



Hochschule für Technik
und Wirtschaft Berlin

University of Applied Sciences

***Implementation of sustainable architecture patterns in
hot and dry regions of Iran by investigating on
vernacular sustainable architecture patterns***

Master Thesis

International Master of Science in Construction and Real Estate Management

Joint Study Programme of Metropolia UAS and HTW Berlin

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Conceptual Formulation

Master Thesis for Mr./Ms. Mohammadreza Gharahshir

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Topic:

Implementation of Sustainable Architecture Patterns in Hot and Dry regions of Iran by Investigating on vernacular Sustainable Architecture Patterns

Vernacular Architecture

All building typologies root in local tradition. They use efficient local resources and available energy and materials, so accordingly to climate, site and culture typologies. The common basic function is to protect from weather conditions and answers to local climate, environment and social features. The shape and structure of buildings is usually studied to answer the climate limit conditions. Understanding principles and values of vernacular architecture is very important. Specially when we see some traditional methods of architecture meets the needs of its time and efficiently fulfill the environmental and economical requirement.

Necessity and Importance of research

The traditional architecture of Iran in hot and cold areas is a reflection of climate-compatible architecture designed to provide comfort conditions. And have used more logical approaches and methods to achieve more comfortable conditions.

About more than half of the area of Iran is located in hot and dry region. In related areas of Iran's plateau, for the construction of buildings with maximum efficiency and in accordance with the climate and comfort of residents, attention to the climate and the proper utilization of the climate, require particular consideration. The maximum use of climatic conditions to improve the comfort of life plays an important role. According to said, understanding the nature of hot and dry climate and identifying the factors which affecting to quality of life is so important.

Unfortunately in recent decades, thoughtless architecture imitation without considering environmental and climatic factors from some foreign irrelevant architectural pattern, caused some energetic, environmental, economical problems which also affected damage urban landscape view. These issues can easily solve or reduce with appropriate researches and consideration climatic and vernacular design combining with utilization of new useful approaches.

This research seeks to understand the principles and values of the traditional and vernacular architecture in the traditional houses in hot and dry regions and finding repeatable and useful features in order to achieve sustainable architecture goals for implementation of present architecture and construction.



Importance of sustainability in architecture

According to the United Nations Environment Programme, buildings account for nearly half of the world's energy expenditures, 40% of greenhouse gas emissions, 25% of the earth's potable water, and, in developed countries, over 20% of all solid waste generated (including food waste, yard waste and unrecycled materials). When we look at these statistics, it becomes clear that adopting sustainable design strategies is an essential way to move forward to minimise environmental damage and reduce energy consumption.

Sustainable architecture seeks to construct or renovate buildings using innovative design, renewable materials and energy-efficient technology and in doing so reduce our dependence on traditional energy sources. Sustainable design therefore minimises both the initial environmental cost of building (through reducing material waste and using sustainable products) and the long-term environmental impact of the building (by constructing efficient buildings that use only a fraction of the energy required to power and heat buildings).

Sustainable design is not limited to new builds, but can be incorporated into existing buildings to increase their energy efficiency

Research methods:

This research will be developed based on different literature, papers and publications and case study projects, internet survey, questionnaires and interviews in this field.

Research question:

- 1- What is the main technics implemented in vernacular architecture in hot and dry regions in past times?
- 2- What is the advantages and disadvantages of vernacular architecture in these region?
- 3- What is the main problems in new construction methods and architecture in context of architecture in hot and dry region of Iran?
- 4- How we can implement advantages of our ancestors traditional architectural and their environmental solution to response to the nature in our new architecture with new approach to make them more sustainable?
- 5- What are the others new alternative solution which is appropriate to use to make architecture more sustainable?
- 6- What is consequence of combination of vernacular architecture with our new and current Architecture?

Signature of the Supervisor

Abstract

Today, sustainable development and the saving of non-renewable energies have become one of the most important and common issues internationally. Considering the significant consumption of fossil fuels in the contemporary building industry, the theme of sustainable architecture and utilizing the potential of climate to reduce energy consumption is one of the most important measures in contemporary architecture and urbanization. Iran's traditional architecture, as one of the best examples of sustainable architecture, has shown that in the old days, Iranians have used effective methods for the proper use of non-renewable energies, which differ in terms of climate and weather conditions. The past architecture of Iran represents the Iranian experience in using non-underground natural energies such as sunlight, wind, etc. Various geographic and climatic situations with the intelligence of the past are used to seamlessly combine natural energies to create a unique pattern for indigenous architecture in Iran.

