without energy consumption. These factors contain wind catcher, vaulted roof, homestead, underground storeroom, Ivan, Soffeh, Khishkhan, barriers, groundwater tanks and natural ice pit design (Khalili & Amindeldar, 2014).

Effects of Passive Natural Ventilation On Energy Consumption

Another aspect of natural ventilation is addressed in a study by Toe and Kubota, a computational analysis of thermal comfort and the related adaptation formula is performed using a data set collected from buildings located in different climates and ventilated by natural ventilation systems. The research has proved that instead of humidity, it is the air flow speed inside the building that influences the adaptive thermal comfort equation. In addition, it is stated that if the house is ventilated naturally the thermal comfort level remains the same (Toea & kubota, 2013).

In average, the ambient air temperature in hot and humid climate during the day varies between 20ºC and 30ºC. On the other hand, for hot and arid regions the average peak reaches 35ºC (Fig.26). Referring to the figure, in moderate climate, average daily temperature remain below 20ºC almost all day long.

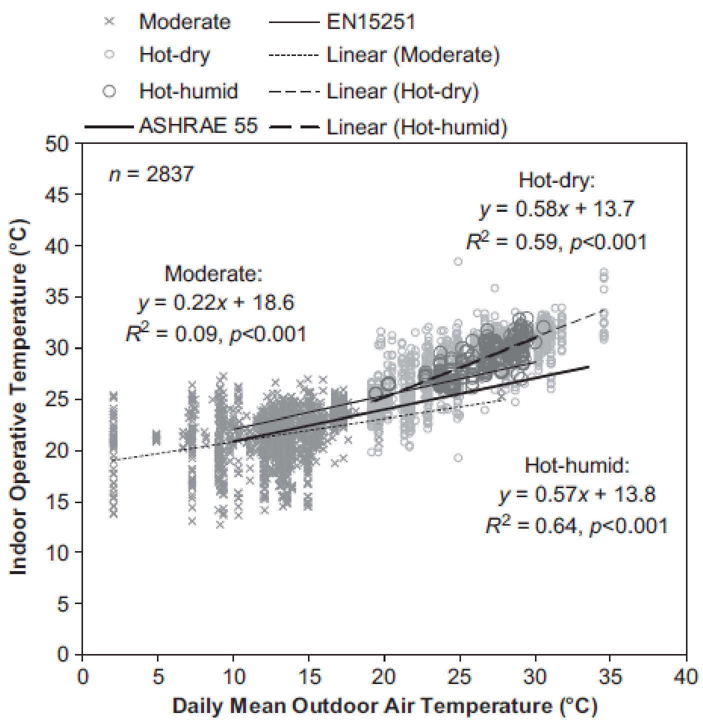


Figure 26 : Scatter diagrams in different climates, indoor operative temperatures versus average daily ambient air temperature in degrees Celsius. The lines represent linear regression models used in the study and in the adaptive equations. (Toea & kubota, 2013).

It is supposed that there are several key differences in the thermal adaptation of occupants in naturally ventilated buildings among climates and the existing standards (ASHRAE, 2010; BSI, 2008). These differences are summarized as below (Toea & kubota, 2013):

1) People in hot climates adapt to higher neutral operative temperatures.
2) The observed daily mean outdoor air temperature ranges predict neutral temperatures of 24.9–31.2 C, 24.8–33.7 C, and 19.0–24.7 C for hot–humid, hot–dry, and moderate climates, respectively.
3) The proportion of occupants “comfortable” increases from 30% at 2.5 C above the predicted neutral temperature to 86% at 2 C below the predicted neutral

temperature for hot–humid climate. A lower comfort limit is not observed in hot–humid climate. Acceptable comfort ranges also show asymmetry and below thermal neutrality for hot dry and moderate climates.

4) Air movement is a possible factor for increasing the gradient of the adaptive equation for hot and humid climate and avoid evaporative heat loss in indoor high-humidity conditions. In contrast, indoor relative humidity influences the adaptive equation for hot and dry climate.

5) Therefore, Natural ventilation is a traditional, well-accepted passive cooling technique used in hot regions to improve thermal comfort.

6) For hot and dry climate, increased air speed allowance is not applicable.

7) The study considered that a minimum indoor air speed of 0.65 m/s is required to increase the neutral operative temperature.

8) With illustrates the effects of indoor relative humidity on the adaptive equations for the hot-humid and hot-dry climates result indicates that humidity influences the predicted neutral temperature in hot and dry climate but not in hot and humid climate.

Effects of Indoor Air Speed and Humidity On Thermal Comfort of Building in Hot Climate

As mentioned in the previous section, the changes in adaptive temperature that is required for thermal comfort are larger for hot and humid regions compared to regions with moderate weather. The humidity also contributes to preferred indoor operative temperature as stated before. In Cândido et al. (2011) it has been shown that comfortable indoor temperature rises when the air moves more swiftly inside the building. It has also been suggested that the relative humidity of the ambient air influences the indoor thermal comfort level (Nicol, 2004). As a matter of fact, the air movement and the relative humidity of the air in indoor spaces have profound impact on the adaptation equation in hot climates either dry or humid.

In the appendix of ASHRAE (ASHRAE, 2010), it is suggested that when the temperature inside the building goes above 25°C, it is crucial to provide higher speed air movement. The swift air draft elevates the level of adaptive temperature that gives the comfort feeling to the residents. When the indoor versus outdoor temperature scatter graph is considered and the points are modeled by a regression line, this upper level point is the end point of the line. This swift air movement is applicable for both hot and dry, and hot and humid climates with no discrimination in the defined standards.

Wind Catcher

Wind Catcher is referred to a traditional architectural component to provide natural ventilation in houses and constructions.[3] For the aim of flowing the air across such a restricted and well-set texture, wind catchers are placed in southern region of the construction. A wind catcher encounters the cool and desirable wind of the region and confines the air at a decisive height and controls the air into the house. It also assists in the decrease of heat of the walls. In the lack of wind or flow of disordering wind, it works according to the absorption of the entrances backward the wind, let the warm air to escape (Fig. 11). Wind catchers in buildings are generally connected to the summer space or the storeroom (Khalili & Amindeldar, 2014).

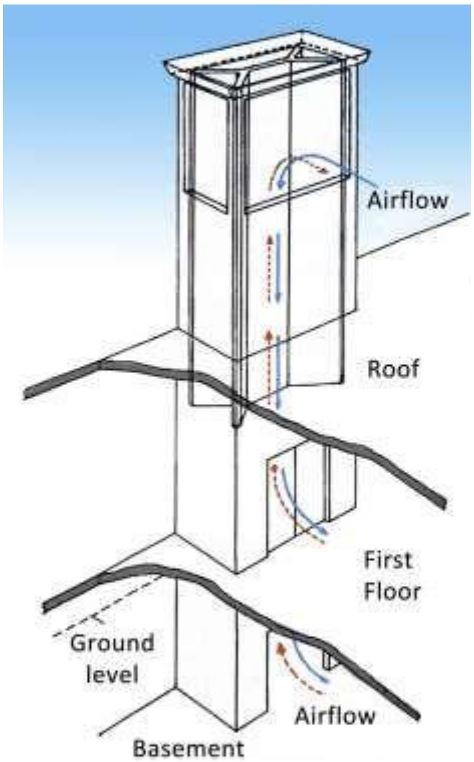


Figure 27 : Section of a traditional wind catcher (Khalili & Amindeldar, 2014).

Integration of Wind Catcher with Basement

In certain traditional buildings in Yazd city (also the examined houses) there has been a channel of Qanat beneath the building. In such situations, Sardab prepared access the channel or between times the Qanat water could arrive the small pond in an area named Hoze-khane (the region covered with a central pool, normally raised and lit through the roof) and exit it from the other side. The pond across the openings of the wind catcher in Hoze-khane may rise the moisture level and cooling condition in this area in the hot and dry region. For the aim of development of the basement effectiveness, the Ivan floor used to be stairs two, three or maybe more steps on the top of the courtyard, preparing a surface appropriate for ventilator entrances underneath the summer environment of the house (Khalili & Amindeldar, 2014).

The moderate temperatures in the basement parts were ceaselessly under the temperature in the outer space, recommending that basements may be a perpetual cooling source and a place to gain comfortable protected area in hot days of summer. However, nearly all the ground-floor areas in which examinations were conducted, the temperature in the interior parts of the building was less than the temperature in the outer side. This states that the chosen houses decrease the temperature in the rooms in the ground-floor through domestic passive cooling systems. (Foruzanmehr & Vellinga, 2011).

The examinations conducted by Haghparast and Niroumand in the basement floor of Borojerdiha House located in Kashan completely acknowledges the results of Forouzanfar in Yazd city. The indoor temperature in the basement floor throughout the 24 h less than the outdoor temperature, and it is generally about the comfort zone, i.e. 21–28 ◦C in summer time. The most important difference between the temperature of the indoor and outdoor spaces is at 2 p.m. amounts to 16 ◦C (Fig. 28).

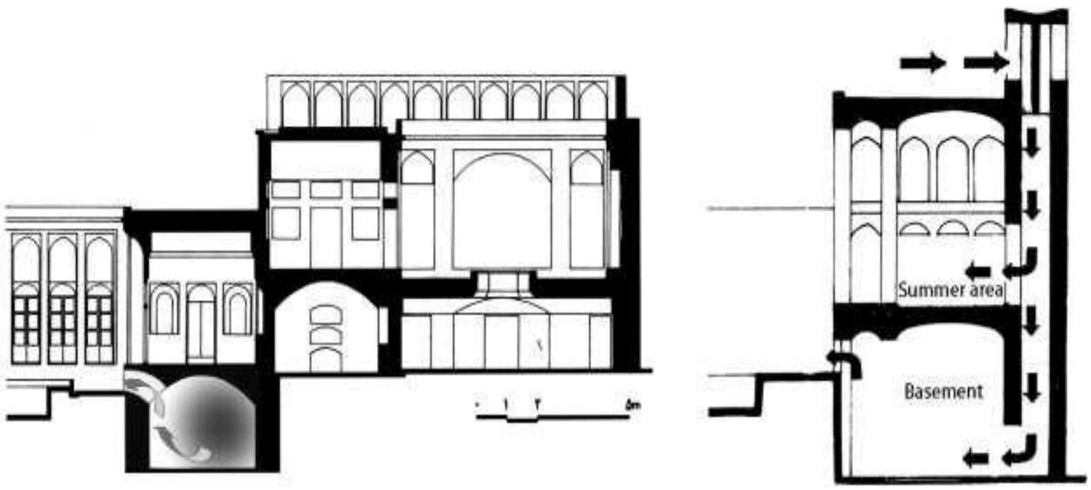


Figure 28 : The difference in height is owing to basement ventilation openings ((Khalili & Amindeldar, 2014).

Heat Recovery Technology for Passive Ventilation

Heat recovery is a technique that is progressively utilized to decrease the heating and cooling requirements of the houses. Building exhaust air is applied as either a source for heat or heat sink conditioning on the climatic conditions, time of year and circumstances of the house. The thermal energy in the exhaust air system can be transported to the incoming fresh air, therefore increasing the temperature and decreasing the heating request in the heating season. Throughout the cooling seasons, the exhaust air can be utilized as a heat sink for the thermal energy in the incoming fresh air that is warmer, consequently decreasing the cooling request (Connor et al., 2016).

In the UK, air temperature inside the building has enhanced by 3 °C through the past decades, requesting a 20% rise in the consumption of heating energy . Utilizing the devices for the heat recovery to transform the temperature into the incoming air and increase the temperature will help to save significant amount of energy. Changes in the behavior and attitude of the residences and the high consumption of electricity in many residential area buildings have terminated in interior heat gains from electrical devices that is significant. The temperature that rises from these heat gains prepare an authentic heat source that could be regained gradually by a heat recovery machine, decreasing the confidence of heating systems (Connor et al., 2016).

Ventilation of a house equipped with passive or natural techniques is a generally used method that is receiving high popularity because of the low organizing costs and developed indoor environments for the residences. An integration of low energy ventilation and heat recovery method is beneficial for building contractors because of the potential for savings oh high cost. Besides, the decreased environmental influence would be reduced emissions for greenhouse gases.

Cooling Load Reduction in Buildings of Hot Climate, Combining Phase Change Materials and Night Purge Ventilation

Night purging ventilation system is a well-known passive method to conserve the cooling energy through storing night cooling activities in the thermal mass of the house fabric (Solgi, et al., 2016).

Night purge ventilation is one of the most effective passive cooling systems, utilized in many houses because of the high ventilation amounts received throughout the night time. Such system also, has no considerable effect on the design and facing of the houses (Endurthy, 2011). Night purge ventilation technique is referred to the circulation of cool air in the night in the internal areas to refresh the interior thermal mass that will terminate in a decrease in the inside temperature and the cooling load of the HVAC systems. Integration of thermal mass with night purge ventilation system, also help to decrease the cooling energy consumption through pre-cooling process of the mass of the building and prepares thermal ease throughout the day time (Solgi et al., 2016).

Thermal energy mass materials are those that could absorb, store and then extricate the accumulated thermal energy into the inside of the building.

The latent heat reservoir in phase change specifications, latent heat, is much greater than the heat stored in materials due to changes in the temperature, sensible heat. Considering such characteristic PCMs are utilized in different usages same as thermal storage mainly in solar active systems (Esen, 2000). Such materials are also utilized to decrease the cooling load of the houses by success using night purge ventilation (Zhou et al., 2009). The integrating phase change materials and also the night purge ventilation will be an engaging solution to preserve the energy. Application of appropriate thermal mass decrease the cooling load of the houses in hot-arid climates, in small weight construction, utilizing phase change materials to develop the cooling efficiency of night purge ventilations. Moreover, the appropriate PCM using in such climate, the conditions to gain maximum productivity of night time purge ventilation mixed with phase change materials, same as air change. The study in hot climate environments demonstrates the 29.6% decrease throughout the year (Solgi et al., 2016).

One major research conducted by (Kolokotroni & Aronis, 1999) represented some variables for the building same as building mass, solar and internal profit, shining ratio and the direction and state that the housing design optimization for night time ventilation according on these parameters may cause a decrease about 20–25% of the air conditioning energy usage.

Solar Chimney

In 1931, the term ‘solar chimney’ is firstly referred in literature (Haaf et al., 1983). Heat funnels or solar chimneys have been designed based on passive mechanical ventilation and are mainly implemented in buildings to prepare heating and cooling with zero energy consumption. Mechanical ventilation is recognized as the traditional way of producing air flow in buildings and this technique has been the major type of air conditioning for hundreds of years. However, alternative energy resources and increased air pollution, encourage designers to introduce modern methods of air conditioning which are simply combined with traditional strategies nowadays to provide a more comfortable environmental control in buildings (Ghalamch et al., 2016).

In (Bansal et.al, 1994), the practical aspects of heat chimney in environmental control of constructions is analyzed by measuring how this system influences the ventilation speed. According to the results, solar funnels are capable of maintaining the temperature of the space almost close to ambient air. Hence, the authors have concluded that solar chimney is an effective way in providing thermal comfort by directing heat from inner spaces to the outside. As a matter of fact, solar induced ventilation is more efficient compared to other ways of mechanical ventilation like leaving windows and doors open.

The optimum inclination of the absorber in solar chimneys positioned at roof top is investigated in 2006 by Mathur et al. Their analysis has confirmed that the most efficient inclination of the absorber is in the range of 40º to 60º which is defined by the geographic latitude. Further investigation has been performed by testing a small size heat funnel for different characteristics and measuring the ventilation rate. Experimental results show that there is a positive relation between the absorber elevation and ventilation rate. In addition, as the size of the gap between the absorber and the glass increases, the ventilation rate is speeded up (Mathur et al., 2006)

Figure 22 shows a graphical plot of the solar chimney in a room. As it is illustrated in the figure, heat chimney has a glass surface exposed to sun. The sun exposure is captured by the absorber surface and increases the temperature of the ambient air near the collector. Thus, the heated up air on the chimney's entrance produces a vacuumed draft and generates a ventilation flow in the living space (Haghighi & Maerefat, 2014).

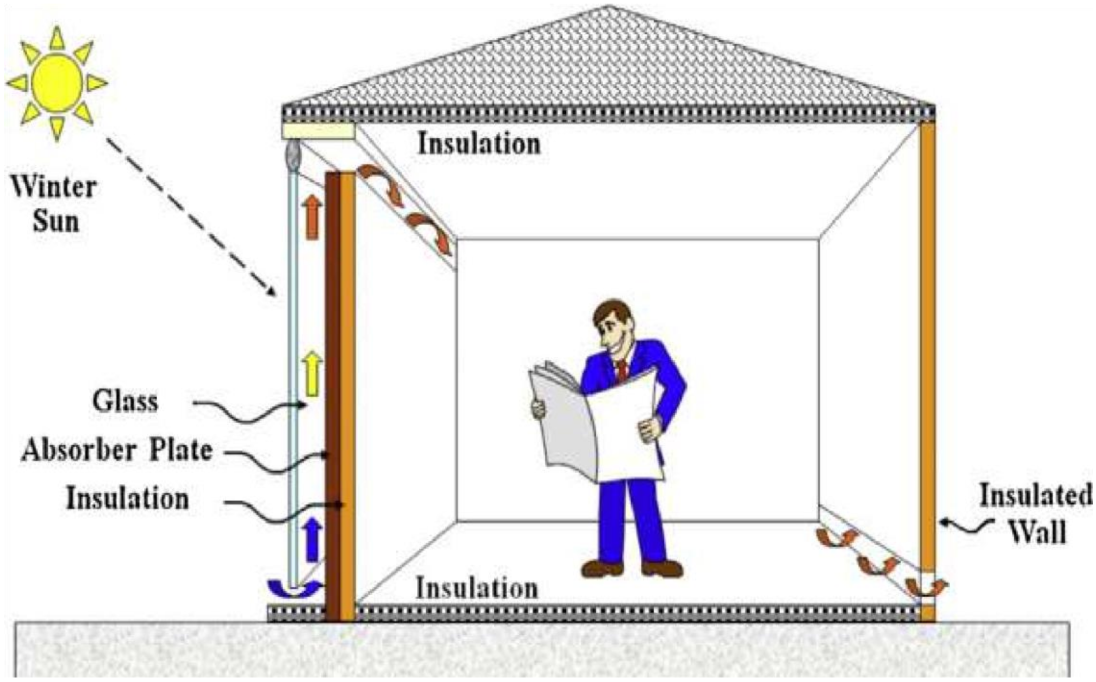


Figure 29 : schematic plan of system (Haghighi & Maerefat, 2014).

Temperature difference between head and feet is identified as temperature gradient. This difference causes either a feeling of warm discomfort at head height or a feeling of cold discomfort at feet level. Therefore, a constant temperature at all levels of the living space is essential for thermal comfort. Numerical investigation conducted on different sizes of outlet in solar funnel has shown that at height equal to 0.3 meters, the outlet provides the room with almost zero temperature gradient. This means that the optimum outlet height is less than 0.3 meters for benefiting from a uniform air temperature in the whole space (Haghighi & Maerefat, 2014).

In addition, the results of previous studies have implied that solar chimney is capable of providing solar comfort when heating and cooling demands are not extreme. In fact, when solar radiation is intense, efficient isolation is required to implement thermal comfort using heat chimneys. A similar trend is also applicable for cold ambient air and low intensity solar exposure; as solar chimney is not enough to fulfil heating demand when isolation is poor.

The Effect of Solar Chimney Layout On Ventilation in Buildings

Solar chimney is considered as a passive air conditioning method designed based on renewable solar energy. This mechanical ventilation system is designed as a duct conducting air flow to provide ventilation for living spaces. Actually, the structure of the heat chimneys implemented in different positions of a construction can effectively influence the rate of air flow in the building (Roach et al., 2013).

Asadi et al. have studied the performance of heat chimneys in ventilation rate in different parts of a building. Solar chimney layouts designed in three spaces located namely at South, East-South and West-South of the resident are studied and compared. More specifically, air ventilation rate in the central part of the plan and the part faced to south is considered for comparison. The investigations have revealed that the best part of the building for heat chimney layout is the part faced East-South as the solar funnel is exposed to intensive solar emission and at the same time benefits from two absorbing surfaces (Asadi et al., 2006).

Heat chimney has been introduced in (Seppanen et al., 2003) as a natural mechanism of ventilation that enhances thermal comfort in buildings. The only difference between a solar funnel and a simple funnel is that solar chimney has a wall faced to South which is made from glass. Sun exposure crosses that glass and is captured by the absorber surface which is the non-reflecting wall. The thermal energy heats up the air trapped in the canal and generates an upward draft according to chimney effect. As a result, the air in the room is directed to outside and replaced by the fresh air in the chimney. The absorbing walls of the solar chimneys stay heated when the sun radiation is poor or even during the night. This phenomenon is effectively utilized for ventilation at nights in hot and dry regions (Roach et al., 2013).

2.3.1.2 Passive Building Design for Visual Comfort by Use of Passive Building Design Strategies

Studies and researches to incorporate passive solar house design methods can involve various cost implications. For instance, analysis of different parameters along the design stage can rise the design time, and consequently the cost. Therefore, it has been considered that the most important decisions regarding the building sustainability can be made in the primary design stages, by the architect or building designer. Proper orientation, location on site, and landscaping changes may potentially decrease the energy requirements of a typical dwelling about 20 percent.

According to Carlos Ernesto Ochoa et al, studies using shading equipment is advantageous for controlling the glare. The best energy-wise design option in these series implemented external blinds, low-emissivity glazing and the stepped light control. Moreover, it also demonstrates more comfortable visual conditions inside the building (Ochoa & Capeluto, 2008).

Utilizing a light shelf for these orientation is a suggested solution to decrease the energy use in artificial lighting methods and keeps glare indexes at appropriate levels. Therefore, discomfort glare due to clerestory window aspects and deep light redirection should be seriously regarded by the designer in such situation.

The integration of optimized active specifications with passive design methods provides in a consistent way very promising energy savings and glare control, but is greatly influenced by the primary intelligent design decisions. Proper daylight admission as well as advanced electric lighting controls (such as dimmer) also decrease the request for cooling and heating purposes (with a slight rise for north regions). Integration of dynamic shading equipment with lighting redirection systems same as light shelves decreases the electric lighting consumption, reducing the energy for cooling purposes. Proper performance is also gained for the units facing the north side, while it is suggested to provide users with means for glare controlling (Ochoa & Capeluto, 2008).

Orientation

Attention to the orientation of a building is a primary step in the integration of passive solar design methods at the building and development steps. At the design step, the proper orientation is a mainly easily implemented, low cost energy efficiency method. Such strategies for energy utilization decrease in buildings need to consider how new houses are designed and constructed. The International Panel on Climate Change (IPPC) addresses this opportunity for higher energy productivities of the built environment, defining the intelligence design and flexible energy solutions as appropriate techniques to help reach a 30% reduction in emissions. Amongst such options is careful orientation of existing designs for the aim of optimizing the passive solar performance. The passive design method has a potentially significant coordinator to thermal performance and consequently the energy efficiency. The results confirm that the passive solar design is an idea that can readily be integrated into house designs at the design stage. In order orient buildings maximize their passive solar advantages.

Amongst passive design rules, the issue of building and window orientation is mainly considered as significant issue. For instance, in temperate climates, where winter heating invariably provides a significant energy requirement, the facing of living room windows to the midday sun decreases the mechanical heating request. When such windows face east or west, the benefit is decreased. So, there are two ways to provide optimal orientation. The first is to analyze different parameters and ensure optimal design and orientation on a building by building foundation and the second is to develop 'adaptable' designs that work well along a range of various orientations (Rabah, 2005).

The Role of Orientation in Passive Design

Passive solar building design methods can be defined as the application of the sun's energy besides the local climate specifications and chosen building materials to directly keeping thermally comfortable conditions within a built-environment (Rabah, 2005).

Proper passive solar design methods should consider main building factors such as building orientation, plan proportion and shape, facade glazing design and obstruction via surrounding buildings. Such parameters, the proper orientation is the most basic and generally the most easily addressed perspective of passive solar design method. Solar glazing, for instance, is considered as an effective passive solar method (Rabah , 2005). By definition, solar glazing should face the winter sun but in reality, the solar glazing of direct gain methods will generally be defined by the orientation of the building itself (Rabah, 2005). In hot climate areas with high radiation, the proper orientation is a highly influential method to lower energy use and, if well designed at the early steps of the design process, may be simple and cheap to conduct (Andersson, 1985). Moreover, proper orientation can provide potential for additional savings from more sophisticated passive solar methods (Fig. 30).

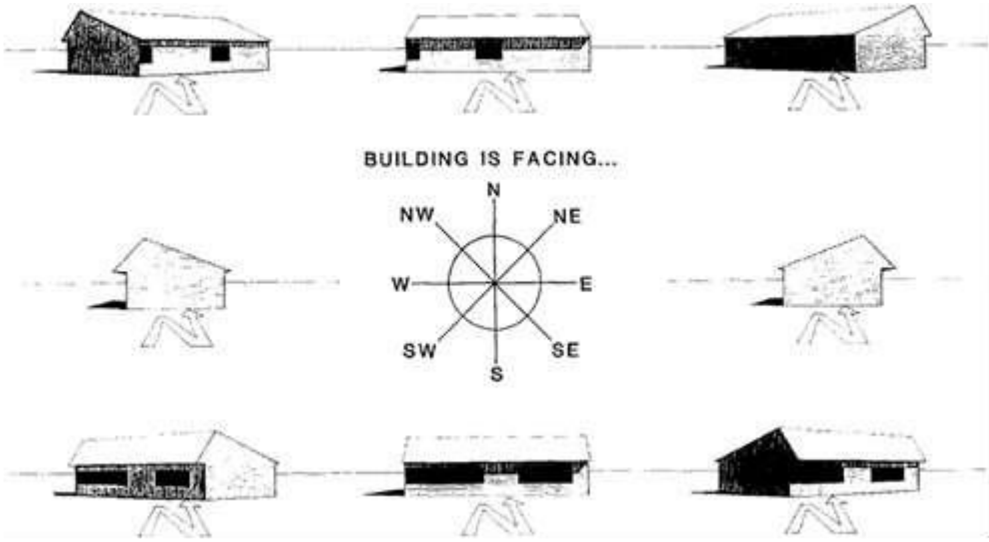


Figure 30 : Schematic showing different orientations for a residential building (Andersson , 1985).

From a north hemisphere aspect, spaces without a south orientation influence on the ‘energy behavior’ of a bughouse or structure in three ways:

(1) decreased availability of daylight;

(2) decreased heating advantages from solar gain in winter

(3) for warmer climate regions, higher cooling loads in summer from solar gain.

Constructions with such specifications require more energy for space heating and cooling compare to the counterpart buildings with good orientation and passive solar energy design.

Orientation is also of importance at the development aspect. Building orientation and its connection to site planning and design of the building can apply a substantial effect on the end-use energy consumption rate of a house and its orientation and lot alignment may mainly influence on the on the 'solar envelope', determined as the physical boundaries of the environment specifications and the time of their assured access to the sun light (Knowles, 2003).Fig. 31 demonstrates the influence of three different block orientations on size and shape of solar coverage effects that have importance for productivities at both the building scale and the development scale.

It is obvious that effective solar absorption as requested by the passive solar functioning, is a complex dynamic usage of orientation, building geometry, glazing ratio, heat-flow path, indoor zone heat transfer techniques and thermal mass.

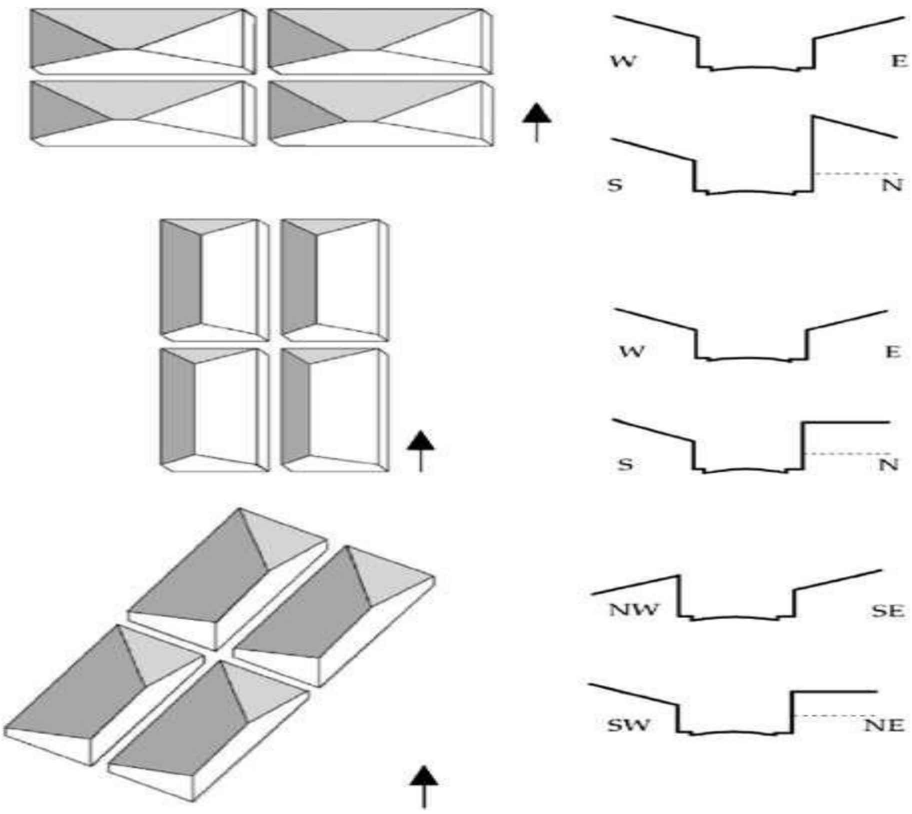


Figure 31 : Effect of block orientation on size and shape of the solar envelope (Knowles, 2003).

Building Form

It is obvious that the form of a residential building and its size influence the energy usage in the building. In (Catalina et al., 2011) it has been proposed that a cubic form helps reducing the energy consumption. In addition, the orientation of the design is crucial for efficiency of the solar system used for heating and lighting. In fact, heating and lighting contribute to a significant proportion of the energy consumption in the building and a proper direction of the design facilitates the use of solar radiation for these purposes (Abanda & Byers, 2016). Appropriate building orientation has been recognized as the most vital factor influencing the effectiveness of the solar energy use. According to Pacheco et al., improper orientation can lead to more energy consumption in buildings (Pacheco et al., 2012). It has also mentioned that by an optimized design considering the correct direction and the proper form of the building, energy can be save by up to 36%.

Other studies have listed location, direction and landscaping as the energy saving mechanisms that can reduce the energy consumption by 20%. In a study conducted in some main cities of China, it has concluded that optimized building orientation can save significant amount of energy (Abanda & Byers, 2016).

Roof Forms

Roof of the building is responsible for about 64% of the energy consumption in Singapore as it transfers heat into the interior spaces. The solar angle is large in this location and thus flat roofs are exposed to sunlight three times larger than vertical walls. So, the heat gain through the roof is the most important proportion of the daily heat gain in the building (Zingre et al., 2015).

On the other hand, the angle of incidence is smaller in flat roofs compared to the dome shaped ones. This is shown in Figure 16. In addition, the curved roof is exposed to more wind that helps removing the heat. During the night, the large surface of the dome provides the indoor space a wide heat loss surface. Furthermore, because of differences in the sun radiation at different parts of the dome, one side is always at the shadow. The shaded side provides colder air under the curved roof. In general, constructing dome shape roofs increases the space and results in an air draft inside the building (Mirrahimi, 2016).

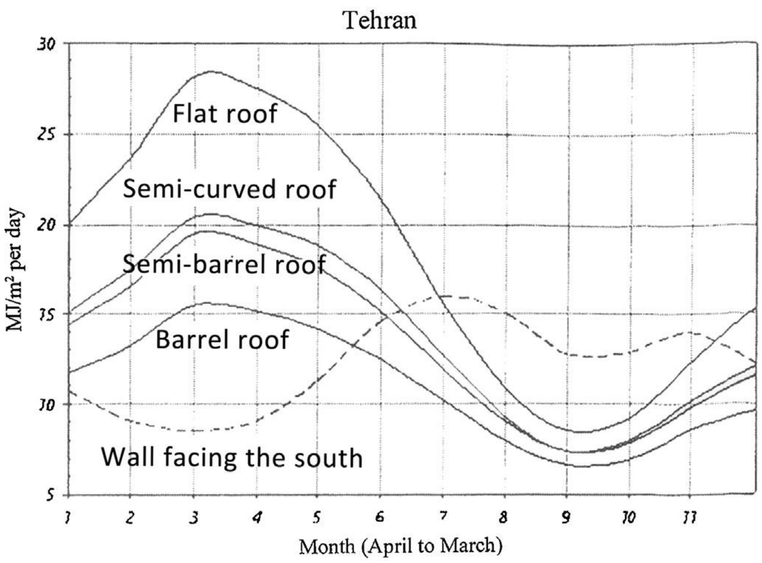


Figure 32 : Distribution of total daily solar radiation on the roof in the dry and hot region (Mirrahimi, 2016).

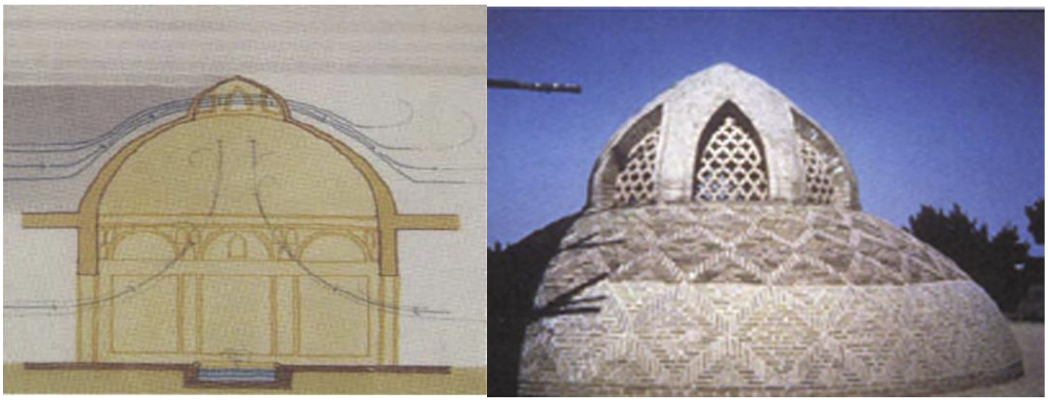


Figure 33.Ventilation by Khishkhan (Mirrahimi, 2016).

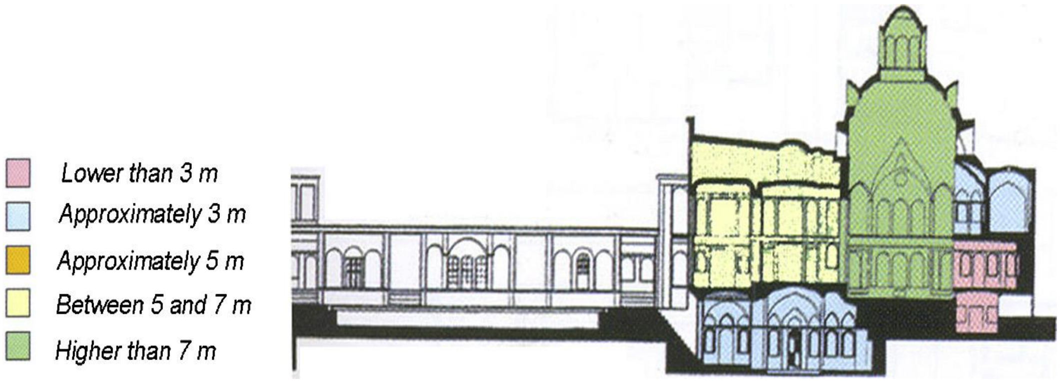


Figure 34 : Khishkhan is located in highest part of the building for better ventilation-Boroujerdiha house, Kashan (Mirrahimi, 2016).

Building Form, Width, Length and Height

The effect of the shape of the building on cooling strategies is studied by several researchers On important aspect of the problem is the application of shading mechanisms. Hyde they study different items in the design including heat isolation walls, roof styles, courtyard, veranda, plan dimension and the direction of the building on thermal comfort. According to the study, dimensions of the spaces should not surpass 15 meters since it reduces the effectiveness of natural ventilation strategies.

In fact, form of the building and its orientation define the extent of solar exposure, day lighting, and passive ventilation. Therefore, energy consumption in the building is influenced by shape and direction. Some researchers have suggested that building from is not important when the building is oriented along north and south. It has shown that this direction decreases the energy usage by a factor of 10% (Mirrahimi, 2016).

It has also stated that a low density envelope results in more energy loss while increasing the height activates passive ventilation. While it is concluded that the relation between the height of the building and energy use is not clear (Al-Tamimi, 2011) the impact of plan dimension and shape well recognized. Thus, considering environmental issues and energy efficiency, the ratio of width to depth can be used to define floor plate depth. It is stated that the optimum ratio differs from one climate to the other one. In hot regions the width to depth ratio may be selected between 1:1.7 to 1:3 and 1:1.7 is the optimal ratio (Mirrahimi, 2016).

Another factor that is affected by the shape and orientation is natural lighting. Visual comfort is improved when sufficient daylight enters the building. This clearly results in less electricity demand for lighting. Moreover, a proper design can reduce the amount of unsuitability by reducing the need for energy produced by fossil fuels (Al-Tamimi, 2011).

Building Layout

Natural lighting is crucial for the occupants to feel visual comfort and be able to do their daily activities in a pleasant environment. According to the study conducted by Wong (Wong, 1988). in the hot and humid climate region of Singapore, integrating an accurate natural lighting integration is a strategy for saving energy for both lighting and cooling since it reduces the heat gain by artificial lighting.

There are some characteristics that define the optimum building layout in a specific climatic including roof design, shape, width to depth ratio, length and height, envelope, the area of glazed windows, passive ventilation and shading mechanisms. Particularly, these factors influence the energy consumption as well as thermal comfort. In the literature, these factors have been analyzed and some recommendations have been made for the designers to improve thermal comfort in different climate conditions (Mirrahimi,2016).

An efficient building design is expected provide a pleasant shelter for the occupants whatever the climate zone is. From this perspective, building envelope is recognized as the primary mediator between the interior space and ambient weather. Since the very beginning of the architecture science, envelope design have been optimized according to the climate conditions. The extent of sun radiation and the mean daily temperature are important factors in designing the façade (Bahaj et al., 2008).

The effect of different shading mechanisms on the energy efficiency of the building have been investigated by (Shen & Tzempelikos, 2013). In this study, the whole year transient and stable thermal conditions and lighting are simulated. Blinds are used to improve visual comfort for the occupants. More precisely, four interior shading strategies have been compared in terms of day light integration, energy use and the quality of visual comfort. The effectiveness of automatic roller shades in energy saving and decreasing visual discomfort has been proved.

Natural shading by means of plants is also a recommended shading mechanism. During the hot season, leaves play the shading role and block the sun radiation. In the cold season however, the leaves fall and let the light enter the building. In related a study the role of the trees in natural shading is explored. It has revealed that not only the heat gain and energy consumption reduce, but also the shaded area is cooler as a result of evaporation n from leaves' surfaces (Yao, 2014).

This phenomenon has been studied in details in Greek. The study has shown that the walls covered with plants have noticeably lower temperature compared to the bare ones as a result of shading and evaporation. Interestingly, the average daily temperature of the walls covered with plants lies in the comfortable temperature range (Yao, 2014).

In the building sector, privacy is also a critical feature. While the occupants want to have a view over the outside, they desire to have their privacy in the interior space. The relation between natural lighting, privacy and view to the outside have been studied by Kim et al. The experimental results have set to compare exterior shading with interior blinds. It has been concluded that external shading is more effective in improving visual comfort. Decreased greenhouse gas emission is another factor that is stated in the literature as the benefit of solar shading mechanisms (Kim & Kim, 2010)

Effect of Semi Open and Open Space to Reduction Energy Use in Hot Climate Regions

In the hot regions of Iran, one of the famous design items in vernacular architecture is called 'Ivan'. This is an exterior space with two semi open sides and an open side overlooking the courtyard. Ivan is a form of veranda connecting the interior space to the open space with preserving special configuration. This architectural element also provides thermal comfort in its close interior spaces. An Ivan facing north is more frequent in Iran since it provides a mechanism of cooling during the hot season. On the other hand, verandas facing south and east are more effective during the cold season for absorbing solar heat.

The spaces with Ivan are mainly located in the summer parts of the building where this shaded semi open space is not exposed to the afternoon sun radiation. These specifications result in lower temperature in the side of the building that the Ivan is located compared to the outer space and the opposite side. The resulting temperature difference produces an air draft that flows from the open space into the veranda and improves thermal comfort in summer (Khalili & Amindeldar, 2014).

Referring to the study conducted by Haghparast et al. (2007), in a vernacular house in the hot region of Iran, the main porch or Ivan is very effective in providing thermal comfort during the summer. They measured several factors in Boroujerdiha house located in the city of Kashan, Iran in their study. At 12 pm for example, the temperature at Ivan is up to 7°C lower than that of the ambient environment. It has concluded that while the resulted temperature is not in the comfortable zone, the drop is considerable in the room connected to the porch (Fig. 35).

The orientation of Ivan is defined by the desired wind in some regions such as desert region of Tabas in Iran. In Tabas, porches and wind catchers are oriented to face north for this reason. Tavasolian has reported similar pattern in the cities located in the northern Africa and Persian Gulf coastal region (Khalili & Amindeldar, 2014).

Figure 35. Different forms of Ivan (semi open spaces) in Yazd and Kashan, Iran. (Khalili & Amindeldar, 2014).

Courtyard (Godalbaghche)

The open space of courtyard has been a fundamental element in vernacular architecture of hot climate. Courtyard or as known in Persian ‘Godalbaghche’ provides a private open space with a microclimate characterized by being cool and humid compared to ambient air. From cultural perspective, courtyard has been used for family gathering and social events. Referring to Figure 2, the interior space is constructed in a way that all openings faced the courtyard to benefit from temperature drop provided in this microclimate (Khalili & Amindeldar, 2014).

In hot desert, the house envelope is crucial to protect the occupants from hot weather outside as well as sand storms in hot deserts. In addition, the open space of street and sidewalks gets extremely hot in the midday makes them origins of hot temperature that reflected to the house. The exterior walls then provide a protective shield against the heat. The walls also shade the courtyard which is the most favorable open space during the hot season.

The pond constructed in the center of the courtyard and the trees are elements to afford more thermal comfort. Water significantly reduces the variation of the air temperature in day and night and moderates the microclimate inside the central courtyard. Plants provide and reduce the heat in hot and arid climate while there is a mechanism for shading in hot and humid regions.