Nowadays, by utilizing the past experiences and reviving the patterns of native architecture that have been forgotten in the present day, not only it is possible to providing comfort living space but also considerably reduce energy consumption and still keeping alive concept of sustainable development.

This research, had tried to present and analyze the sustainable architectural pattern in hot and dry region of Iran as the most prominent example of architectural adaptation to the climatic condition. Currently importance of energy reduction in Iran according to current high energy consumption of building sector in contemporary architecture is a critical issue. This research had tried to find out solutions for reducing energy Consumption in contemporary architecture by analysis of vernacular architectural concepts and samples. This study shows just by proper implementation of the climate characteristics and considering important aspects effecting energy building demand in an optimum way, providing comfort living spaces by considerable lower energy consumption in contemporary buildings is achievable in the study region.

Key words: *Hot and dry region of Iran, Vernacular Architecture, Contemporary Architecture, traditional architecture, Sustainability, Energy consumption*

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CHAPTER 1: INTRODUCTION

1.1. Introduction

First of all we need to concentrate on architecture in all over the world, soon we will figure out that there is a gap between scientific fields and professional executives in architecture. In Iran for many years architects have performed traditional works in traditional way, they believe traditional architecture is suitable for all aspect of country members like their behavior, culture and also their beliefs. Nowadays there is a real contestation among architects, Lots of them try to design and create a way to produce a model which society wants but with the focus on modernity.

Sustainable architecture can provides different advantages, but the main goal of sustainable architecture is reducing energy. Therefore, problems and precautions in design and construction have never changed totally, although a lot of development and progress has been seen in materials and technology. When “sustainable design and construction strategies for Iran” are under scrutiny, then it is possible to observe how traditional buildings and settlements in this region design and construction could be integrated in today's design practices (Ghiasvand & Akhtarkavan, 2008).

By paying attention on Iranian traditional architecture we could confirm that its fact suit buildings in best way in sustainability and in correspondence to the local cultural, behavior, topographical and climatic conditions which have the least conflict effect on environment as well as design compatible with nature by obeying its rules. Therefore, being in a harmonic architecture with the regions, “the old habitable states and cities have been serving both as a residential complex and as an answer for material, spiritual and cultural needs of indigenous people” (Ghiasvand & Akhtarkavan, 2008).

In this paper we introduce some of Iranian traditional and sustainable features in old buildings in and try to suggest some unique ways to have these elements in our modern buildings again.

1.2. Necessity and Importance of research

The traditional architecture of Iran in hot and cold areas is a reflection of climate-compatible architecture designed to provide comfort conditions. And have used more logical approaches and methods to achieve more comfortable conditions. About more than half of the area of Iran is located in hot and dry region. In related areas of Iran's plateau, for the construction of buildings with maximum efficiency and in accordance with the climate and comfort of residents, attention to the climate and the proper utilization of the climate, require particular consideration. The maximum use of climatic conditions to improve the comfort of life plays an important role. According to said, understanding the nature of hot and dry climate and identifying the factors which affecting to quality of life is so important.

Unfortunately in recent decades, thoughtless architecture imitation without considering environmental and climatic factors from some foreign irrelevant architectural pattern caused some energetic, environmental, economic problems which also affected damage urban landscape view. These issues can easily solve or reduce with appropriate researches and consideration climatic and vernacular design combining with utilization of new useful approaches.

This research seeks to understand the principles and values of the traditional and vernacular architecture in the traditional houses in hot and dry regions and finding repeatable and useful features in order to achieve sustainable architecture goals for implementation of present architecture and construction.

1.3. Importance of sustainability in architecture

According to the United Nations Environment Programme, buildings account for nearly half of the world's energy expenditures, 40% of greenhouse gas emissions, 25% of the earth's potable water, and, in developed countries, over 20% of all solid waste generated (including food waste, yard waste and unrecycled materials). When we look at these statistics, it becomes clear that adopting sustainable design strategies is an essential way to move forward to minimize environmental damage and reduce energy consumption.