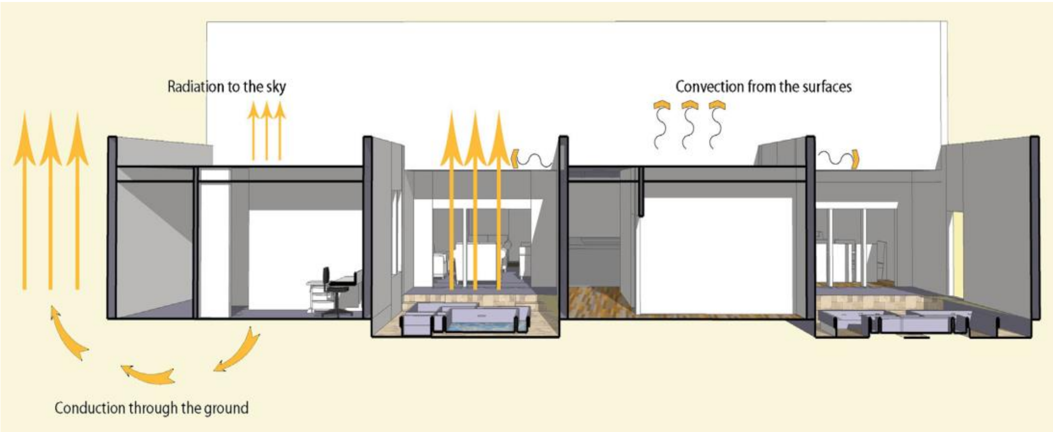


Figure 36 : Thermal performance analysis of central courtyard at night (Khalili & Amindeldar, 2014).

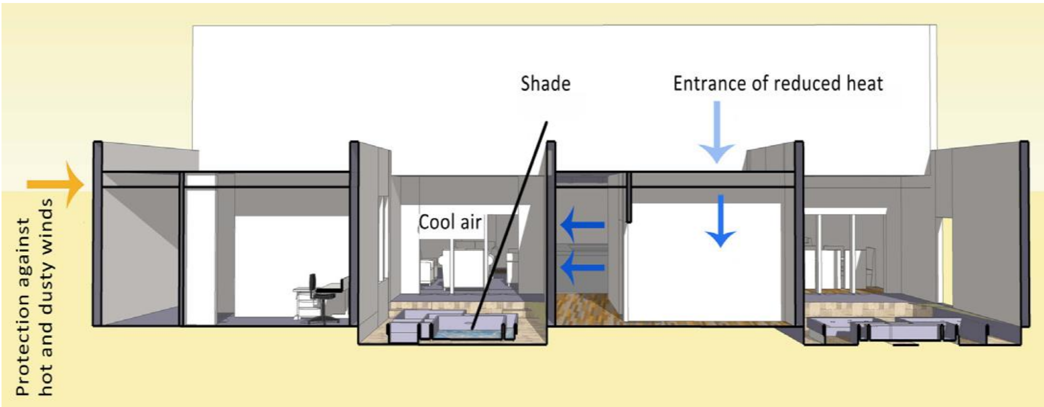


Figure 37. Analysis of central courtyard in terms of thermal efficiency during the day (Khalili & Amindeldar, 2014).

The air draft flows in courtyard as a result of temperature differences is also an important factor in thermal comfort. In a study by Heidari, it has stated that the air flow pattern and velocity influences the indoor thermal comfort as a mechanism for heat removal during the day. Accordingly, it can be concluded that the courtyard and its design elements including plants and water resource is a passive cooling mechanism that naturally cools down the interior space via air draft. It has proved that the speed of the air draft in the yard varies with depth to width ration. In Figure 36, the optimum dimension of the courtyard for achieving maximum air speed is plotted.

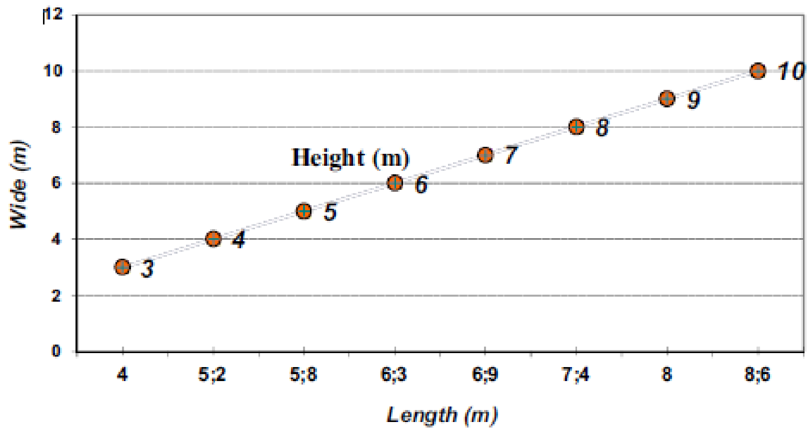


Figure 38 : The optimum width and length for a central courtyard to maximize air velocity (Khalili & Amindeldar, 2014).

Transparency and Window Design

The scale of windows affects the amount of natural lighting and heat gain. In hot climate regions, large size of the window increases the solar heat abortion and enlarges the cooling load. On the other hand, small windows increase the need for artificial lighting that means more energy consumption and more heat generation in the interior space. Hence, the optimum size of the window should be designed accurately considering day light utilization, energy saving, and cooling specially in hot climate (Fasi & Budaiwi, 2015).

Window glazing and interior shading mechanisms such as blinds are the additional items added to the window design to improve visual comfort.

Shading mechanisms are fundamental components of daylight integration. Blinds, either automatically or manually controlled, reduce the heat gain in hot seasons and improve visual comfort. As the daylight integration is more convenient with shading devices, energy efficiency is enhanced as well.

In visual comfort concept, glare index is another important metric. When the daylight integration is designed considering only energy saving, glare index can increase more than acceptable range. A promising level of comfort in addition to energy saving requires accurate design of window size, orientation, blinds and glazing all together.

In a simulation study conducted in hot and humid climate of Malaysia, Lim et al. have analyzed the natural lighting performance of windows equipped with blinds and glazing in a family house. It has been stated that these elements improve visual comfort for the occupants significantly (Fasi & Budaiwi, 2015).

In (Knowles, 2003) an assessment on commercially offered glazing has been performed in terms of energy saving. For each glazed window type, energy efficiency is measures in two different settings with and without natural lighting. They have concluded that choosing the optimum alternative for maximum daylight integration and minimum glare is crucial depending on the design properties. As previously stated, these two factors (daylight metric and glare index) are the commonly used measures for evaluating thermal comfort.

Frequency of Visual Comfort (FVC)

Frequency of visual comfort is a metric to assess the percentage of time that the visual comfort for occupants is provided with daylight only. This value is defined by lower and upper limits of illumination named as E_l and E_u. The acceptable range for illumination to give the occupants the feeling of comfort lies in the range of $E_l \leq E \leq$

E_u, where E is the luminance provided by daylight. Accordingly, in the case when $E<E_l$, the building needs artificial lighting. On the other hand, if $E>E_u$, the glare index is too high and blinds are required (Sicurella et al., 2012).

The limits of the acceptable range are not fixed but defined according to the activities in the building, light reflection and absorption properties of the interior space, the other sources of light around, etc. However, the typical limits for FVC calculation have proposed to be from 100 lux for E_l and 2000 lux for E_u. As FVC is an average estimator, visual performance of different natural lighting strategies and designs can be assessed by it based a monthly or yearly evaluation (Sicurella et al., 2012).

Nabil et al. have represented an analogous criterion named ‘daylight illuminance’. The advantage of FVC over daylight illumination is that FVC measures the proportion of time during the day and thus it is an estimation of average efficiency of daylight for visual comfort (Nabil & Mardaljevic, 2006).

Effect of Solar Shading On Thermal Comfort and Energy Saving

Shading strongly influences the energy consumption in summer and winter. Shading mechanisms are classified into fixed and removable devices. Fixed exterior shades installed on top of the windows, mainly used to block sun radiation in hot season. Extra solar energy produces heat in the interior spaces and results in increased energy use for cooling. On the other hand, fixed shades block the solar energy in cold season as well which is not desired by the occupants. In winter, sun radiation heats up the building and energy usage for heating decreases. To address this issue, a specific design (angle and dimension) should be considered for the fixed shading mechanism which lets the winter wide angle radiation enter the building whilst block the close angle sun exposure in summer. However, the solar energy can still induce cooling load in hot season. Figure 37 graphically illustrates this phenomenon in overhang shades (Yao, 2014).

Movable shading devices are investigated by Jian Yao in terms of solar radiation transmission and indoor luminance. The measurements conducted in a typical building equipped with exterior movable shades on southern facade have shown that using these devices solar radiation is decreased by 8% while they maintain the interior illuminance at approximately 1000 lux. These characteristics have proven the efficiency of exterior movable shades (Yao, 2014).

The energy saving efficiency, visual comfort and thermal performance of movable shading devices are also evaluated in Yao's study. According to the reported results, removable shades installed on the facade facing south decrease the energy consumption up to 31%. Visual and thermal comfort are also improved by approximately 20% and 21% respectively.

As a matter of fact, windows are the poorest element in the building considering the heat loss in cold season and solar radiation heat gain in hot season. Hence, shading is necessary to improve their performance. From this point of view, removable shading devices are recognized as more applicable and effective components than fixed ones.

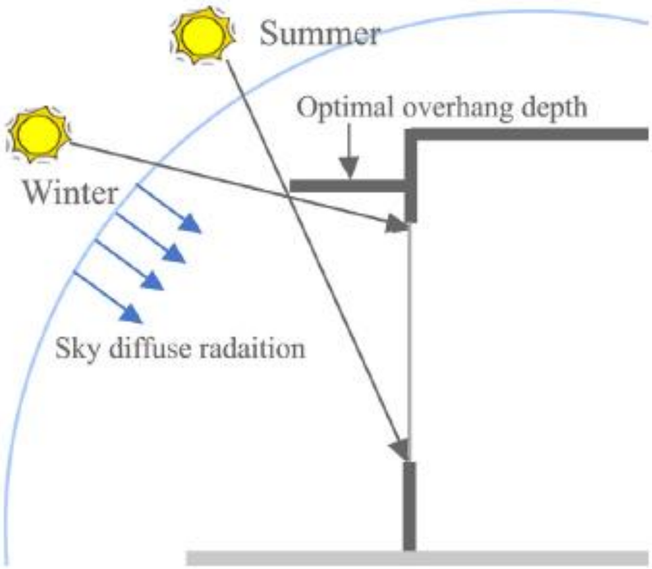


Figure 39 : An optimum configuration of an overhang shading mechanism (Yao, 2014).

In the case of removable shades, external devices are more functional than internal ones since interior blinds absorb the solar energy and convert it to heat that increases interior temperature. The major drawback of external removable shades is their high cost. As a result, although these items are effective in hot climate, they are not so common in the building design. Instead, removable rolling shades or blinds are frequently installed for controlling illuminance and sun radiation heat.

Energy efficiency of removable shading devices has been widely studied in the literature. Simulation results reported by Tian et al. have proved the energy saving potential of these shades during the hot season. The reported rate of energy saving is more than 17% up to 22.7% in different cities (Tian et al., 2009)

Two different solar shading layouts including fixed horizontal blinds and adjustable dynamic blinds are compared with windows without shading. In dynamic blinds the direction of the slat is regulated based on solar radiation. As expected, simulation results have revealed that dynamic venetian blinds are more efficient in energy saving and provide a higher quality visual comfort using daylight integration. In addition, the proficiency of dynamic louvers with solar blocking mechanism has also been verified in (Yao, 2014).

Effect of Solar Shading On Visual Comfort

Solar shading devices influence visual comfort and enhance environment conditions. The experiments conducted in a test room with real dimensions have demonstrated that automated blinds improve environmental performance compare with manually controlled venetian blinds. Performance was by measuring temperature and illuminance in the interior space and for the manual blinds artificial lighting was used when they were completely closed (Yao, 2014).

In tropical climate, the performance of automated blinds is studied by (Chaiwiwatworakul et al., 2009) In this type of blinds an automated controller regulated the shading slat orientation according to the solar radiation intensity. It has concluded that the system is capable of maintaining the visual comfort at high quality by providing enough illuminance and decreasing glare index when necessary. Further studies have evaluated movable shading devices by measuring interior light and glare index variation and temperature inside the building.

A comprehensive analysis of the performance of movable shading devices was performed by Yao. His experiments include simulations and filed measurements using movable shades installed on the southern facade of a conventional building. Energy saving, thermal comfort and visual efficiency are used as the metrics for performance assessment.

According to the measurements, movable shading devices reduce extreme solar radiation that enters the interior space during the summer. Actually, 8% more solar radiation is blocked compared to windows without shades. The amount of energy saving is more than 30% which is equal to the half of rate that may achieved by installing expensive heat isolation walls and Low-E double glazed windows. The thermal comfortable durations are improved (by 21%) and the uncomfortable period reduces significantly (more than 80%). The enhancement is visual comfort duration is equal to 19.9% as well (Yao, 2014).

Emerging Glazing Technologies for Façade Design

The facade of the building is responsible for visual and thermal comfort of the occupants. This is the glazing of the facade that plays an active role in visual and thermal comfort. In hot regions, the target of an air-conditioner is to maintain the quality of the interior space at a high level by consuming minimum energy. The glazing design is important then for reducing the heat gain by solar radiation as well as providing air draft for a fresh environment. There are different aspects of study on the development of advanced glazing including natural lighting, solar radiation control, high performance isolation, and even photovoltaic glazing. There are also some modern emerging approaches like aerogel glazing which consider all the aspects. Regardless of the technology utilized in the design, facade has two basic elements reacting to solar radiation: windows and blinds (Bahaj et al., 2008).

Different glazing technologies have different characteristics such form the energy saving, and performance perspective. Figure 40 illustrates the features of 7 different glazing. Referring to the figure, it is obvious that each technology has its strength and weaknesses. As a matter of fact, some of the performance metrics are not satisfied for each technology. However, it is concluded that a combination of shading devices with Low-E glazing is the optimum technology to save energy and provide visual and thermal comfort.

Matrix of Facade Technologies

		Solar Control	Daylighting	Glare Control	View to Exterior	Maintenance	Availability	Lifetime
Emerging Glazing Technologies	Aerogel Glazing *	−	+	−	O	+	−	O
	Vacuum Glazing *	−	+	−	+	O	O	O
	Switchable Reflective Glazing	+	+	O	O	O	−	−
	Electrochromic Glazing	+	O	O	O	O	O	−
	Suspended Particle Devices	+	O	O	O	O	O	−
	Reflection HOE	O	+	−	O	O	−	O
	Photovoltaic Facades	O	O	−	O	O	+	O
State of the Art	Low-e Glazing	O	+	−	+	+	+	+
	Tinted Glazing	O	O	O	O	+	+	+

Legend
+ good performance
O intermediate, moderate performance
− poor or unknown performance

Figure 40 : A comparison of performance and risk metrics for 7 different glazing technologies (Bahaj et al., 2008).

Holographic Optical Elements

One of the advanced visual technologies in building design is Holographic optical elements (HOE). As shown in Figure 41, HOE is consisted of two glass sheets sandwich with a holographic thin film inside. The key characteristic of this technology is that it changes the angle of sun radiation at specific angle. By installing the glazing at an appropriate angle according to the solar incident radiation, the rays are diffracted into the ceiling. Accordingly, the need for artificial lighting is reduced which means less heat gain and less energy usage. Although the HOE technology improves the quality of daylight integration, it has some drawbacks. Firstly, the glare effect is still remains since the diffraction performance of the transmitted solar radiation varies from 25% to 55%. Additionally, rainbow phenomenon at edges can cause discomfort. The milky appearance of the glazing is also a problem (Bahaj et al., 2008).

Another emerging technology is reflective holograms. The incident solar daylight is reflected in this technology while the scattered daylight is entered the building. This glazing technology decreases the heat gain properties of the facade but in order to have a view over the exterior some adjusting or ray guiding mechanisms should be implemented.

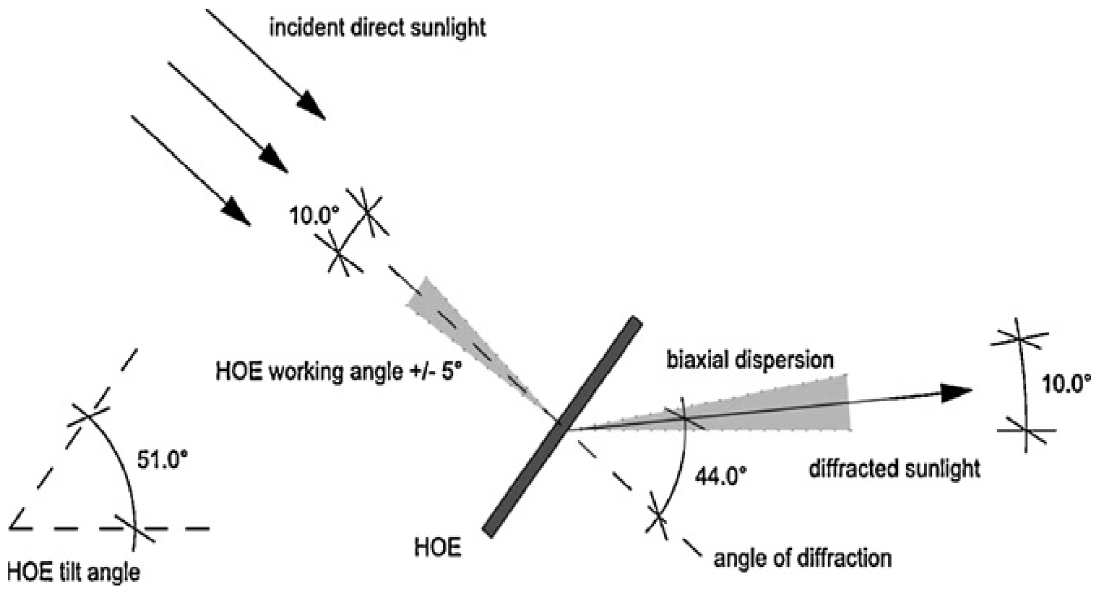


Figure 41 : Functionality of HOEs in the building's facade (URL 12).

2.3.2. Energy Efficient Mechanical System

One of the main technology which is utilized in cooling and heating industry and also modern building is HVAC system. Infect, HVAC system as a section of mechanical engineering is abbreviation of heating, ventilation, and air conditioning which could dehumidify, heat or cool air flows via several ducts to spread all parts of apartment or hotel and manage proper temperature and suitable quality of interior air. Moreover, there are remarkable benefits to use the HVAC system such as prepare ventilation, decrease air infiltration and keep pressure among spaces (Teke & Timur, 2014).

The HVAC industry as a global enterprise plays significant role in construction section and being prior parameter to design the modern buildings.

In addition, the real demands for HVAC system is specified by significant parameter which is named occupancy also when real occupancy adopts with HVAC system then energy consumption decreases and load of cooling and heating reduces by high efficiency of performance. Actually, with low occupation of space, there is no need for loads to address by HVAC systems (Pauschinger, 2012).

Generally, the main thermal control units in buildings are combination of several zones which total loads in whole spaces of zone are determined and considered.

The various values of occupancy through zones could decrease the efficiency of system.

Furthermore, there are some recommendation which are stated by authors to reduce energy consumption such as suggestions of Yang et al. who offered that occupancy diversity is applied in design of buildings to decrease extra loads. Moreover, he stated that real time and long term occupancy information are determined for energy efficiency for the buildings supplied by ambient sensor network. Finally, he suggested that occupancy driven set point control could be optimized universal to decrease the loads created by occupancy diversity which is possible by giving permeation to various zones to have several values of failures and various waiting time to operate the setback such as various supply air flow temperatures and rates.

In addition, HVAC system is the major energy consumer in the buildings and also approximately it calculates for 60% of whole cost of energy inside of building (URL 14).

Basically, heating operation of HVAC system is utilized in cold weather and also cooling operation is utilized in warm climates and the operation of air conditioning which is elimination of the humidity of interior air. Usually, the applications of central HVAC systems are inside the skyscrapers or high rise buildings or medium apartments and split system is utilized in houses.

In fact, HVAC systems are categorized into two sections which are direct expansion (DX) and central systems. In DX Systems, refrigerant inside the evaporator is utilized as the cooling media to remove heat from air flows. Furthermore, second section is central system which is utilized for air conditioning by using of series of equipment to spread cooling media to remove heat and provides conditioned air from one place to another part of building (Teke & Timur, 2014).

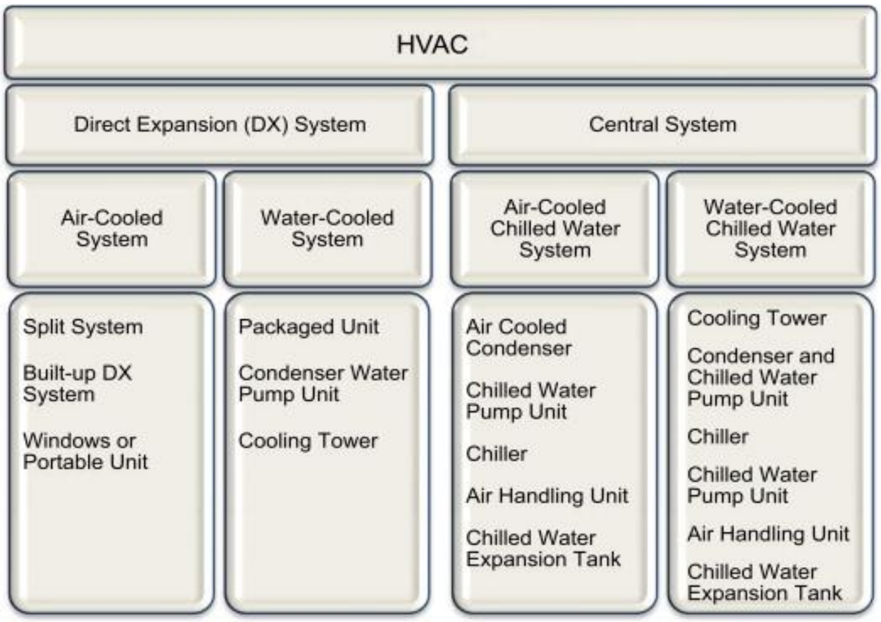


Figure 42 : The classification of HVAC system (Teke & Timur, 2014).