Sustainable architecture seeks to construct or renovate buildings using innovative design, renewable materials and energy-efficient technology and in doing so reduce our dependence on traditional energy sources. Sustainable design therefore minimizes both

the initial environmental cost of building (through reducing material waste and using sustainable products) and the long-term environmental impact of the building (by constructing efficient buildings that use only a fraction of the energy required to power and heat buildings).

Sustainable design is not limited to newbuilds, but can be incorporated into existing buildings to increase their energy efficiency

Research methods: This research will be developed based on different literature, papers and publications and case study projects, internet survey, questionnaires and interviews in this field.

1.4. Research question

1- What is the main technics implemented in vernacular architecture in hot and dry regions in past times? 2- What are the advantages and disadvantages of vernacular architecture in this region? 3- What is the main problems in new construction methods and architecture in context of architecture in hot and dry region of Iran? 4- How we can implement advantages of our ancestors traditional architectural and their environmental solution to response to the nature in our new architecture with new approach to make them more sustainable? 5- What are the others new alternative solution which is appropriate to use to make architecture more sustainable? 6- What is consequence of combination of vernacular architecture with our new and current Architecture?

1.5. Research Methodology

The architecture of the Iran was investigated in terms of construction based on the dry and hot climate, and sustainable conditions through proposing the definition of concepts, such as sustainability and its relation to the construction and architecture, and climatic features of this region. Building typology (i.e. housing in each region) indicate that the region is affected by environmental, cultural, and climatic factors. Data were collected using field studies as well as the library, documentation and statistical resources. The data were analyzed using the descriptive -analytical method.

CHAPTER 2: LITERATURE REVIEW AND EVALUATION

2.1. Introduction

Considering that the climate has an impact on architectural design also affecting the creation of a sustainable architecture, and with regard to environmental impacts and the untapped use of non-renewable energies and issues such as the global warming of land and the growing greenhouse gas emissions in the atmosphere, Proper design of buildings has been based on the topic of these days. Sustainable development is one of the most controversial issues of architecture today. Various ideas have been presented. Sustainable architecture can be considered as an architecture that responds to environmental conditions and improves its platform capabilities, the least damage to the environment and, moreover, to changing flexible conditions.

The use of domestic materials and the reduction of energy consumption by using traditional methods lead to environmental sustainability and durability of buildings. In this section, we are going to explore the Iranian vernacular architecture in a hot and dry climate of Iran and present methods and solutions which had been used for adaption to environmental conditions and their effect in preserving the natural environment and energy consumption reduction.

2.2. Investigating different climate & regions of Iran

2.2.1. Climatic Regions of Iran

Iran is located in the arid belt of eastern hemisphere, in the West Asia borders the Caspian Sea in north and Persian Gulf in the south. Two ranges of high mountains, Alborz in the north and Zagros in the west, have the basic role in preventing the Mediterranean and Caspian winds to the central plateau, which is the prime determinant of creating urban and architectural form in the hot arid regions.

The Iranian plateau is situated in a dry geographic region. The dry climates of the Northern Africa and the Middle East continue into Iran and the Central Asia with the result that average precipitation in Iran is less than the global average (Koeppen, 2014). Even though Iran is generally classified as a dry country. In fact, it is climatically diverse and can be divided into four main climatic regions :

- 1- The Northern Coastal Region - Temperate Climate
- 2- The Mountainous and High Plateau Region – Cold Climate
- 3- The Southern Coastal Region – Hot and Humid Climate
- 4- The Central Plateau Region – Hot and Dry Climate