2.3.2.1. Energy Efficient HVAC System

Among the surveys, scholars obtained several factors which are evaluated to design a low energy building such as design combinations, element thermal characteristics and efficiencies of HVAC systems. Moreover, these parameters specify the demands of space heating and cooling energy, energy consumption and life cycle cost through the lifetime of the building (Aparicio Ruiz et al., 2016).

In general, the construction companies interest in low energy but there is lack of budget in building design as an important sector. Through the literature, the investigators demonstrated the link between index of energy efficiency and investment for optimization of building. In According to their findings, the scholars stated that with utilization of HVAC in the integrated optimization method, the proper value of energy rate has reached for residential buildings. Actually, the fundamental aims of applying this methodology is to decrease investment and the demand of energy and chooses the highest quality of construction materials, giving chance to consider the cost in various issues of economy (Aparicio Ruiz et al., 2016).

The major aim of HVAC systems in buildings is confident about a specified value of thermal comfort and also generally this target emphasizes on huge amount of energy consumption and high cost for the installations. In addition, insufficient coating of building and outdated installations are major obstacles to reach optimal interior climate comfort in common design and systems.

Based on drawback of conventional systems, K. Lai stated that there are two major aims in design of buildings which are HVAC system and building coating design and also the two solutions are proposed to modify the performance of energy in a building which are increasing the coating thermal quality and the efficiencies of HVAC system (Lai et al., 2014).

Moreover, the first solution specifies the need or demands of energy and the second one has straight relationship with major consumptions of energy in buildings.

On the basis of these solutions for modification of performance of energy, the certain methodology is proposed which includes two stages. At the first stage, needs of energy are decreased with utilization of passive design and also using a better thermal coating of building. For the second stage, efficient HVAC systems are utilized to heat or cool the space (Cho et al., 2014).

These two steps demonstrate the three most significant decisions which are connected to thermal comfort in buildings as illustrated in Fig.43.

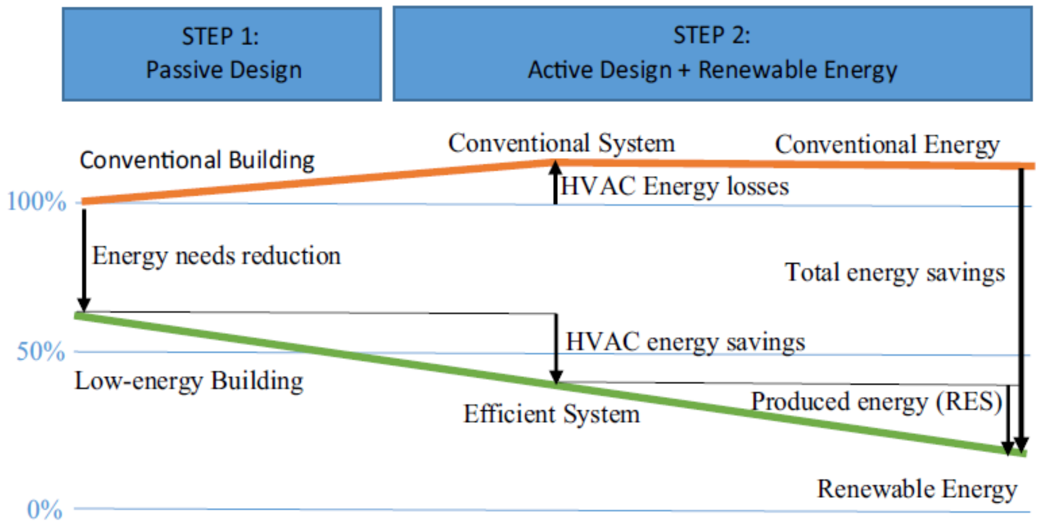


Figure 43 : By implementation of both important decisions, zero energy building (nZEB) design is reachable in the passive and active designs which suggest low energy consumptions and the utilization of renewable energy sources (Aparicio Ruiz et al., 2016).

A. Energy Efficient Cooling System

Among the surveys, scholars proposed various types of cooling systems which are utilized in sections of building. Schematic view of a cooling system demonstrated in figure 44.

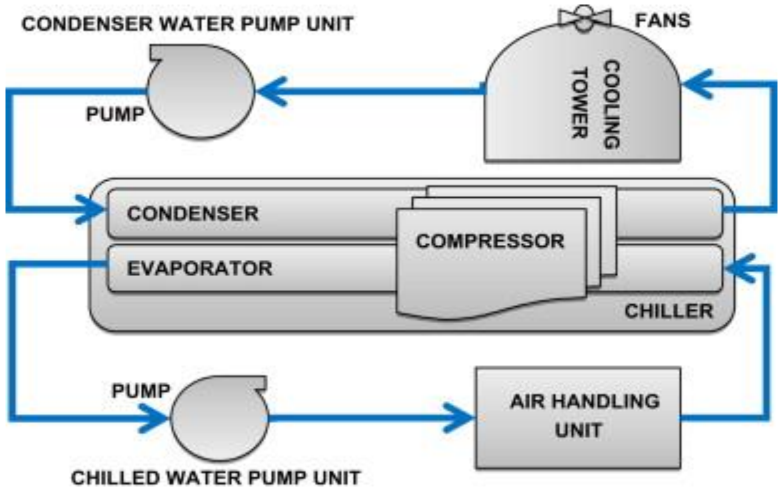


Figure 44 : Schematic view of a cooling system (Design brief, 2010).

Generally, the cooling system includes chiller which consists of condenser, evaporator, compressor and expansion valves. Actually, the greatest consumer of energy in cooling systems are chillers. Basically, there are two categories of condensers which are air cooled and water cooled. However, water cooled condenser is utilized in high-rise buildings and also small buildings utilize air cooled condenser.

Furthermore, authors surveyed on the cooling part in HVAC systems with consideration of energy efficiency that fans, pumps and chiller group are concentrated (Teke & Timur, 2014).

The Federation of European Heating, Ventilation and Air-conditioning Associations (REHVA) has reported that sales of Chillers by construction section are 69% air cooled non-ducted, 25% water cooled, 4% water cooled ducted and 2% condenser less. Consequently, with consideration of an efficient design concept and choosing efficient components and also controls and operating the system, there is possibility to create a chiller plant which utilizes 30–50% less energy than a system designed (Chillers 39% savings, pumps 65% savings, cooling towers 40% savings) (Design brief, 2010).

B. Energy Efficient Heating System

Basically, the major part of heating system is a boiler which is a component of the pressure vessel class. Generally, on the basis of pressure, temperature, boilers, capacity, burner types, boilers are classified into various types and constructed to create steam and gain hot water.

The steam pipelines transfer the hot water which is produced in a boiler to the inside of building. There are several collectors to forbid the pressure losses at the pipelines which are located in the buildings and send the steam to other places. In addition, the combustion impacts on the energy efficient in a boiler which is prepared by burner. Through the literature review, scholars mentioned some parameters which impact significantly in heating system such as supplied air, mixing of fuel and air, temperature and combustion time for combustion. A schematic view of heating system is demonstrated in Fig. 6. Almost 40% of buildings utilize boilers for space heating and 65% of the boilers are gas fired, 28% of the boilers are oil fired and 7% of the boilers are electric. Based on taken data, the combustion efficiency of insufficient boilers has amount of efficiencies between 40% and 60%. In fact, the efficiencies of energy efficient gas-fired or oil-fired boiler systems are between 85% and 95% (Energy star, 2010).

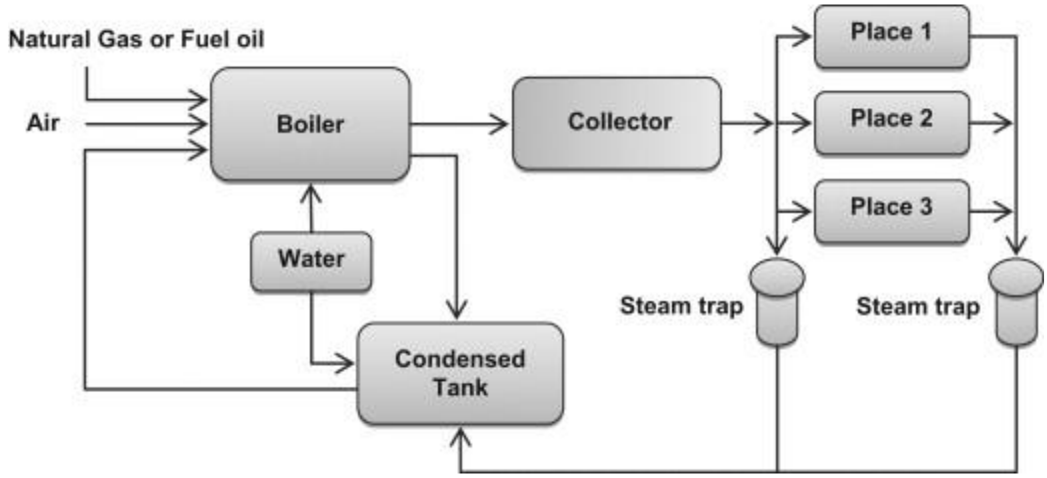


Figure 45 : Schematic view of a cooling system (Energy star, 2010).

Energy Recovery Ventilation (ERV)

Generally, authors defined the Energy recovery ventilation (ERV) as the energy recovery procedure of interchanging the energy which is included in exhausted building and utilizing it for preconditioning the inlet outdoor ventilation air in commercial and residential HVAC systems.

whenever, there is need to produce a great amount of fresh air in buildings then Energy Recovery Ventilator is utilized. In addition, ERV pre-cools and dehumidifies the air in summer time and also humidifies and pre-heats in the winter time.

For evaluation of the effect of uncertainty of building and HVAC system factors on the energy savings potential and economics of ERVs, Resole proposed that a sensitivity analysis should be utilized. Moreover, Resole demonstrated that the ventilation rate has the on total HVAC system energy performance and also showed that an ERV with 75% sensible and 60% latent effectiveness decrease the peak heating load by 30%, the peak cooling load by 18%, the annual heating energy utilization by

40% and the annual cooling energy utilization by 8% with a payback period of 2 years (Teke & Timur, 2014).

Heat Pump

The heat energy is prepared from source of heat to a determined place called a heat sink with utilization of heat pump. Moreover, heat pumps are constructed to transfer thermal energy reverse to the direction of heat flow with taking heat from a cold area and deliver it to a place with higher temperature which this performance is accomplished by applying amount of external power (Teke & Timur, 2014).

In fact, heat pump is utilized to enhance the efficiency of energy continual in HVAC usages. In addition, Shen illustrated that the heat pump is utilized in a medium size of building to displace a natural gas boiler to provide hot water. Furthermore, this specified system provide steady demand of warm water in temperature and flow rat and also has great energy saving in compare to natural gas boiler (Shen & Tzempelikos, 2013).

Authors surveyed on the heating part of HVAC systems with cogeneration on economizers, heating exchangers and combustion on burners. Actually, economizers as a type of heat exchangers are utilized to heat boiler feed water with utilization of waste heat of the chimney gases.

Based on utilization of electric power, the efficiency of heat pumps are four times than conventional electrical resistance heaters and also the cost of installation for a heat pump is approximately 20 times more than for common resistance heaters.

C. Energy Efficient Mechanical Ventilation System

Among the literature, ventilation is defined as the procedure of transferring or taking air in any space to prepare high quality which includes temperature control, oxygen replenishment, and elimination of smoke, dust, heat, moisture, odors, airborne bacteria, carbon dioxide and other types of gases. Basically, procedure of ventilation eliminates unbecoming odors and redundant moisture, retains indoor building air circulating and barricades stagnation of the indoor air.

In addition, the process of ventilation consists the transfer of air to the outdoor such as circulation of air among house and preserves desirable interior air quality in buildings. Scholars categorized ventilation process in building to mechanical or forced and natural types.

Moreover, Mechanical or forced ventilation is created by an air handler and utilized to control interior air quality, extra humidity, smells and pollutants should be managed among dilution or replacement with outdoor air. Furthermore, the more amount of energy is needed to eliminate extra moisture from ventilation air in humid climates.

Generally, kitchens and bathrooms have mechanical exhausts to control smells and certain amount of humidity.

The specified parameters have concentrated by factories to design the ventilation systems such as the flow rate which is a performance of the fan speed and exhaust vent size and also noise level.

In addition, to reduce feeling temperature, ceiling fans and table or floor fans are proposed which circulate air among a space with enhancement of evaporation of perspiration on the skin of the residents.

On the basis of concept of rising hot air, ceiling fans are utilized to retain a room with high temperature in the winter time by circulating the hot stratified air from the up to the down. Moreover, an air handler or air handling unit which is called AHU is utilized to adjust and circulate air as section of HVAC system.

Generally, an air handler is a huge metal box which consist of a blower, filter racks or chambers, heating or cooling elements, sound attenuators and dampers. The conditioned air is distributed among whole parts of building with use of a ductwork ventilation which is related to AHU and after that the air returns to the AHU via ductwork ventilation. But, in certain case study, there is no need to utilize ductwork ventilation to exchange air in space.

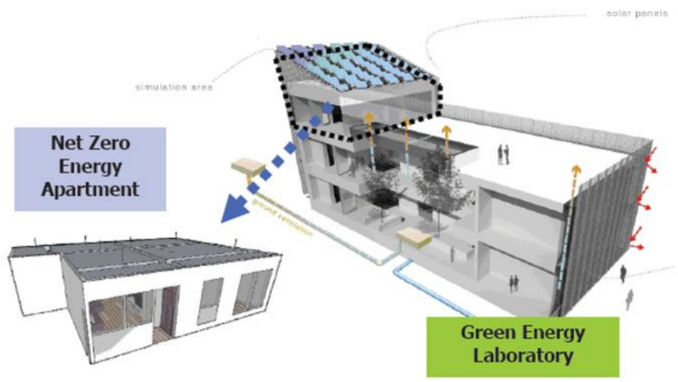
Generally, there are several applications of air handlers which are related to size of the buildings. For instance, terminal units are utilized as small air handlers for local utilization which consist of an air filter, coil and blower which are called blower coils or fan coil units.

In addition, a larger size of air handler which conditions total outdoor air without recirculation of air is called a makeup air unit (MAU). Another type of air handler which installed on the roofs and is utilized for outdoor is called a packaged unit(PU) or rooftop unit (RTU).

Hybrid Solar-Assisted CO2 Heat Pump System

The novel type of CO2 heat pump is called hybrid solar-assisted CO2 heat pump which is a combination of regular CO2 heat pump and a solar thermal-driven ABS chiller. In addition, the hybrid HP sustains specified abilities of the both systems such as a proper performance of heating, natural working fluids, utilization in sources of renewable energy and independence on electricity. In the other words, hybrid solar-assisted CO2 heat pump system integrates two thermodynamic loops into one well-set configuration to reach the year-round demands of the building consisting heating, cooling, and DHW demands with the help of solar thermal energy. However, solar thermal energy is utilized for ABS cooling in summer, space heating in winter, and DHW supply in transitional seasons then the consumption of electricity in the energy systems for buildings decreases (Deng et al., 2012).

(a)



(b)

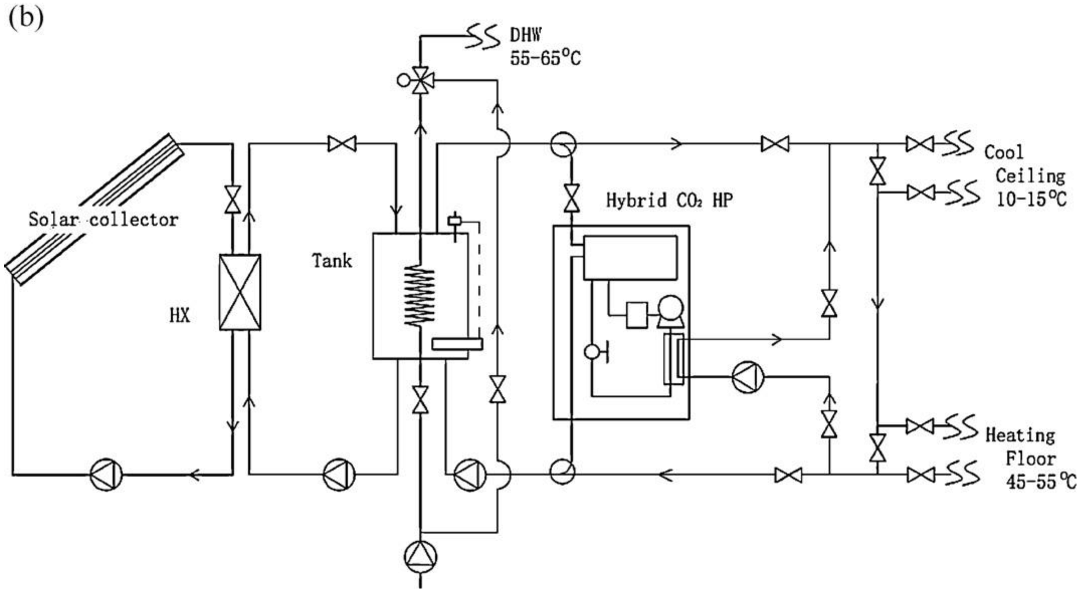


Figure 46 : Design concept of NZEA: (a) architecture; (b) HVAC and DHW system (Deng et al., 2012).

Moreover, the building load and the device supply capacity are compared to each other and then static thermal balance is analyzed which demonstrated a mixing of a solar thermal-driven ABS chiller with a regular CO2 heat pump can reach the year-round HVAC and DHW demands energy utilization in building in different types of climates. The whole consumption of electricity in building is 7832 kWh every year in Shanghai for a common Chinese lifestyle. The electricity consumption of the hybrid CO2 heat pump for adjusting the demands of HVAC and DHW is valid for almost 58% of the total consumption (Deng, 2012).

Solar-Assisted HVAC System

Among the investigations, scholars proposed novel type of HVAC system which includes an air-based photovoltaic–thermal (PVT) collector and a phase change material (PCM) thermal storage unit integrated with a reverse cycle heat pump in a ducted system. Solar-assisted HVAC system was constructed to operate both summer and winter with utilization of daytime solar radiation and night-time sky radiative cooling. In addition, the main performance of PVT collector is to cool or heat fresh air from ambient and prepares heating or cooling instantly to interior space or to the PCM storage unit. The heat stashed in the PCM is utilized to condition the area or precondition the incoming air the air handling unit. In recent years, there are tremendous investigations on the PVT collector and PCM unit were accomplished and the data was utilized to accredit the effectiveness of the models and it demonstrated a proper agreement between the model simulation results and experimental test data (Fiorentini et al., 2015).

2.3.2.2 Energy Use for Visual Comfort (Lighting) Systems

One of the main concern for investigators is to sustain lighting futures and there is significant concentration on how lighting is appreciated and dedicated among regular practices in the home.

Furthermore, the appreciation of lighting relates to aesthetic attributes and also its capacity for producing pleasure, self-expression and communication and the appropriation of lighting refers to how lighting is reconciled and utilized for the aim of capably performing practices inside the home. The household lighting plays main role in emissions of greenhouse gas which is given the trust on prevalent futures of producing electricity (Lai et al., 2014).

Sustainable Domestic Lighting

In recent years, the utilization of low-energy electric lighting plays an important role in sustainable solution such as compact fluorescent light bulbs (CFLs) existed in the first of 1980s and symbolized as a low-hanging fruit in the 1990s. Furthermore, lighting become one of the few categories of domestic electricity-using in 2013(Monreal et al., 2016).

In addition, enhancement of entire numbers of light bulbs which are mounted in homes such as halogens and CFLs for standard or incandescent bulbs produce less amount of CO2 emissions related to lighting which this approach increases from 2001to 2007.

Furthermore, Halogen (tungsten) lamps are a diversity range of incandescent light-bulbs that perform more effective at higher temperatures. Also, Fluorescent strip lighting is modified its luminous efficacy continual however mostly remained exclusive to a specified application of huge space lighting such as schools and offices which bright light is needed. Moreover, there are several advantages with utilization of the LEDs which are on the basis of solid state technology such as obtaining more energy efficiencies which are continuously updating and also long life times which is the consequence of having the potential to revolute lighting (Monreal et al., 2016).

However, the domestic lighting is a complicated and multidimensional phenomenon which makes ambience and atmosphere as important parameters by respondents and leads to ask numerous sources of light. However, the qualities of light are categorized on the basis of demands of people such as time of eating or cooking or watching television.

There are several dynamics factors which plays significant role in this context such as the changing bulb and its light-emitting qualities, the cost of bulbs, varying appreciations of lighting qualities inside the home, utilization various fashions for interior design and different type of domestic practices.

Generally, these types of dynamics are operated in different ways through domestic area with variegation and proliferation of lighting sources in kitchens and living rooms and common replacement of high for low energy bulbs inside the house (Monreal et al., 2016).

It is significance to measured numerous factors which form domestic light consumption, appreciations of lighting qualities, lighting changes among domestic space and varying every day practices. It is the reciprocal actions between processes of acquisition, appreciation and appropriation that shape trajectories of domestic lighting.

During recent decade, there are several approaches about energy efficiency in domestic lighting which scholars forecast fast mass diffusion of LEDs such as substitution of existing bulbs for 2020s and sharp reduces in the electricity consumption of domestic lighting.

2.4 Renewable Energy in Grid System for Energy Usage Reduction

Considering the form of balance to maintain, a Net Zero Energy Building (NZEB) is not consistently defined in the published works. This notion is explained by the U.S. Department of Energy (DoE) as “A net zero energy building (NZEB) is a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies”.

One of the most acceptable and efficient balances is to keep the amount of energy usage equal to the amount of renewable energy that is produced. In fact, off-site or on-site renewable energy sources should provide most of the energy needs in a nearly ZEB. This matter is firstly addressed by Torcellini et al. (2006) who stated that this energy requirement may be covered either by the supply implemented on the site or be purchased from renewable energy resources off the site. In addition, they have suggested that renewable energy supplies can be ranked as the most favorable to the list favorable one as shown in Table 6.