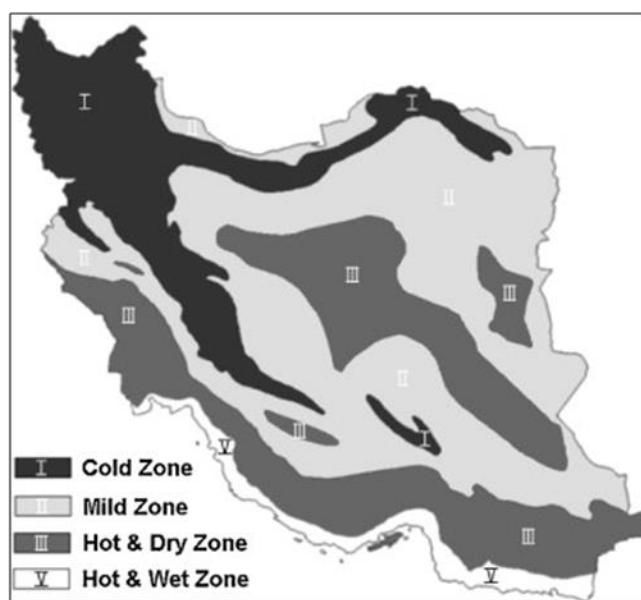


Fig .1: Map of Iran and its four climatic regions (Koeppen, 2014)

- The Central Plateau Region – Hot and Dry Climate

This is the biggest climatic region in terms of surface area and covers most of the central Iranian plateau. It is cold in the winter and hot and dry in the summer. Average annual precipitation is between fifteen to thirty centimeters, and relative humidity is about 20% in the summer and 60% in the winter (Kasmai, 1984). The two large central deserts of Dasht-e Kavir and Dasht-e Lut which comprise one seventh of the total area of the country are in this region.

Considering the research and attention to the hot and dry region that has been the majority of the center of Iran, we look at this area and investigating on the traditional houses and the vernacular architecture used there.

2.2.2. Effect of Climate on Design of Traditional Iranian Houses

In today's architecture the ecology of building includes the climatic issues and also use of the energy and resources in a logic way, at the same time the space quality and also the comfort of user should be considered. Traditional architecture of Iran can be called as a sustainable form of architecture. "It is able to response to environmental problems from a long period. Its features are based on climatic factors as well as local construction materials of hot-arid regions" (Soflaee, 2005).

Traditional architecture is the place where the most practical forms and substances of architectural activity have showed up, and also were tested, and approved by looking for harmony with the natural environment. The main factors in traditional architecture are similar to factors of natural evolution in terms of its time period, the durability of the most successful solutions, and no very big changes in the style and solutions. Traditional architecture accrues as result of many years of experience in use and formation of architectural forms in the local environment by local materials, and from one generation to the other generation produces the best functional home and design outlines and systems (Moradchelleh, 2011).

2.2.2.1. General Principles in Design of Traditional Buildings in Iran

The principles of Iranian architecture are divided into two main categories of physical and non-physical aspects. The following is the short explanation of these principals which have important role in the design of traditional Iranian buildings and houses in general:

According to Monshizadeh (2009) the classification of characteristics of Iranian traditional house is as following:

2.2.2.1.1. Harmony with requirements of people (Mardomvary)

It means concerning people demands and functional terms in the design of the house. Total requests of people in a house with variety of social classes must be

responded. Therefore the duty is to design for people's needs. It also means that all measurements in a building are in accordance to human scale (Monshizadeh, 2009).

2.2.2.1.2. Self-Efficiency (Khod-Basandegy)

In traditional Iranian architecture, the use of local material for construction was one of the things to be considered. For instance the soil which was taken from the building site was used to make bricks for the same building (Monshizadeh, 2009)

2.2.2.1.3. Module Unit (Peymoon)

The main unit for measurement in building is Peymoon. This unit (module) is a reference for the other proportion and measurements of the building. Gaz (103 cm) is a unit for measuring different parts of the building (Monshizadeh, 2009).

2.2.2.1.4. Inward-Looking (Daroon-Garaei)

The functions of the houses are based on the very important issue in Iranian culture which is 'privacy', for Iranian traditional families the family activity should be in different parts of the house which is less public and more private (Monshizadeh, 2009).

2.2.2.1.5. Avoiding Un-necessities (Parhiz as Bihoudegy)

The construction of the building was done respecting to consideration of not wasting materials and finishing the construction by reasonable cost, as an example removing the unnecessary dead loads of construction to have a lighter structure (Monshizadeh, 2009).