Table 6 : ZEB renewable energy resources ranking (Torcellini et al., 2006).

Off-site supply options		
3	Use renewable energy sources available off site to generate energy on site	Biomass, wood pellets, ethanol, or biodiesel that can be imported from off site, or waste streams from on-site processes that can be used on-site to generate electricity and heat
4	Purchase off-site renewable energy sources	Utility-based wind, PV, emissions credits, or other "green" purchasing options. Hydroelectric is sometimes considered

According to the previous studies, a significant proportion of energy consumption in most of the countries is used for household purposes. For instance, 47% and 40% of the total energy usage in the whole country is used by the buildings in the UK and the US respectively. Hence, energy consumption in buildings is a crucial aspect in sustainability. Considering the process of electricity production and the green gas emission related to this, designing modern ZEBs is the main target while improving the efficiency in old residents should also be taken into account (Hassoun & Dincer, 2014).

Today, the issues related to shortage of energy resources are becoming more crucial all over the world specifically in developing countries where the industrial growth and modernization increase the demand for energy. Less fossil fuel consumption and relying on renewable energies are the aim of the sustainability programs. According to (Hassoun & Dincer, 2014) following a long-term policy for using sustainable forms of energy is the best solution for the today's environmental issues.

When aiming at a net zero energy building, in addition to efficient envelope design, there are some alternatives for providing the energy demands. These options include solar power plants, thermal solar collectors, wind turbines, and ground heat pumps (Hassoun, 2014). In a case study conducted by Wang et al. in the UK, they have stated that a ZEB is achievable by using photovoltaic energy and wind turbine together (Wang et al., 2009).

In (Grac et al., 2012) a nearly zero energy house is implemented in south of Europe by means of photovoltaic plants and solar water heater. It is concluded that there are four main factors to take into account for a ZEB as follows. Firstly, use of natural light and passive natural heating and cooling is important. Furthermore, the equipment should be energy efficient. Another factor is to utilize optimum scale photovoltaic and solar heating mechanisms. Finally, appropriate design is crucial.

In another case study on photovoltaic cells located on the roof it is concluded that the energy efficiency is increased significantly. The modern equipment including solar cells that produce electricity, the controlling system and the integration mechanism resulted in a significant energy saving in the building.

On the other hand, the envelope of the building and its architectural style are influencing factors on the energy consumption. In other words, sustainable energy resources are not enough for the energy demands in a building unless the envelope is designed to minimize energy loss. Passive ventilation techniques and natural lighting are also vital for energy efficiency in a building. All these factors should be considered in the very beginning of the design for the building (Hassoun & Dincer, 2014).

In order to make the concept clearer, a case study by Hassoun is briefly described here. The study has listed the following goals for a net zero energy building in which the energy consumption is equal or less than the energy that is produced by renewable resources.

- Innovative power resources are required for a NZEB
- Considering different factors such as season, electricity load, and energy needs, energy consumption patterns should be analyzed by simulated modeling.
- An optimized energy plan based on renewable energy resources should be devised to decrease the expense of other energy resources and CO_2 emission as much as possible.
- The total expenditure on energy need to be investigated by simulating different alternatives of power plants.
- Architecture pattern and design parameters should be optimized aiming at efficient energy usage and cost reduction.
- The final energy resource has made of different constituents each of them needs to be studied for optimum revenue.

Renewable Energy Building

In order to make a building purely sustainable, it is essential to invest on renewable energy resources instead of paying the cost of non-renewable energy. The shift from relying on the electricity power in the grid system to permanent self-provided energy is the procedure directed to REB. From thermodynamics perspective, a renewable energy building is a balanced sustainable environment that progressively switched to renewable energy resources as the only power source. In populated mega cities such as New York, the buildings may implement on-site renewable plants and at the same time being connected to the off-site energy grids fed by sustainable resources to fulfill their total energy requirement (Srinivasan et al., 2012).

The concept of 'Renewable Emergy Balance' (REB) is defined as the maximum proportion of the renewable energy use in the building that is possible during the life time of the building. In fact, after the building is designed in the first stage, there are possible strategies to improve the energy efficiency. The aim of the procedure is to reach the maximum limit as the technology develops innovative mechanisms for replacing non-renewable energy with the renewable energy resources. In other words, renewable sustainability is the building potential to rely on renewable energy as much as possible. Through the improvement procedure, REB should be achieved. It is notable that this maximum potential is not fixed and changed by the emerging advances in renewable energy production.

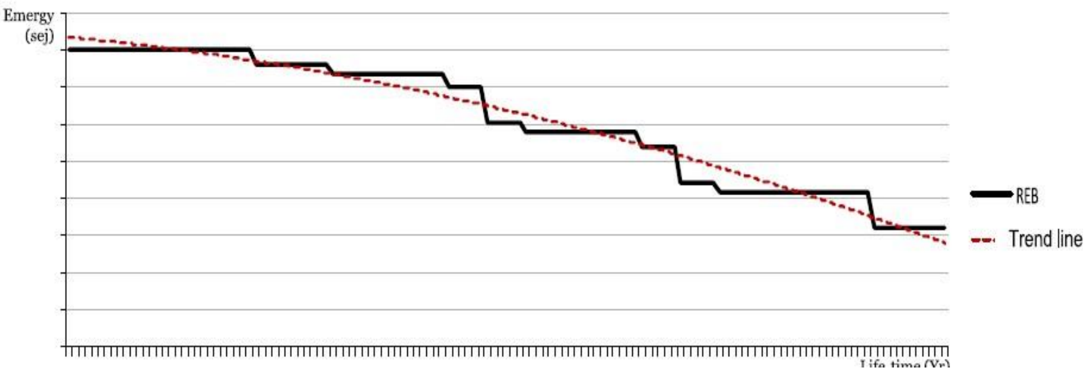


Figure 47 : The curve of trends in the maximum renewable emergy potential during the building life time. As the emergy improves by the life time, it finally reaches the REB (Srinivasan et al., 2012).

In order to illustrate the relation between the improvements and REB, a trend line can be plotted. In Figure 46, the trend line of maximum emergy potential over the life time of the building is shown by the dashed line. REB limit is also plotted for comparison. It can be seen that the trend line finally reaches the limit. However, it is not always the process that happens because in some cases the maximum renewable emergy potential rises by time. The reason is improper procedures of maintenance in the building. In addition, a precise decision-making procedure in the first stage of the design and in the improvement procedure should be taken to preserve the balance during the building life cycle. The deficiencies can be compensated in the maintenance process to regulate the trend line. It is also possible to examine different options by simulation before implementing them on the site (Srinivasan et al., 2012).

On the other hand, in the renewable sustainability process, the construction materials are not as crucial as proper decision making in replacing non-renewable energy with renewable resources. Hence, over the time the maximum renewable potential may decrease as shown in the previous figure.

2.4.1 Solar Energy

The energy emits by the sun is one the most available energy resources in many regions of the world. There are two main methods for converting solar energy into a practically usable form, active method and passive method. The main advantage of using solar energy is the reduction in fossil fuel burning and consequently greenhouse gas emission. It is also mentioned extensively in the literature that on-site renewable energy plants decrease the electrical energy consumption that has to be produced by fossil fuels. In hot regions there is a great potential for using on-site solar energy plants to produce electricity. Considering the fact that almost 15% of the solar radiation energy can be converted to electrical energy, solar plants are valuable options in hot climate to save both money and the environment in long term (Aldossary et al., 2014)

A case study on the efficiency of the photovoltaic cells is conducted by Eldin in Berlin Germany and Aswan, Egypt. The photovoltaic panel function is modeled considering the sun tracking system. The model is then validated by the experiments. The two cities are selected as examples of clod and hot climate respectively. It has shown that in the cold climate, a PV panel with sun tracking mechanism can produce approximately 39% of the electrical energy requirement. However, in hot region of Aswan, only 8% of the electrical energy can be produced by PV panels. Considering the energy needed to drive the sun tracking system, it has concluded that that this system is not rational in hot regions (Eldin et al., 2016)

Optimum Solar Hot Water Systems

Solar water heating system is an active solar energy conversion that converts sun radiation to thermal energy. Solar radiation data is should be analyzed for the locating to implement active and passive systems. This measurement is done by mean of radiometric nets that evaluate solar energy with low spatial resolution (Banos, 2011).

Irregularity of the source is one the specifications of the solar energy as a result of changing in sun radiation by the earth's movement. Thus, the only way to have access a continuous energy flow is to save the converted energy in a capital storage system at peak hours in the PV plant. In recent years, large scale commercial solar plants are growing quickly in terms of technology and reasonable price. It is becoming possible to connect buildings into an electricity grid driven by photovoltaic panels (Banos et al., 2011).

One of the most challenging issues in implementing a solar power system is to find the optimum size. As the panels are relatively expensive, there is a trade-off between the energy consumption money saving and the investment on the solar energy system. The costumer aims at benefitting from this renewable energy term in a short term with high quality.

One of the advantages of solar energy is that it can be used to directly heat the water for residential use. An efficient solar thermal panel system should be designed precisely to fulfil the occupants' needs and save energy at the same time (Banos et al., 2011).

The feasibility of the solar water heating system is studied in detail by conducting five simulation experiments in a conventional family building. The system constitutes of a solar thermal system, a cooling tank and a heat pump. The results of this investigation have revealed that in the days with low solar radiation and in the days with high radiation the hybrid solar water heating technology can fulfill about 60% and 100% of the family hot water needs respectively. It is also worth mentioning that in the paper, daily solar radiation larger than 5.0 kWh/m2 is considered as high in all the experiments (Jouhara et al., 2016)

The study also investigated the efficiency of the energy conversion in different system configurations. In photovoltaic panels with integrated solar heat pipe collectors the efficiency of solar to thermal conversion varies from 35% to 52%. In the solar flat thermal collectors this number ranges from 45% to 64%. In addition, the advantage of the cooling system is proved in the study by recording the temperature of the photovoltaic panels. In fact, the temperature decreases by up to 48% compared to PV panels with no cooling mechanism. This is of a great importance since the performance of PV panels deteriorates at very high temperatures. In general, it can be concluded that utilization of PV panels or solar thermal panels is efficient for implementing a Domestic Hot Water (DHW).

Another system that is analyzed in the study is water heat pump (Jouhara et al., 2016). The simulation results have confirmed that the solar hybrid system constituted of PV panels, thermal panels and the heat pump in which the PV panels are cooled by the cooling water tank can produce a substantial proportion of the energy needs (approximately 58%) of the family in low solar radiation condition. When the radiation is relatively high, the hybrid system covers the total energy needs though. Lastly, it has been stated that the number of the hybrid panels installed is important. As a matter of fact, each unit of a PV and thermal panel can cover 12% and 23% of the family energy demand in low and high solar radiation conditions respectively.

Combination of Photovoltaic/Solar and Thermal Energy Systems (Hybrid PV/T)

The hybrid solar power system is a combination of PV panels with thermal panels which is known as PV/T solar system. The main advantage of the hybrid plants is that the solar energy is concurrently converted into electrical energy and thermal energy. Furthermore, embedding the water heating system into the PV panels makes it possible to cool the panels and increases the energy efficiency of the system accordingly (Jouhara et al., 2016)

As mentioned above, the hybrid plant comprises two fundamental components: the PV panels to produce electricity and the thermal panels to heat the stored water. These two systems have their own weaknesses and strengths but when they are combined together a propitious renewable energy plant is constructed that is capable of covering energy demand for low energy buildings (Bakker et al., 2005).

International Energy Agency devises a standard installment rule for the hybrid plants. It has stated that the integrated solar collectors should be put on the roof or on the front exterior wall. The PV/T collectors have different dimensions and technical characteristics and they can be selected based on specific applications in the architecture (Tyagi et al., 2012).

Depending on the fluid content, flat PV/T collectors can be categorized as follows. There are water PV/T collectors in which the heated medium is water. I air hybrid collectors there is no liquid. The last class of the PV/T collectors is combined air and water collectors. These hybrid panels can also be classified according to the technological fact that whether there is an absorber under the plate or not. Regardless of these categorizations and except for the absorber collector which is optional, each

PV/T panel constitutes of some basic components including a crystal coverage (glazed/unglazed), solar cells, and embedded materials. The absorber plays an important role in the panel. It cools down the solar cells and also produces thermal energy form the waste heat by heating air or water. Therefore, the absorber collector increases the efficiency of the hybrid system (Jouhara et al., 2016).

Hybrid solar system has several advantages over simple PV panels. The first important feature is the higher energy efficiency compared to the low performance of the simple PV panel. The price is also more reasonable and it fits the design limits such as limited roof space. These benefits make it a better option than conventional solar panels that have not been widely used because of these issues. The cooling mechanism in PV/T collectors improves the efficiency of the solar to electrical conversion. They occupy a smaller area and the payback time is reasonable (Zondag et al., 2002).

Another influential factor on the efficiency of the solar panels is the temperature. When the temperature of the PV panel increases, the system experiences high thermal pressure and the energy conversion performance decreases significantly. For instance, a 10°C rise in temperature deteriorates electricity production by up to 5%. For instance, the optimal operative temperature of the PV panels is 25°C at which the performance of energy conversion is around 15%. If the temperature increases by 20°C, the performance falls under 14% (Chow, 2010). Hence, cooling is crucial in solar panels and many of the frequently used heat collectors are implemented in PV/T panels based on water or air cooling mechanism. Referring to the experimental results of (Karami & Rahimi, 2014), it is stated that even active cooling system is beneficial in the solar panels. Particularly, the PV panel temperature is decreased by 20% using active cooling mechanism which results in an improved performance of 9%.

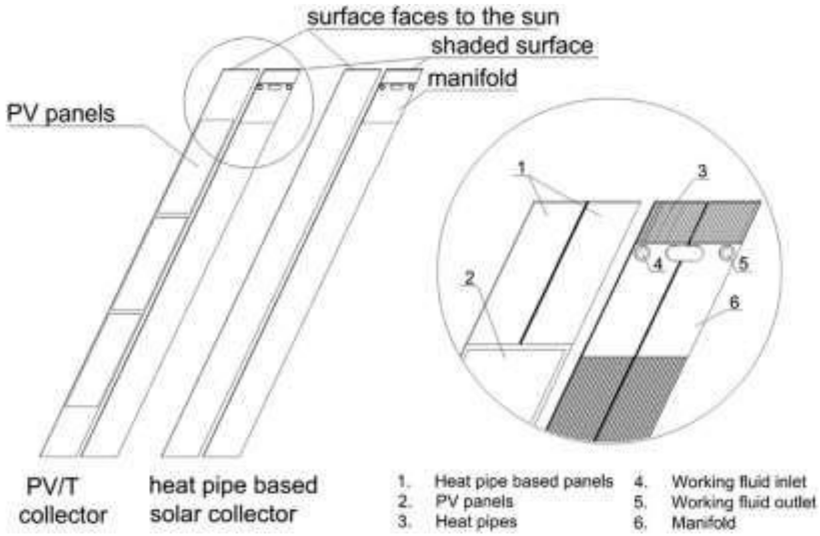


Figure 48 : The assembly of the PV/T panels (Jouhara et al., 2016).

PV Glazing

Enameling the PV panels is favored for the aesthetic appearance in the modern architecture. It is also essential in the electricity production procedure. Nevertheless, the traditional glazing is not a proper heat isolator as stated in (Cuce, 2016).

The PV plates are positioned so that the necessary transparency is undertaken. Figure 48 illustrates a typical c-Si glazed PV panel graphically. This scheme has the efficiency of about 16% up to 22%, but the technology of the silicon wafer production is highly costly. The level of transparency is also limited. On the other hand, there is semi-transparent c-Si PV glazing technology which results in improved lighting proficiency. This feature makes it possible to install more panels and generate more electricity. This procedure amplifies the heat gain during the hot season though increasing the energy consumption for cooling in the building. Therefore, it should be a tradeoff between the natural lighting, electrical energy production and the heat load when ordinary c-Si PV glazing panels are utilized (Miyazaki et al., 2005).

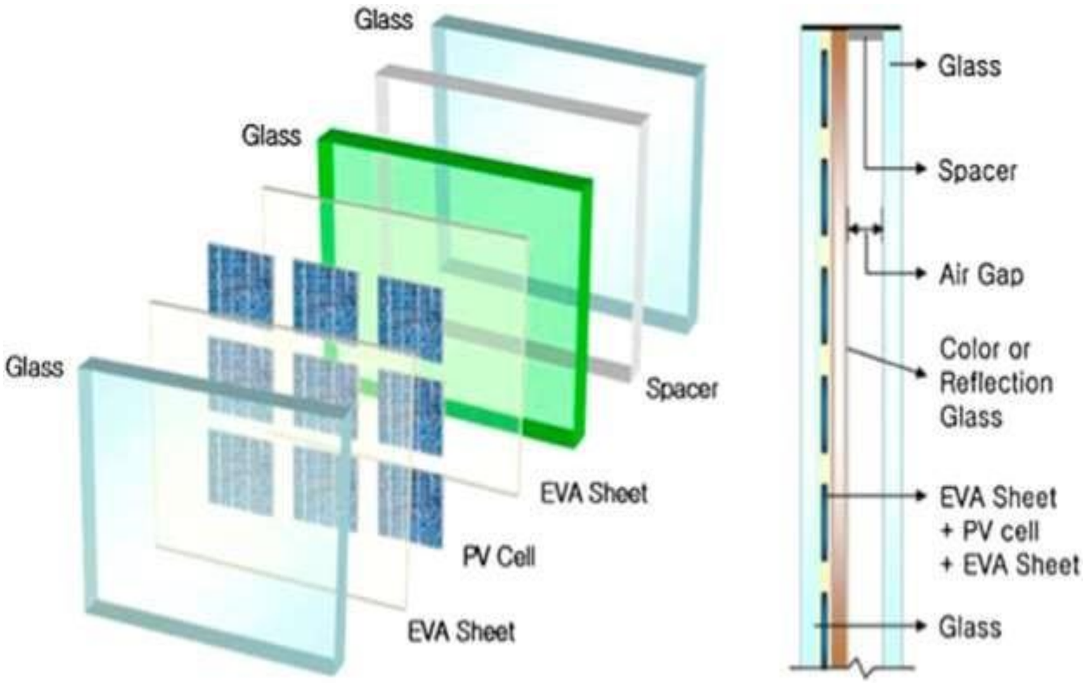


Figure 49 : Structural details of a conventional c-SiPV glazing utilized (Miyazaki et al., 2005).

Advanced PV Glazing Systems

Recently, the advanced technologies in material science result in development of efficient glazing for PV panels. Organic enamels have attracted many attentions since they are cheap and they have specific characteristics which makes them suitable for this purpose (Cuce, 2016). The following table lists different types of PV glazing analyzed by the researchers in recent years.

Table 7 : Performance metrics for different modern PV glazing systems (Cuce, 2016).

Structure	Efficiency (%)	Transparency (%)	Benefits/issues	Year
Nine PV cells in series	–	60 (visible)	The method for electrical contacts can suppress the IR drop	2003
Glass frit sealing technology	3.5	Semi-transparent	Successful in a large scale application	2008
Twenty nine PV cells in series	7.0	Semi-transparent	Cost-effective	2006
Flexible dye-sensitized PV cell	7.6	-	High efficiency and low-cost	2010
Silver grid-embedded transparent conducting glass	4.2	Semi-transparent	Similar performance with platinum	2008
Stainless steel substrate flexible dye-sensitized PV cell	4.2	–	High temperature sinter ability small loss in efficiency	2006
Screen-printing technology	5.5	–	Stable performance	2007
Heat insulation solar glass	12.0	Semi-transparent	Cost-effective and energy-efficient	2007
thin film amorphous silicon			suitable for retrofitting purposes	2015

PV Glazing Systems in Terms of Energy Reduction in Hot Climate

In hot regions the PV plates are effective mechanisms for reducing energy consumption. In a comprehensive analysis by (Bahaj et al., 2008), it has been mentioned that thin-film PV glazing reduces the energy usage for cooling by about 30% in the first year of installment. In commercial buildings, PV glazing mechanism installed on the facade can decrease the total energy demand by around 2%. Considering the energy demand for air conditioning, it has been shown that PV glazed systems ventilated by natural mechanisms reduce this energy by more than 60% . (Chow, 2010) have proposed and innovative method for decreasing the temperature of PV doubles glazing system. Their proposed system is effective in reducing the energy consumption for air conditioning. In fact, air conditioning energy demand is detracted by 28% compared to the ordinary PV glazing system.

Multi-Functional PV Glazing Technologies in Low/Zero Carbon Buildings: Heat Insulation Solar Glass (HISG)

The advanced technology of heat insulation solar glass (HISG) is recently introduced as an energy saving, solar panel that reduces the heat gain and provide thermal comfort in a sustainable way. This technology is constructed as transparent amorphous-silicon PV panels coated in a specific way. The major differences between the HISG and the ordinary PV glazing are significant decrease in energy consumption, thermal isolation property, being sound proof and self-cleaning. The hundred percent UV blocking feature and negligible shading properties makes HISG an ideal option for zero energy/emission buildings. In addition, the production cost of HISG is comparable with double glazed sound and heat proof windows. Hence, it is anticipated that HISG will replace all other glazing systems very soon (Cuce, 2016).

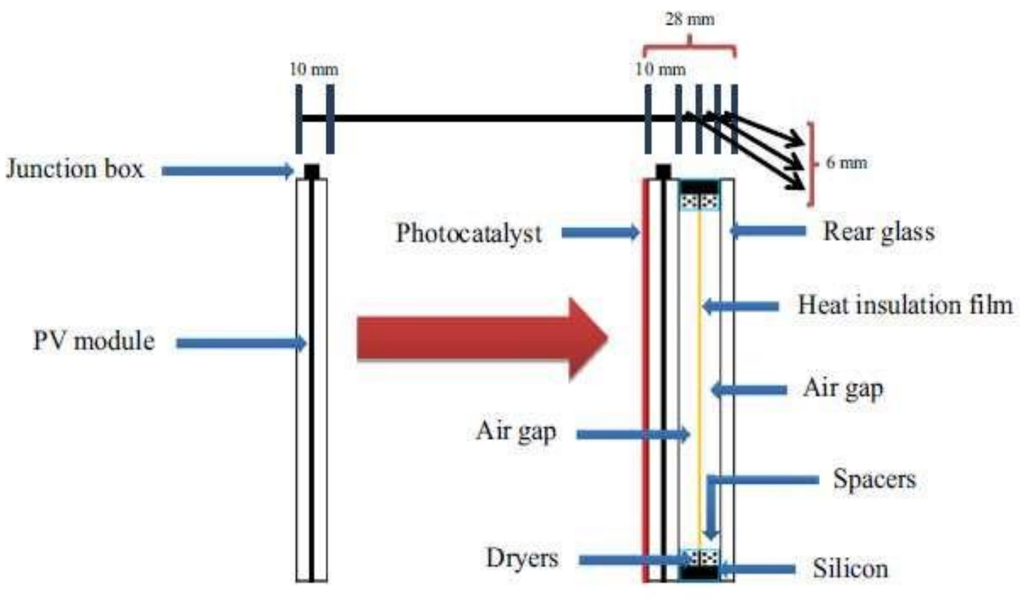


Figure 50 : Structural details of HISG from a cross sectional perspective (Cuce, 2016).

Multi-Functional Features of HISG

As previously stated, the shading coefficient of HISG is very low which results in high quality visual comfort for the occupants. The layered architecture of this fabric also makes it an effective heat insulator essential for improved thermal comfort. There are two air gaps in the construction of the HISG that play the role of sound and heat blockers. Thus, both in hot season and cold season, this glazing reduces the energy demand for air conditioning . The low shading coefficient also blocks solar radiation during the hot season reducing the cooling demand . The U-value of the HISG results in lower heating demand during the winter . Additionally, this glazing is coated with a photo-catalyst material with self-cleaning property. This means the dirt collected by the PV panel surface is putrefied by the coating so that it is washed easily by the rain . This property also contributes to more energy saving and high quality comfort for the maintenance . In fact, for the tall towers, utilization of HISG solves the issues of window cleaning. These properties are summarized in Table 8 (Cuce, 2016).

Table 8 : Special properties of HISG (Cuce, 2016).

Type	Region	Study	Objectives	Outcomes
a-Si	Middle East	Trnsys simulations for highly glazed buildings	Performance investigation of BIPV integrated in high glazed buildings	31% energy saving for cooling over a year
a-Si	United Arab Emirates	Energy-10 simulations	Interaction between PV modules and thermal performance of a building	1.1–2.2% reduction in the building's total operational energy consumption. Reduced payback time
a-Si	Hong Kong (Subtropical)	Daylight illuminance, solar irradiance and power generation measurements for semitransparent a-Si PV	Investigation of the essential parameters affecting the thermal and optical characteristics of the PV	Reduced electric lighting and cooling energy requirements (12% annually) and environmental benefits (CO_2, SO_2, NO_x decrease)
a-Si	Hong Kong (Subtropical)	Airflow analysis inside the cavity of ventilated STPV window	Factors affecting the heat transfer coefficients of vertical surfaces	Cooling loads are mitigated by 61% via naturally ventilated PV glazing systems
a-Si	Hong Kong (Subtropical)	Experimental study of PV window integrated on typical office building	Experimental validation of theoretical models developed in ESP-r platform	23% saving in electricity for cooling annually for the single glazed, and 28% for ventilated PV system.

SOFC-Trigeneration

Another sustainable item in the architecture is trigeneration which offers cooling, heating and power for the building. Solid Oxide Fuel Cell (SOFC) is becoming a frequent item in building design as a result of its easy maintenance process and high temperature characteristics. Fong have analyzed two schemes of SOFC-trigerenration utilization in a building (Fong & Lee, 2014).

The first scheme known as full-SOFC method is based on the SOFC property to cover the energy demand at peak hours without relying on the electricity grid resource. The second one named as partial SOFC method is designed to fulfill the energy demands at peak hours partially by means of SOFC-trigeneration and the remaining by grid energy connection. In the second approach, still the net zero electrical energy is preserved in the yearly basis.

The proposed systems are evaluated by a year round simulation in terms of complication, interaction of the mechanisms, environmental aspects and energy efficiency. The results have been compared with the traditional air condition systems in the building. Evaluation results have revealed that full-SOFC system reduces the greenhouse gas emission at least by 50% during the year. The second scheme (partial-SOFC) also cuts down the CO_2 emission approximately by 24%. The electricity demands for the two schemes are reduced by 7.1 and 2.8% respectively per annum. Particularly, in hot and humid regions, full-SOFC strategy improves the design characteristics in terms of sustainability (Fong & Lee, 2014).

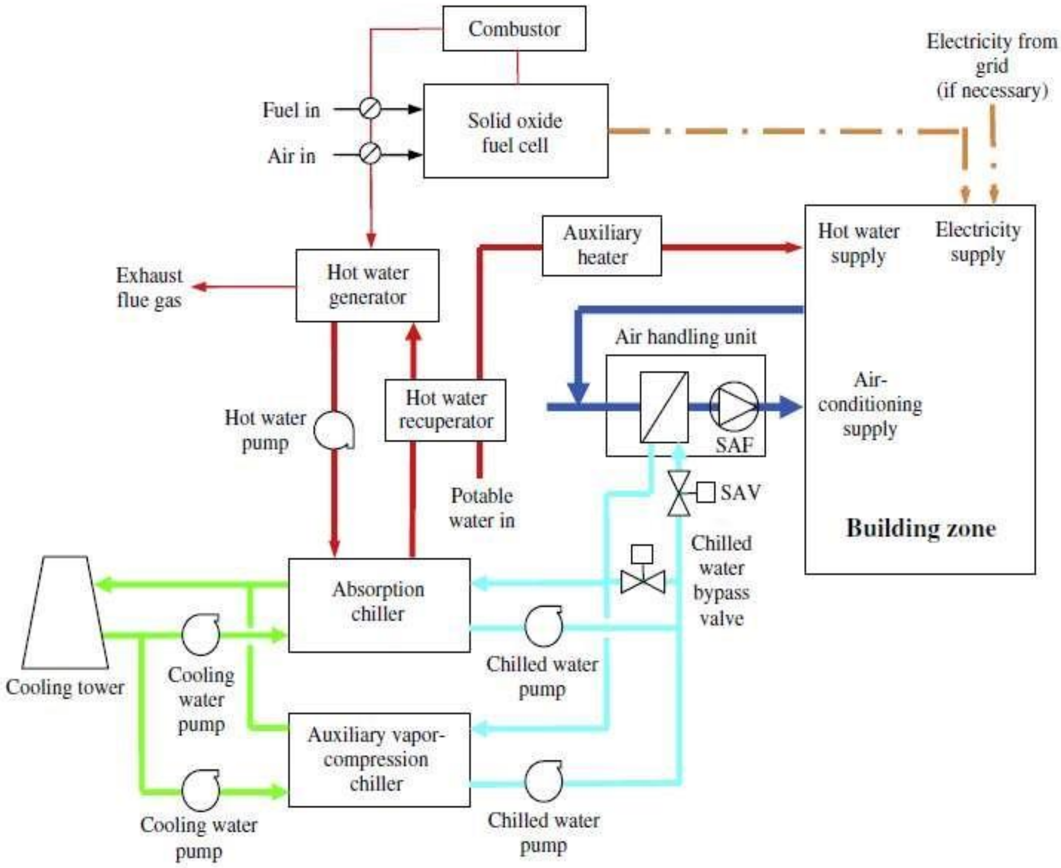


Figure 51 : Schematic diagram of SOFC-trigeneration system. (Fong & Lee, 2014).

Selecting Power Plants for Building Application

The conventional power plants' efficiency is at most 40%. However, by means of hybrid power supplies (cogeneration or trigeneration) the performance can be improving up to 80% through which the greenhouse gas emission is significantly cut down. The efficiency of the hybrid system is influenced by the comfortable temperature levels though (Wu & Wang, 2006).

In trigeneration systems the prime mover is a crucial item. In recent years' fuel cells are introduced and utilized as the prime mover in these systems by means of the leftover heat. There are different types of fuel cells including SOFC, proton exchange membrane, phosphoric acid, alkaline, molten carbonate and SOFC as mentioned before. Both molten carbonate fuel cells (MOFC) and SOFC are in the category of high temperature fuel cells functioning at temperature equal to 600ºC and higher. According to the efficient electrical energy conversion, SOFC is recognized as one the best alternatives for prime mover in trigeneration. Additionally, the heat energy in the exhaust gas flow can be utilized in cooling mechanisms at the same time. The solid electrolyte used in SOFC and the cost-effective catalyst, makes them a reasonable choice for the long-term usage (Lund, 2011). As previously stated SOFCs operate at high temperature and the risk of deformation in the internal mechanism is high. Thus, for producing hydrogen, different types of fuel cells may be exploited.

A decentralized system based on SOFC has been proposed for application in building sector. The proposed system has a double-effect absorption heat pump and it has implied that the greenhouse gas emission is reduced by up to 30% using this system compared to conventional power system.

Another mechanism based on SOFC is investigated by simulating an internal reforming tubular SOFC equipped with a single-stage absorption heat pump. The system is used to produce electrical energy for deriving air conditioning system. The whole system named as SOFCHP with 87% efficiency when the electricity and heating are generated simultaneously. When electricity is produced with cooling the efficiency is 95.7%. (Zink & Schaefer, 2007).

SOFC-Trigeneration System in Hot Climate Zone

The mechanism of the SOFC is an electrochemical reaction as follows. The reaction of the fuel with the air produces electrical energy. In the combustor, the remaining fuel is burnt and the resulting hot gas is utilized to heat the fuel and air as well as a hot water storage. So electricity and hot water are generated at the same time. The heated water is utilized in an absorber in the cooling chiller first. After passing the absorber, the hot water is used as the supply for the building need. In hot regions, the hot water usage in the building includes the consumption in bathroom and kitchen an addition to drinking water for tea or coffee. For the drinking water supply, another heater is attached to the system to provide the appropriate temperature for the drinking hot water (Fong & Lee, 2014).

In hot climate because of the high energy demand for cooling, the hot water supply may not be enough to cover all the cooling demand. In this cases, additional vapor compression chillers are used in the building. The cold water is pumped to the coil of the chiller that provides cooled water to cool the air for the supply air fan or SAF. The air is used to provide thermal comfort in the interior space.

It is suggested that the SOFC trigeneration mechanism and the chiller are designed so that the electricity and the cooling demands of the building are both covered all over the year. For this purpose, in hot climate regions an energy storage system is also necessary especially in summer.

The scale of the SOFC trigeneration system is defined by the energy demands of the zone and sustainable strategies aiming at reducing the dependence to the electricity grid system. The major proportion of the electricity demand in the building sector is for the home appliances, service facilities such as elevators, artificial lighting, the chiller plant, and the SAFs. The efficiency of the electricity production in the proposed SOFC based system is reported to be equal to 47% under typical energy demands (Fong & Lee, 2014).

Proposed Zero Off-Grid-Electricity Design Strategies

The SOFC trigeneration systems are classified into two main classes according to the dependence on the grid electricity connection: full-SOFC and partial-SOFC systems. In the full-SOFC system, the total energy demand of the building is covered by the trigeneration procedure and there is no need to connect the site to the grid electricity. So, the SOFC system is required to be sufficient all around the year even in the peak energy demand period. The system should work continuously during the week. In order to save energy and reduce greenhouse emission, the system is implemented as a number of operating units activating according to the power demand. 4 The number of these units is defined by the maximum electrical energy demand of the building. Hence, during the non-peak period an additional power may be generated by the system. for a specific operation unit, the flow of the hot water is constant and thus the flow of the hot water that derives the chiller depends on the number of units that are functioning.

As mentioned in the previous sections, in partial-SOFC system, the building is connected to the electricity grid. Referring to the annual energy saving analysis, in a partial-SOFC system, 2.8% more energy is saved compared to the traditional system. This rate is equal to 7.1% for the full-SOFC system. This reduction in the electrical energy demand is mainly because of the hot water waste that is used in the chiller to cover a proportion of the cooling energy (Fong & Lee, 2014).

Greenhouse gas emission, on the other hand, is decreased substantially by means of both systems based on SOFC. As a matter of fact, 23.9% and 51.4% reduction in CO_2 emission has been reported for the partial and full system respectively. In addition, both SOFC-regeneration have a performance level more than 70% in electricity production. But, in an annual basis, full-SOFC system is more efficient than partial one (Fong, 2014).

2.4.2 Geothermal Energy

The source of geothermal energy is the heat deep inside the Earth. This renewable energy can be derived from the ground by geothermal pumps and utilized for air conditioning in the buildings. The scientific fact behind this technology is that going deep into the Erath the temperature is constant. It means it is lower than the temperature of the ambient air in hot seasons but higher than that during cold season. Compared to solar and wind plants, the geothermal energy is more stable as it is not interrupted at any time during the day all over the year (Banos et al., 2011).

There are many other advantages of using geothermal energy in buildings. The CO_2 emission related to this energy source is zero (Fridleifsson, 2001). In hot and arid areas specially, the geothermal energy plants are beneficial as the civilized areas are established near the fresh water resources. Furthermore, the geothermal pumps may be used to supply the hot water needs simultaneously (Mahmoudi et al., 2014).

During the cold season, the heat is transferred from the depth of the Earth to the interior space by the geothermal pump. In hot season, however, the heat inside the building is shifted toward the Earth as the temperature is lower there (Omer, 2008). The heat exchanger is a fundamental component of the geothermal system which is responsible for the heat transfer. The transfer area of the exchanger is one the most important features of this element.

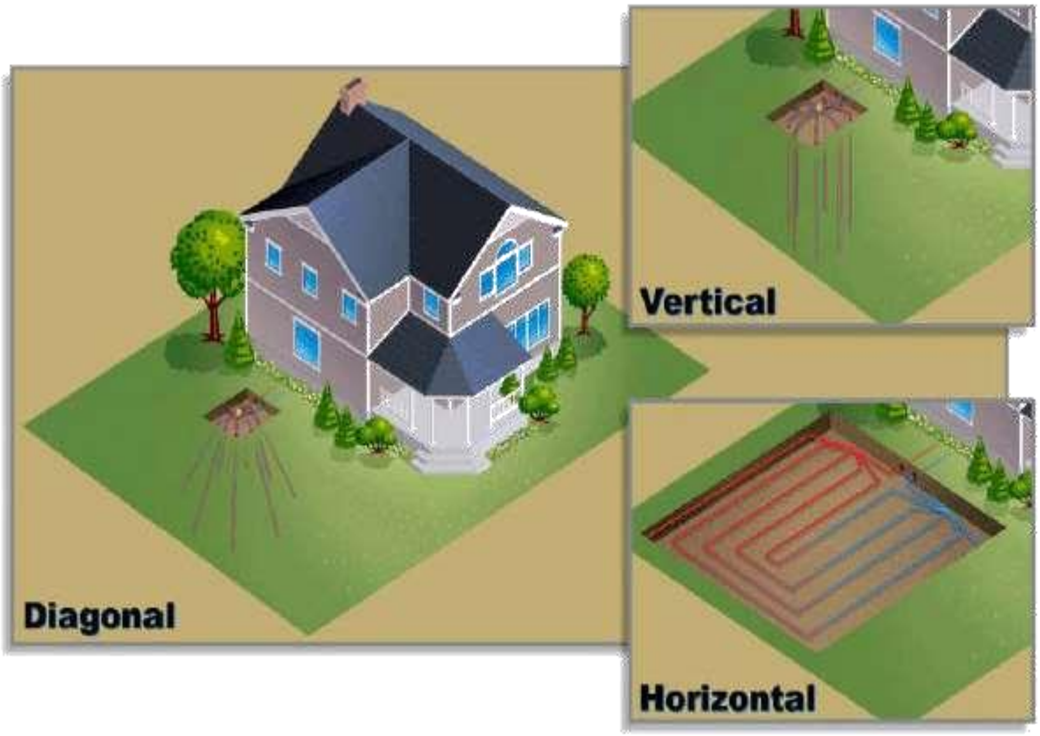


Figure 52 : A geothermal heat pump configuration. (Banos et al., 2011).

The layout of a geothermal system constitutes of indoor and outdoor equipment. The flow center connects these two together. The system also contains the ground mesh and the heat pump which transfers the heat from one location to the other one. The heat exchange between the pump and the Earth is performed in the ground loop which is installed deep in the ground.

There are two configurations for the ground loops including horizontal and vertical well. The horizontal design is more cost effective but it requires space. When the space is limited, horizontal loops are implemented. The hot water derived from the well can be used as a hot water supply in the building. In an open-loop vertical well, the hot water is consumed in the building and the waste water is directed to the drainage. The close-loop system, on the other hand, constitute of returning pipes and an antifreeze liquid is added to the loop water flow. The loop transfers the heat from the Earth into the residential zone (Banos et al., 2011).

2.4.3 Wind Energy

Generating electricity by wind power is an emerging technology specified for windy regions. While the mechanism is highly efficient compared to the ordinary system, the implementation and maintenance is not simple. In some European countries such as Germany and Spain, wind power is the fastest growing sustainable energy (Montoya et al., 2014).

The use of wind power has increased faster than other forms of renewable energies in the recent years. The proportion of the energy demand covered by the wind plants is surprisingly high in developed countries such as the US, Germany and Spain. More precisely, wind power produces on average 21% of the energy demand in a monthly basis. 18% of the total national demand for the electricity and up to 60% of the hourly need is produced by the wind power in these countries (Montoya et al., 2014).

Today, wind is recognized as a periodical geological event in large areas. The growth in the size and production capacity of the wind turbines as well as the reduced expenditure for each unit of electricity generation, have proved that the previous studies in this field were successful. There is ongoing research in this filed focusing on other aspects of the problem including small scale distributed turbines connected to the grid for buildings, off-shore efficient turbines, and designing turbines suitable for less windy regions of the world. The studies to improve the performance of the wind power plants by innovative design strategies are still ongoing (Henriksen, 2010). Nevertheless, compared to solar energy, wind energy is less steady. In addition, in some geographical regions where the wind speed is low, it is not possible to utilize wind turbines. In fact, wind power plants are suitable for high regions with strong and almost permanent wind flow.

In order to design an efficient wind power plant, several factors need to be investigated. Firstly, it is essential to estimate the speed of the wind precisely in order to select the appropriate site. The distribution of the turbines and their scale should also be considered. In (Henriksen, 2010) a simplified cheap passive design is proposed for the wind turbines with no power and control mechanism. Most of the studies in the field of wind turbines aims at maximizing the power and minimizing the vibration at the tower moving parts. However, a handful number of works address the issue of optimized design for an efficiency and sustainability. It is worth mentioning that, while the greenhouse gas emission of the wind turbines is zero, during the periods of low demand, they may increase the emission as a result of thermal transmission (Boqiang & Chaunwen, 2009).

Chapter 3

CASE STUDIES IN HOT CLIMATES ZONE

In This section, four residential buildings constructed to achieve zero net energy (ZNE) consumption in hot climate region are reviewed. To obtain better conclusions, 2 cases have been selected in hot and humid region and the other two are located in hot and arid region.

Design of zero net energy (ZNE) buildings is an emerging modern topic in design and construction in building sector. It is notable that many of the proposed designs have not been successful in practice but a handful proportion satisfied ZNE standards. Hence, valuable knowledge can be learnt from these vanguards. In fact, information about the design procedure, approaches, passive and active systems to minimize energy consumption and renewable plants for generating energy is valuable for future designs. In this chapter, the four ZNE cases are analyzed from these aspects in detail.
The experts involved in the design and implementation process of ZNE construction are required to make appropriate decisions in the design and construction procedure of all components in the building. Hence, the aim of this review is to provide regulations for this decision making course. The three main steps taken in every net zero energy design are as follows:

- Reduce energy consumption by replacing active systems with passive ones
- Choose efficient mechanical systems for energy saving
- Generate the rest of energy demand by renewable resources

3.1 Overview of Lima Zero Energy House in Barcelona

Figure 53 : Zero Energy Lima house (URL 8).

The LIMA prototype has been developed by a research team led by Sabaté associates Architecture and Sustainability (SaAS) with participation of 40 companies from the sustainable construction and energy efficiency sector. It is based on a series of previous studies focused on remarkable reduction of the global environmental impact of buildings in warm climates and to provide a reference for future building in the Mediterranean area. The objective is to have a high standard of low-impact construction during the whole life cycle of both construction and operation (URL 7).

The project has received the Environment Award of the Government of Catalonia 2009 and the Acció 21 Award 2010 of the Barcelona city council for its innovation and sustainability, as well as the XIII Architecture Biennial of Buenos Aires Award. The project is part of the Strategic Metropolitan Plan of Barcelona Towards Net Zero Energy Solar Buildings.

Architectural Design Concept

Designed to minimize heating and cooling loads: (relatively) compact design, high insulation levels, thermal mass (green roof), ventilated façade, and solar protections (Venetian blinds with automatic control).

- Name: LIMA
- Location: Barcelona, Spain
- Layout: Suburban Site - single family houses 1-2 story
- Climate Zone: Mediterranean climate, hot-humid
- Completion: September 2013
- Climate Challenge: Heating & Cooling Dominated

Figure 54: plan and elevation of Lima hose (URL 8).

Climate of Barcelona City

Barcelona located in a Subtropical-Mediterranean climate (Köppen climate classification: Csa), with mild winters and warm summers. Barcelona in the eastern coast of the Iberian Peninsula, and the proximity to the Atlantic makes its summers less dry than many other Mediterranean Basin locations (URL 6).

Winter

Winters in Barcelona are mild. December, January and February are the coldest months, with average temperatures around 14 °C during the day and 5 °C at night.

Summer

Generally, the summer season started from May to October while July and August are the warmest months, with average temperatures around 27–28 °C during the day and 20 °C at night. In June and September, the average temperature is around 25 °C during the day and 15 °C at night, and the average temperature in May and October is around 21 °C during the day and 13 °C at night. The Climate Challenge for the designer of building are either cooling or mixed heating and cooling dominated.

Reduction of Energy

the main features of the LIMA house are remarkable reduction in environmental impact by using raw materials, and reducing energy demand and water consumption/

MATERIALS: 3.7% are renewable or recycled materials, reducing the impact associated with the processes of extraction and manufacture of building materials (damage to the environment by extraction of raw materials, local pollution caused by manufacturing processes, acid rain, etc.). 63% of materials come from renewable sources, mostly of plant origin (wood or bamboo), while 20.7% are from recycled materials (compost, gravel, etc.). Another aim is to reduce the toxic load of construction, limiting chemical inputs by finding natural alternatives for insulation, paints and oils.

ENERGY: predict 97.4% reduction in CO_2 emissions over the 60-year life cycle. The reduction in energy use and emissions associated with construction materials is achieved by substituting concrete, steel and aluminum and other materials that require high energy inputs with materials of plant origin (wood or bamboo). To minimize energy consumption during the occupancy of building, LIMA offers increased insulation and solar protection, the use of heat recovery and ventilation regulated according to occupancy, centralized high efficiency heating and cooling with solar thermal collectors for hot water and heating, the incorporation of control systems and management, the use of low energy and LED lighting, class A + and A + + appliances and photovoltaic electricity generation.

WATER: 52.9% reduction in water consumption by using water efficient appliances and fixtures, rainwater harvesting for plant watering and the washing machine, and the use of gray water from the shower for the toilet flush. It also incorporates biological sewage treatment.

Passive Design

High resistance to heat flow (high R-value, low U-value) is important in hot climate where cooling system needs to maintain a large temperatures difference between indoors and outdoors.

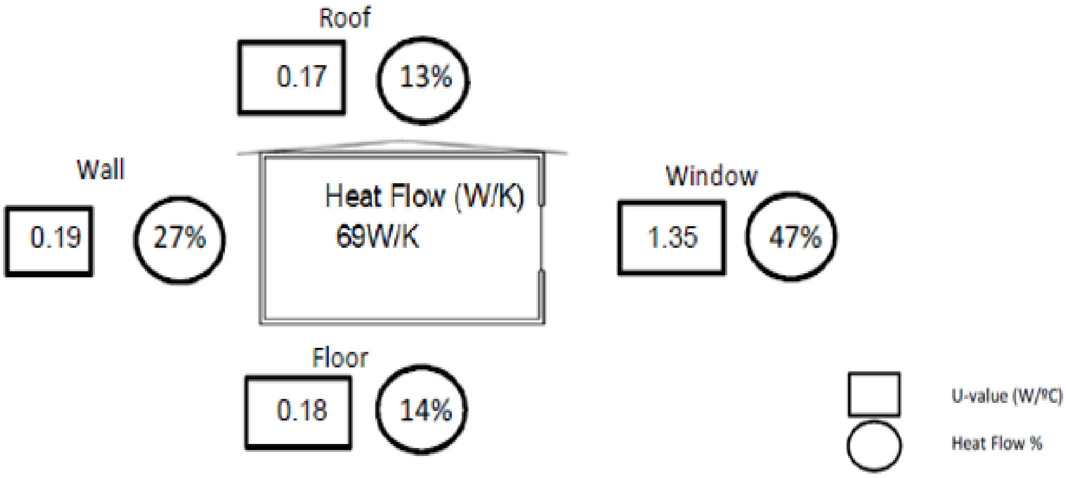


Figure 55 : show Heat Flow (W/ºC) and u value of lima envelope (URL 8).

Thermal Comfort

In LIMA house A heat recovery unit reduces the energy use for heating system. For cooling, Solar Absorptivity Natural Ventilated façade reduces heat transfer through the wall in summer. Openings are oriented for natural ventilation to reduce energy use in building and reach comfort temperature. Green Roof increases the thermal inertia and reduces the peak load.


Figure 56 : roof of Lima house (URL 8).

Visual Comfort

The orientation of the windows and their size in passive design has a considerable effect on the heating, cooling and the daylight of the building. LIMA Building oriented to use maximum daylighting therefore it need more attention to control sun radiation. Windows in west facade have higher U-value to reduce solar heat gain (1.57 W/m² ºC) while in east facade it is 1.35 W/m² ºC.

On other hand for facing solar noon, west and east direction used horizontal timber cladding, ventilated cavity, semi-permeable polypropylene membrane, wood fiber insulation, cross laminated timber panels, cavity, plasterboard used to reduce heating absorption. There are also automatic horizontal shading devices to control day light and radiation. Lighting in this building is also controlled. A light tube lets daylight into the bathroom, reducing the lighting energy.

Figure 57 : show orientation of buildings and windows with automatic shading devices (URL 8).

Construction section
Roof (U = 0.25 W/m2 • K)
-soil for extensive green roof, 70mm - Geotextile felt, polyester and PP
- Drainage and water retention, EP
- Filtering blanket, PP fibres
- Impermeable sheet, EPDM
- Geotextile felt, polyester and PP
- Wood fibre insulation, 120mm
- Vapor barrier of PP
- cross laminated timber structural panel, 125mm
- plasterboard, timber substructure (50x50), 15mm
Windows U = 1.1 W/m2 • K; solar factor g = 0.48). (U = 1.4 W/m2• K overall)
- window frames of larch
- Laminated glass with air chamber and +3 = 6/15/3
- Exterior aluminum blinds, adjustable slats
Facade (U = 0.26 W/m2 • K)
- horizontal timber cladding on timber substructure (30x50), 19mm
- ventilated cavity, 30mm
- Semi-permeable sheet, veil PP
- Wood fibre insulation, 120mm
- Structural cross laminated timber panel, 108mm
- ventilated cavity, 30mm
- plasterboard, on timber substructure (30x50), 15mm
Slab
-floating bamboo flooring, 15mm
- wood fibre insulation, 30mm
- geotextile-felt, polyester and PP
-ballast, 60mm
- geotextile-felt, polyester and PP
- structural cross laminated timber panel, 125mm
- Cellulose insulation, 40mm
- ventilated cavity, 10mm
Ground slab (U = 0.36 W/m2 • K)
-floating bamboo flooring, 15mm
- wood-fibre insulation, 100mm
- structural cross laminated timber panel, 125mm

Figure 58 : partial section of lima zero energy house (URL 8).

In lima house all appliance and lighting have energy efficiency certify. This building use mechanical air heat recovery with heating and cooling radiant.

Renewable Systems

This building produces 28 % of annual heating from the ground and 101% of annual cooling form ground by use of heat pump.

This building used fix photovoltaic (PV) panels on the roof with 30 degree angles and use of polycrystalline technology that expected to produce 1100 (kWh) energy. The building provides hot water with use of solar thermal on the roof with area of 4 meters to produce 49 (kWh/m². year) water and 100% of annual hot water. The following graph shows the expected proportion of generation (kWh/m²) of energy by the various renewable energy sources.

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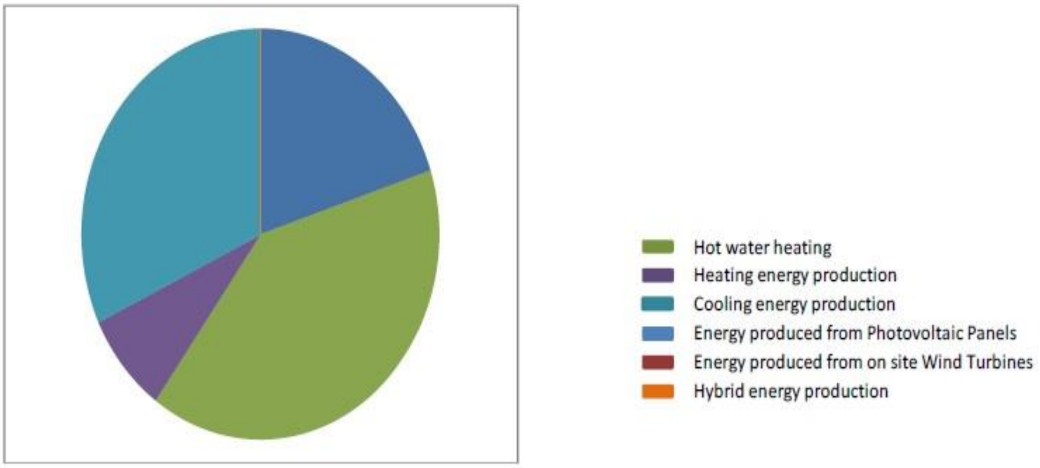

Figure 59 : shows the expected energy produced by renewable energy sources (URL 8).

Table 9: Evaluating of Lima House

Reduction of Energy Use in Building (Passive thermal and visual comfort)						Energy Efficiency Mechanical Use			Renewable Energy In Off-Grid Building		
Envelope	Orientation	Building Layout	Natural Ventilation	Form Of Building	Transparency/ Shading	Selecting Efficient HVAC Systems	Lighting	Mechanical Ventilation	Solar Energy Electricity/Hot Water	Geothermal	Wind Energy
high insulation, green roof (To increase the thermal inertia - reduce the peak load), Solar Absorptivity U-value (W/m² ºC) 0.17 high insulation thermal mass, Ventilated façade (reduce heat transfer through the wall in summer), wood fibre insulation, 3.7% are renewable or recycled materials, mostly of plant origin materials (wood or bamboo), limiting chemical inputs by finding natural alternatives for insulation, paints and oils, 20.7% recycled materials (compost, gravel).	Simple Linear form oriented north to south to absorbed maximum radiation but need more attention in hot seasons orientation of the openings to use Natural Ventilation	Place in open suburban site	Ventilated façade to reduce heat transfer through the wall in summer, Natural façade ventilation requires large amounts of fresh air	single family houses, that help building to absorb more radiation to use day lighting and produce energy but need more cost for insulation to reduce heat transmission in hot seasons	solar protections (Venetian blinds with automatic control), west direction uses higher U-value (W/m² ºC) of 1.57, U-value (W/m² ºC) 1.35 for east glass windows, Solar Absorptivity 0.19, Horizontal timber cladding, plasterboard to reduce heating absorption, a light tube lets daylight into the bathroom, reducing the need to turn on the light in a windowless space, automatic horizontal shading devices to control day light and radiation to enter building with use of sensor	mixed heating and cooling, heat recovery unit largely reduces the energy uses for heating the ventilation air, all appliance and lighting have energy efficiency certify, mechanical air heat recovery with heating and cooling radiant, Heat Pump with 28%heating and 101%cooling efficiency, 52.9% reduction in water consumption by using water efficient appliances and fixtures, rainwater harvesting for plant watering and the washing machine, and the use of gray water from the shower for the toilet flush	lighting have energy efficiency certify, control systems and manageme nt, low energy and LED lighting, class A + and A + + appliances	air heat recovery with mixed heating and cooling unit(radiant**)**	fix photovoltaic(PV) on the roof with 30 degree angles and polycrystalline technology that expected to produce 1100 (kWh) energy, solar thermal on the roof with area of 4 meters to produce 49 (kWh/m². year) water and 100% of annual hot water centralized system with high efficiency heating and cooling with solar thermal collectors for hot water and heating		

3.2 Overview of Zero Energy Leaf House in Hot Humid Zone

Figure 60 : Zero Energy Leaf house (URL 23).

The Leaf House inspiration is the Italian rural house - an autonomous and sustainable microcosm where every resource is exploited and nothing wasted. Its main features include North South orientation, high thermal mass boundary walls, and glazed surfaces on the South facade. The house entirely produced renewable sources without CO_2 emissions. Leaf House is a technologically innovative house: its characteristics of lees cost building, simplicity, efficiency combine and integrate to create a house in the environment.

Leaf House is an example of saving and respect; it is a house contain of six apartments, a real house where real people live.

- Name: Leaf House
- Location: Petrarca, Italy
- Layout: Village, Urban Edge -5 story buildings
- Climate Zone: Mediterranean climate, hot-humid
- Completion: 2008

- Climate Challenge: Heating & Cooling Dominated

Climate

The climate of Ancona is hot and humid (Köppen climate classification) with cool winter and frequent rain and fog. The most intense cold waves come from the north or east. Summers are usually warm and humid, higher degrees sometimes reach between 35°C and 40°C, especially if the wind is blowing from the south or from the west (URL 15).

Passive Solar Design

The Leaf House is North/South oriented and presents a compact shape; to increase its thermal performance. The North facade is set into an edge, enhancing thermal exchange with the ground. On the South facade, the glazed surfaces allow for good daylight in the building, and for enhancing the useful solar gains useful in Winter. During the summer a large photovoltaic roof, integrated into the envelope protects the building from the sun. It overhangs on the South facade to shade the upper level of the building. the overhang of the balcony at the second level, provides shadow to the first level.

In Leaf House, temperature, humidity and CO_2 can be set automatically for the air-conditioner.

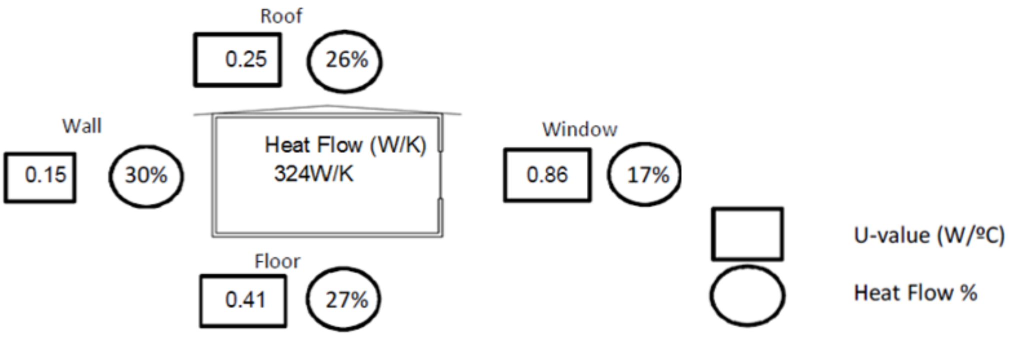

Figure 61: show Heat Flow (W/ºC) and u value of leaf house envelope (URL 23).

The structure of walls of the Leaf House is composed of five layers and compositions with excellent insulation properties. The roof structure is composed by 10 layers (from the inner to the outer surface), while the basement was properly insulated by 4 cm of Polyurethane (the thermal resistance is 2.45 K m2/W). In the Leaf House, windows have maximum double panel insulated glazing (U-value = 0.86 W/m^2K) with a 6 mm of external glass, 14 mm gap filled with argon and 4 mm of internal glass. The Solar Heat Gain Coefficient (SHGC) is 0.61. The window frame is made up of triple panel of wood, thermal foam and aluminum.

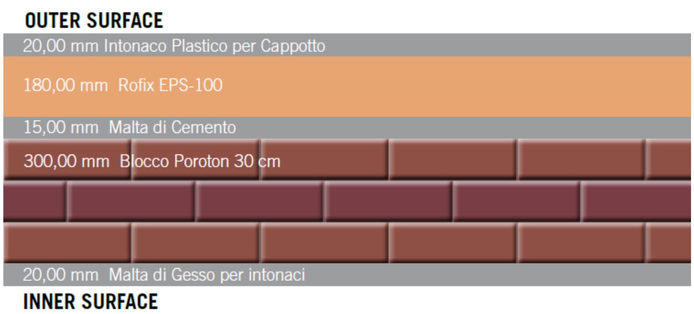

Figure 62 : wall section ,2cm Plaster, 30cm Poroton Brick, 18cm Polystyrene Rofix EPS 100, 2cm Plaster (URL 23).

Mechanical Systems

Every apartment in the Leaf House is equipped with a special Green Set, made of the most water and energy efficient appliances. The overall energy and water savings reaches up to 30% compared to the most efficient similar set in the market. Energy consumption is also optimized.

Renewable Systems

The production of heat and cold is carried out by a geothermal heat pump (GHP). The Air Treatment Unit (ATU) is provided with heat exchangers. Outer air is heated in winter and cooled in summer before entering to the flats thus exchanging thermal energy with the water coming from the heat pump. The outer air is also naturally pre-conditioned through an underground path of about 10m before getting to the ATU. Different sensors systems have been installed to measure the presence of CO_2. If the CO_2 is more than a user defined value, the ATU is activated. Anyway, if windows are open, the air system will automatically stop to avoid energy wastes.

The subfloor is a radiant floor made by several layers: an acoustic barrier (6 mm), an insulating layer (10 mm), a tubing base module which allows an easier installation of the tubing system; the underlayment has a high global transmittance value and is 50 mm thick. Furthermore, the temperature in each room is controlled by a system of zoning valves and thermostats that contribute to reduce the energy consumption.

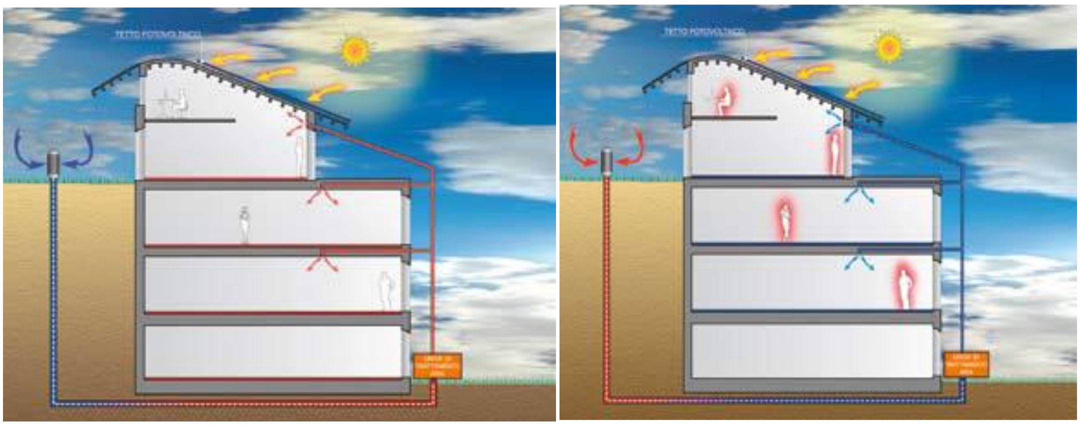

Figure 63: schematic geothermal heat pump summer and winter period (URL 23).

The space cooling system is provided by the Geothermal Heat Pump. In the Leaf house, there are seven flat solar thermal collectors (2.6 m2 each). They are integrated or completely replaced by the heat pump to produce hot water according to the season. The PV panels produce electric energy needs for the heat pump which cover all the surface of the roof facing south.

Figure 64 : photovoltaic (PV) integrated roof and use of roof as shading devices (URL 23).

Table 10: Evaluating of Leaf House.

Reduction of Energy Use In Building						Energy Efficiency Mechanical Use			Renewable Energy In Off-Grid Building		
Envelope	Orientation	Building Layout	Natural Ventilation	Form Of Building	Transparency/Shading	Selecting Efficient HVAC Systems	Lighting	Mechanical Ventilation	Solar Energy Electricity/Hot Water	Geothermal	Wind Energy
local building materials thermal mass Walls and floors have high thermal mass. Green roof increase ventilation Walls and floors have high thermal mass. Building use same Solar Absorptivity with U-value (W/m² ºC) 0.15 and 2cm Plaster, 30cm Poroton Brick, 18cm Polystyrene Rofix EPS 100, 2cm Plaster 0.25Solar Absorptivity with U-value (W/m² ºC) use for roof 3x1cm Plasterboard Pregyplac, 10cm wood fibre, 10 cm rockwool, 4cm airspace, 2cm Pinewood and 0.41 U-value (W/m² ºC for ground floor 2cm ceramic tile, 5cm concrete, 4cm polyurethane, 5cm concrete, 0.5cm bitumen, 20cm concrete, 19cm air, 11.80cm gravel	North/South oriented and presents a compact shape; to increase its thermal performance.	The North facade is set into an edge, enhancing thermal exchange with the ground.	Ventilated roof reduces the solar loads during summer.	the overhang of the balcony at upper levels, provides shadow to the lower levels. which have been used to design the optimized control of the building radiation absorb and reducing the energy consumption of the building	the glazed surfaces allow for good daylight in the building, and for enhancing the useful solar gains useful in Winter. Large roof photovoltaic overhangs on the South facade to shade the upper level of the building the overhang of the balcony at upper levels, provides shadow to the lower levels. which have been used to design the optimized control of the building radiation absorb and reducing the energy consumption of the building Wide windows on the southern facade allow solar radiation to heat the building. The roof, solar thermal panels and the balcony behave like solar shields. For windows in all direction use U-value (W/m² ºC) 0.86 g-value 0.61	High efficiency appliances , Energy Efficient Lighting Heating and Cooling Radiant	The two apartments on the ground floor and the two apartments on the first floor have a bathroom not provided with windows: solar tubes allow natural light to light these rooms.	Heat recovery ventilation system Mechanical Air Heat Recovery overall energy and water savings reaches up to 30% compared to the most efficient appliance	Photovoltaic system Solar thermal system Solar tubes lighting, large photovoltaic roof overhangs on the South façade Flat plate collectors Solar Water Heating produce 63% of hot water Photovoltaic (PV) integrated roof with 22 fixed degree	Geothermal heat pump Preconditioning in an underground duct of the fresh air for heating and cooling, produce 78% heating and 100% cooling Space heating (radiant floors) and domestic hot water demands are covered by an electric heat pump operating with three ground probes and by the heat produced from flat plate solar thermal collectors in the facade at first floor. Cooling provided by the radiant floor, cooling demand covered by a heat pump. An electric dehumidifier is switched on if the UR becomes critical (a few hours a year)	

3.3 Overview of Zero Energy Albuquerque House in Hot Dry Zone

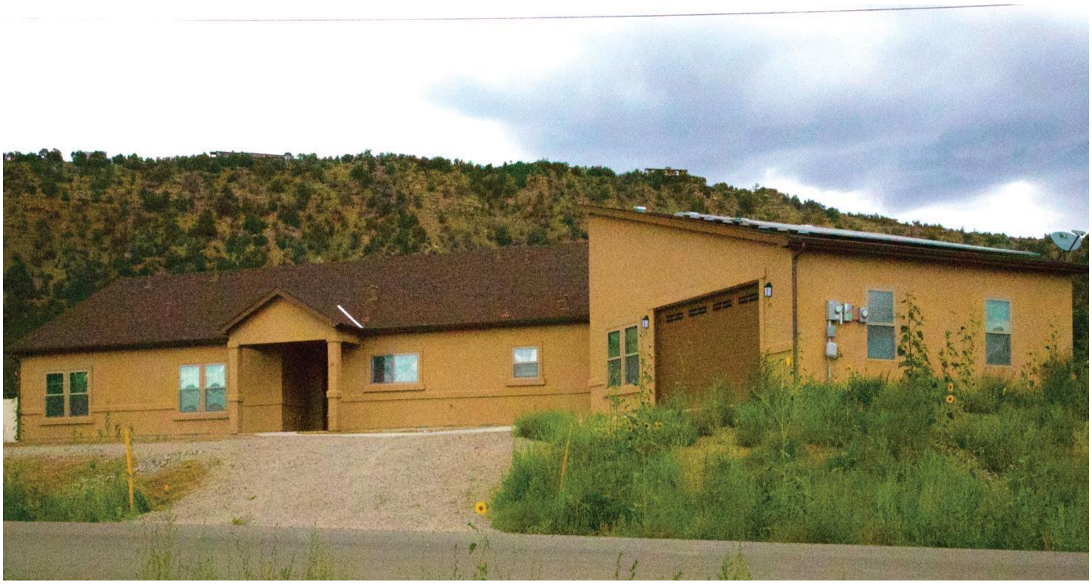

Figure 65 : Zero energy Albuquerque House (URL 1).

Project Data:

- Name: Palo Duro
- Location: Albuquerque, NM-united states of American
- Layout: 3 bedrooms, 2.5 baths, 1 floor
- Conditioned Space: 2,654 ft2
- Climate Zone: hot-dry
- Climate Challenge: Heating & Cooling Dominated
- Completion: September 2013

Figure 66: elevation of Palo Duro House (URL 2).

Palo Duro constructed Zero Energy Homes in the USA in 2014, certified by U.S. Department of Energy (DOE). In this building approximately 30% energy is saved which is roughly consistent with the 2009 International Energy Conservation Code (URL 1). These single-family homes were built with high-quality energy-efficient construction and zero energy consumption with a small amount of roof-mounted PV panels.

Climates of Albuquerque City

Albuquerque has a cold semi-arid climate (Köppen climate classification). Albuquerque is in the northern tip of the Chihuahuan Desert, near the edge of the Colorado Plateau. Albuquerque's climate is defined by brilliant sunshine, averaging 278 days a year; periods of variably mid and high-level cloudiness temper the sun at other times (URL 4).

Winters

Winter is rather brief, with December, the coolest month, averaging 2.4 °C, although low temperatures happen in January (−12 °C).

Spring

Spring is windy, sometimes unsettled with some rain, though spring is usually the driest part of the year in Albuquerque. March and April tend to see many days with the wind blowing at 20 to 30 mph (32 to 48 km/h).

Summer

The summer heat is relatively tolerable for most because of low humidity, except for some days during the monsoon. There are 2.7 days of 38°C highs annually, mostly in June and July and rarely in August due in part to the monsoon; an average 60 days see 32°C highs.

Thermal Comfort

Palo Duro Homes have EPA airPLUS Certification. EPA airPLUS are a set of stringent guidelines designed to remarkably improve indoor air quality of homes. Homes which meet the stringent airPLUS guidelines must first meet all of the guidelines under the ENERGY STAR label. The ENERGY STAR label ensures these homes will have a dramatically reduced energy consumption.

This home with Indoor airPLUS certification incorporates minimize pollutants, increase comfort, protect against combustion pollutants, and offer protective elements to occupants, such as carbon monoxide detectors in all sleeping areas. In addition to high comfort standards for occupants and energy efficiency, the home has specialized features to protect against moisture and mold. In addition, Palo Duro home features a passive radon management system.

Visual Comfort

the building compact of two rectangles with windows for all the rooms (living and sleep) to reach maximum day light and for artificial Lighting are include 90% LED and 10% CFL to minimize energy consumption.

On other hand porch roof work as shading elements therefore they extended all-around of building to defuse solar radiation in hot seasons with high radiation in hot and dry climate.

Energy Saving

Palo Duro home would save about $1,060 per year in energy costs and 19,348 kWh, 84 ga compared to general homes. For this high-performance homes, contractor additions a series of photos showing each wall of the home before drywall is installed with wiring, plumbing pipes, and shafts labeled, for future remodeling or repair projects.

Passive Design

Despite the standard construction methods, Palo Duro is able to achieve an airtightness of 2.0 air changes per hour at 50 Pascal pressure when tested with a blower door. To achieve this level of airtightness, Palo Duro assigns a project the homes are air sealed and they purchase an advanced air sealing package.

Envelope Design

Palo Duro Homes uses advanced framing techniques including constructing on a 70-cm grid with 2x6 studs spaced 70 cm apart, open or insulated headers over windows, two-stud corners, single top plates and ladder blocking at intersecting walls. These measures reduce the amount of lumber and thermal bridging in the walls while increasing the space for insulation. All of the ducts for the home’s central heat pump are located in conditioned space to minimize duct length, reduce heat loss and improve system air flow. In fact, Palo Duro Homes achieves Home Energy Rating System (HERS) ratings of 48 to 58 by stuffing walls with R-22 of blown fiberglass and carefully air sealing at top and bottom plates, around windows and doors, and at any outlets, wiring or plumbing holes.

Figure 67 : show construction process and installing equipment (URL 1).

Palo Duro builds standard stick-framed walls but uses 2x6 studs spaced 70 cm on-center rather than 2x4 studs spaced 40 cm on-center for a deeper wall cavity with less studs, providing more room for the R-22 of blown fiberglass insulation. Corners are constructed with two studs rather than three studs, and the studs are positioned to allow space for insulation installment. Walls have single rather than double top plates. Headers over doors and windows are engineered to use only as much wood as is necessary. Reduced number of studs reduces wall’s thermal bridging.

Mechanical Systems

In Palo Duro building an air source heat pump with heating efficiency equal to 8.7 HSPF is installed. The cooling performance is 15 SEER. In addition, an energy recovery ventilator (ERV) is used to improve air quality in the interior space. The outward ducts of ERV remove exhaust air to outside and provide fresh air for the interior. The heat in the exchanger is directed by two ducts to the cooler route. Since ERV was designed to work all the time, it should be electrically efficient. Palo Duro installed a very efficient electronically commutated motor (ECM) to reduce energy demand in ERV. The mechanism of ERV is as follows. The fresh air is distributed through the ducts of ventilation system but there are separate channels to return the stale air to the ERV.

Table 11: Evaluating of Albuquerque House.

Reduction of Energy Use In Building						Energy Efficiency Mechanical Use			Renewable Energy In Off-Grid Building		
Envelope	Orientation	Building Layout	Natural Ventilation	Form Of Building	Transparency/ Shading	Selecting Efficient HVAC Systems	Lighting	Mechanical Ventilation	Solar Energy Electricity /Hot Water	Geothermal	Wind Energy
porch roof work as shading elements therefore they extended all-around of building to defuse solar radiation in hot Advanced framing wall; 2x6; 24" on center; blown-in fiberglass (R-21); double layer tar paper; stucco. building use R-50 ceiling / R-10 foundation insulation Double exterior house wrap to minimizing moisture intrusion and improving a building's energy efficiency. roof uses asphalt shingles to reflect sun radiation reduce thermal bridging in the walls while increasing the space for insulation with special construction technics All holes for plumbing and wiring are caulked and foamed to minimize energy consumption. advanced framing techniques are used to further reduce lumber use and increase space for insulation. Green guard certified blown fiberglass/synthetic insulation Non-cellulose insulation prevents settling and shrinkage Blown-in insulation completely free of gaps, voids, compression or cuts R21 exterior wall insulation R50 ceiling insulation	North/South oriented and design opening in these sides to use better sun radiation with controlling by low e glass windows and automated shading devices	Single family homes place in dry region cause to absorb radiation that need more isolation and shading devices and it could use maximum radiation for renewable energy producing Front and backyard stub out for irrigation to Maximize water efficiency use	Passive radon ventilation system have a ventilated slopes attic roof	the building compact of two rectangles with windows for all the rooms (living and sleep) to reach maximum day light	quality energy performance windows with Energy Star Rated Low E glass with argon gas blend Use Divided light/mullions to control day lighting Double-pane Windows, argon-filled, U=0.29, SHGC=0.23, low-e windows	central heat pump is located in conditioned space in dropped soffits in hallways and other central locations to minimize duct length, reducing heat loss and improving system air flow. achieves HERS ratings of 48 to 58 by stuffing walls with R-22 of blown fiberglass and carefully air sealing at top and bottom plates, around windows and doors, and at any outlets, wiring or plumbing holes.	artificial Lighting are including 90% LED and 10% CFL to minimize energy consumption .	high efficiency air filtration system; fresh air circulates Mechanical exhaust ventilation system for garage Overhead forced-air heating with system efficiency up to 95% Palo Duro is able to achieve an airtightness of 2.0 air changes per hour to achieve this level of airtightness, Palo Duro assigns a are air sealed and they purchase an advanced air sealing package. uses an ERV with a very efficient electronically commutated motor (ECM) to minimize energy use High efficiency refrigerated air conditioning unit	Thermal solar hot water with 90% hot water efficiency Fixed Solar panel roof: 3.0 kWh, can produce as much power as it consumes in a year.	9.0 HSPF air source heat pump with 40% – 100% more energy efficient than a code built home	

3.4. Overview of Zero Mutual Housing in Hot Dry Zone

Figure 68 : view of Zero Energy Mutual Housing (URL 16).

Project Data:

- Name: Mutual Housing at Spring Lake
- Location: Woodland, CA
- Layout: 1-4 bedrooms, (2-3 story apartment buildings)
- Conditioned Space: 216 to 461 m^2(19.961 m^2 total)
- Climate Zone: hot-dry
- Completion: March 2015

Located in the Spring Lake subdivision in the city of Woodland, Mutual Housing at Spring Lake provides 62 apartments and townhomes, supportive services, and community building programs for agricultural workers. Mutual Housing at Spring Lake is the first nationally certified Zero Net Energy rental housing in the USA. Mutual Housing at Spring Lake is the first opportunity in the nation that renters have to live in 100 percent certified zero net energy homes (URL 16).

Green Certifications for Mutual Housing at Spring Lake include:

Figure 69 : mutual house energy efficiency certified(URL 16).

These certifications are achieved by meeting strict performance guidelines that cover one or all green building strategies that relate to Energy Efficiency, Indoor Air Quality, Resource Conservation, Water Conservation and Sustainable Community Living, which are set by the U.S. Mutual Housing at Spring Lake was selected as a 2015 Housing Innovation Award (HIA) winner in hot dry climate by the U.S. Dept. of Energy.

Energy and water efficiency features include innovative electric heat pumps, photovoltaic system, LED lighting, energy usage monitors, extremely well-sealed and insulated buildings, low-flow toilets, water-saving showerheads, and drought tolerant landscaping. The shower heads have automatic cutoffs that reduce water flow to a trickle when water goes from cold to hot until an individual enters the shower instead of wasting water and electricity when no one is yet in the shower.

Climate

Woodland has dry and hot summers, and cool and wet winters. The rainy season is generally from October to April. Average high temperatures range from 35 °c in July to 12 °c in January.

Summer brings warm days, with temperatures frequently in the 32 degree, but the "Delta Breeze" that blows into the valley through the Carquinez Strait usually makes for comfortable evenings and nighttime temperatures. Occasional heat waves raise the temperature above 38 degrees. During late fall and throughout the winter months, Woodland experiences cooler temperatures, rain from storms originating in the Pacific Ocean (URL 10).

Energy Reduction and Producing

The development performs at net zero energy. The buildings are expected to save 36% to 40% anal energy. They are also expected to see a reduction of 40% in water use and related costs. The built-in energy efficiency and rooftop photovoltaic system are expected to cut utility costs by $58,000 per year. The development will provide permanent housing for about 230 people, half of them children. The residents are all farm workers in the Sacramento Valley. Therefore, Energy efficiency is very important because the families served are low income.

The Spring Lake project is their first project labeled to ENERGY STAR and the EPA's Indoor air PLUS certification. They are also seeking a LEED platinum certification on it. For this issue building need to meet Indoor air PLUS and super-insulated building envelope as the basis for the energy efficiency.

To get the Home Energy Rating System (HERS) certified building met proper installation in the whole envelope except the foundation. In the hot California climate, it's considered to leave the slab uninsulated allowing it to serve as a heat sink during the summer.

For heating and cooling, Mutual Housing selected air-to-water split-system heat pumps to provide space heating and cooling as well as water heating. Although somewhat more expensive than other options, these systems offer several advantages:

- The simplification of using a single system to serve all heating and cooling needs
- The elimination of long refrigerant lines, natural gas piping, and combustion venting.
- The system offers space savings

Figure 70 : The air-to-water heat pumps provide efficient, combustion-free heating, cooling, and hot water (URL 10).

In the apartments, the ductwork is located entirely within conditioned space therefore ducting was installed with very short ducts that supply sidewall registers in each of the rooms off the hallway. The solar electric system of PV panels installed on the rooftop expected to offset 97% of estimated annual electricity use for the project.

Table 12 : Evaluating of Mutual House.

Reduction of Energy Use In Building						Energy Efficiency Mechanical Use			Renewable Energy In Off-Grid Building		
Envelope	Orientation	Building Layout	Natural Ventilation	Form Of Building	Transparency/ Shading	Selecting Efficient HVAC Systems	Lighting	Mechanical Ventilation	Solar Energy Electricity /Hot Water	Geothermal	Wind Energy
super-insulated building envelope as the basis for the energy efficiency Exterior walls were framed using 2x6 studs spaced 16-inch on-center with high-density R-21 fiberglass batt insulation. The foundation is an uninsulated slab on grade. In the hot California climate, it's considered best practice to leave the slab uninsulated allowing it to serve as a heat sink during the summer cooling season. Cool Roof Rating Council-certified composite shingles; 3' ice and water shield; waterproof underlayment.	Mutual hoses oriented north to south to use day light for visual comfort and use radiation for solar panels to produce energy	Mutual Housing 1-4 bedrooms, 2-3-story apartment buildings with park around and middle of building to combine building with green area to reduce around temperature and effect on natural ventilation of buildings	Building have cool roof with slope attic to have natural ventilation	Mutual Houses with compact form reduce energy transmission and decrease cost of insulation of houses	Windows: Double-pane; argon filled; vinyl-framed; low-e; U=0.29; SHGC=0.19.	For heating and cooling, selected air-to-water split-system heat pumps to provide space heating and cooling as well as water heating with high efficient certify. the ductwork is located entirely within conditioned space to decrease ducts length ENERGY STAR-rated refrigerator, clothes washer, and dishwasher. ENERGY STAR appliances for all purchases (HVAC, domestic hot water, windows, appliances) has a consistent positive return on investment when investing in solar.	100% CFL and LED. ENERGY STAR appliances for all purchases	Exhaust fans. ENERGY STAR HVAC	The photovoltaic panels installed on the rooftops of the house expected to offset 97% of estimated annual electricity use The system includes	produce hot water by Air-to-water heat pumps;	

Findings and Discussions

For evaluating of founding in literature review 4 cases selected in hot climate region, two cases in hot humid regions and two cases in hot dry regions.

These cases evaluated according to three main subjects as listed below:

- Reduction of energy use in building by using passive building systems
- Energy Efficient mechanical use
- Renewable energy in off-grid building

Founding's show similar results in compare with literature investigation that show in real cases as well important part is reduction of energy by use of passive systems and architects and engineers try to reduce energy use by passive systems specially they investigated in envelope of building that separate indoor space of house with rush weather of outdoor.

In other section they use most efficient mechanical systems even better than energy code of countries that confirm to reach ZEB need more policies and codes than current one.as well architect and engineer monitoring all steps of installation during construction.to reach more efficient energy they reduce ducts and selected best places for install mechanical systems to reduce energy lose.

In last section selecting of proper renewable are very important and as well experiment in these cases show should be having future perspective, because in such ZEB they lose their balance characteristic after years and they have change or add some renewable systems that have extra costs.as seen in table most usable energy in hot climates is son direction and in all cases they don’t use wind energy that need engineers should have investigated on this.

Chapter 4

CONCLUSION

Investigations have revealed that buildings consume a significant proportion of the total energy worldwide and emit masses of green gases and it will increase day by day. This process has speeded up with climate changed during last decades, that cause countries with moderate and cold climate have affected by these changes. Therefore, this research on zero energy building in hot climate become more important considering the energy provided by fossil fuels will be finished very soon and world population is increasing rapidly which increases the energy demand. On the other hand, people in hot climate region adapted to air conditioned environment and they live in small range of comfort. It proves when Middle East countries start to found new energy plant as a result of energy cost in these countries which is rapidly becoming expensive. In fact, people living in hot climate adapted to use too much energy to reach comfort in recent decades. Therefore, in the future our world will confront two big challenges. Firstly, the countries located in hot regions consume lot of energy to reach comfort, and secondly, countries will be hotter and need more energy because of climate change.

According to the literature, approximately 40% of total energy is used in buildings in the world. Therefore, energy management in the building sector plays an important role in formulating sustainable development strategies. During lasts years, researcher investigated the unstainable and passive energy buildings but according to the research conducted on traditional architecture of hot climate, designers and engineers built masterpiece. However, nowadays we need something more because of behavioral change and new needs. Our world needs future building with balance in energy as well as being built for all people with different income and behavior that causes growing interest in zero energy buildings (ZEBs) in recent years.

Understanding thermal comfort in hot climate region is one the most important issue that investigated in this research to find out related problems in this climate. The review of literature shows that humidity is one of the most effective elements in hot region and people in hot and humid region feel different temperature (generally higher) than people in hot and dry climate. Humidity is the main difference between the types of hot climates that should be taken into account during design and construction process.

The cheapest way to reach zero energy in building is implementing passive systems to minimize the need for energy consumption in buildings especially cooling in hot climate. This investigation shows that by using traditional passive design and combining it with new technologies energy consumption in building could be reduced remarkably. Proper decisions taken based on easier and cheaper construction design will be effective as well such as proper orientation, layout, insulation, shading devices etc. This investigation shows that selecting and installing proper passive systems are very important according to the type of hot regions. The most efficient construction methods are also summarized.

Another decision that has impact on reducing energy is selecting efficient mechanical system. To reach efficient mechanical system, several governmental organizations and councils have established targets to address selected efficient systems such as air plus, energy stars etc.

After minimizing energy consumption, adopted renewable energy helps to reach balance in zero energy building. By reviewing the related literature, it has been found out that the most usable energy plant according to daylight radiation and sunny days in hot climate region is solar panel to produce hot water and electricity. The second level is geothermal energy. According to the research, although wind is the most available energy in the word, it could not be used in all regions because permanent wind flow does not exist. The US and Europe invested on farm wind turbines to produce electricity and extensive investigation have conducted to optimize the turbines, but in off-grid building is not useful because of interrupted wind flow.

In this research, the latest theoretical and experimental optimizing investigation on passive, mechanical and renewable systems are mentioned and analyzed to find the most usable and efficient systems in hot climate regions. These finding are evaluated by selecting 4 cases in hot and humid climate and hot and arid climate. The result shows similar patterns. The designer aims to minimize energy by understanding the best local passive systems and optimizing them by recent technologies such as sufficient materials and most effective insulation.

As a matter of fact, it is clearly mentioned that during the design process, the proper decision according to local climate conditions such as insulation location is important. As seen in hot and humid region, for instance, using high insulation in ground level is effective while in hot and dry region insulation is not installed to use transition heat by ground. Particularly, during construction process, every element is installed very carefully to make sure that each system has maximum efficiency according to the defined goal. In addition, every selected mechanical system and appliance should be of high efficiency and certified guaranteed. Similar to the literature findings, most of the energy for the case studies is produced by solar radiation. More precisely, they fulfill 100% of the energy demand and hot water needs only using solar energy. Wind energy is not used in any of the four cases. Therefore, in hot climate either dry or humid, by using proper solar energy a significant proportion of energy need could be produced. Nevertheless, attention should be paid about heat gain by radiation using proper insulation and envelope design. It can be seen in all the cases that controlling solar radiation to reduce heat gain is considered as an important part of the design. The findings of this study can be used as guidelines in the design process to reach nearly zero energy buildings.

In summary, buildings are places where we spent most of our time. Occupants of the modern buildings expect comfortable conditions combined with balance in energy consumption to reduce environmental effects as well as energy cost. Therefore, all these goals should be considered simultaneously in the decision making process. These facts highlight the importance of zero energy buildings (ZEB). ZEB should be designed for all people with different needs (even for low income people) and the designers hope to reach ZEB in all the future buildings.

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