2.2.2.1.6. Structural Rigidity (Niaresh)

The technology of that time and also the knowledge of the architect were completely used to create a durable structure which can be also strong enough for disasters like earthquake (Monshizadeh, 2009). According to Pirnia (2009) some of the characteristics of traditional houses are listed as following:

- Introspection Architecture
- Symmetric
- Analogy in Architecture

- *Autarchy*
- *Respect to Neighborhood*

A: Introspection Architecture: *In the traditional Iranian houses a very simple design in the exterior and a very glorious design for the interior were used. Usually the Interior of the houses was very noble. As it was mentioned before the other characteristic of this architecture is that it is not possible to see inside from outside. The interior of the house is like a surprise for the one who is entering to the house and observing the simple design of the exterior (Pirnia, 2009).*

B: Symmetric: *In most of the traditional houses if we imagined a line on the middle of houses we could see the symmetric characteristic of the plan, which also helps the building to be more stable against earthquake. This symmetric characteristic can be also considered in three dimensional form of the building (Pirnia, 2009).*

C: Analogy in Architecture: *In traditional houses of Iran different spaces were constructed based on considering the infrastructure in architecture. For instance, design of the house was done in a way that in any geographical location, there would be a nice air circulation in summer, and also some rooms which are directed to the sunlight for winter time. So in both cold and hot seasons of the year there are some spaces which is suitable for that weather condition (Pirnia, 2009).*

D: Autarchy: *One of the other features in Iranian architecture was autarchy. Each time, for building a house the material which were used in the construction was mostly the same soil of the site, so the ground was excavated and the same soil from the land was used to make mud for construction of the walls and the other parts of the building (Pirnia, 2009).*

E: Respect to Neighborhood: *Although each owner of the house had a different financial situation, considering the economical aspect, most of the houses were built in the same level. For instance one owner who had a good financial situation could have more floors on his building and in this case they would have an overhang facing to the next house, but because of respecting to the neighbor they never made the house like that. This as another feature of traditional Iranian architecture shows the morality of architects owners and neighbors (Pirnia, 2009).*

2.3. Characteristics of traditional architecture in hot & dry climate region

Hot and dry climate include most parts of the central region of Iran. In this climate there is no rain and almost it is hot and dry. In the other hand, the weather become severely cold. There are no clouds in the sky in most of the months of the year and there is no humidity. The temperature is variable in this district. In the summer, maximum of temperature is 50-70c but at night it is reducing to 15c-25c. Traditional architects found ways to bring comfort for human beings in such a weather conditions. "Early men built houses to keep out the elements-rain, wind, sun and snow. Their purpose was to produce an environment favorable to their comfort and even to their survival" (Shokouhian, 2007).



Fig. 2: Desert land (by the author)

There is almost no humidity in the air due to far distance to the sea and ocean. In all seasons there is a big change of temperature between day and night because of the lack of humidity. There is also the prevalence of sandstorms from desert that can happen during all months of the year in places which are near to the central desert part of the country (Hyde, 2008).

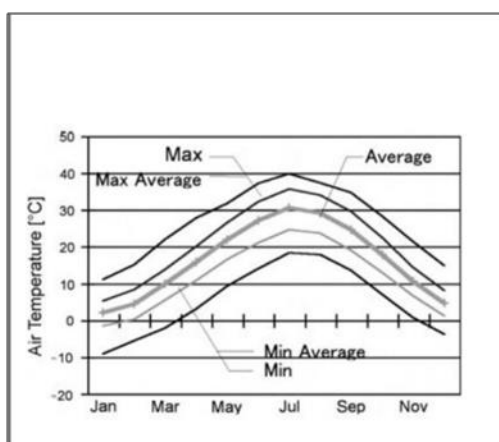
2.3.1. The characteristics of traditional Iranian architecture

The characteristics of traditional Iranian houses reveal natural, geographical, and cultural needs. A main feature of the traditional Iranian house is the adaptation to the harsh climate of the central parts of the country. Climatic problems are severe sunlight and temperature in the summer; fluctuations of temperature; low humidity; limited water supplies; and dusty, sandy winds. In hot and arid climate parts of Iran, traditional architectural designs found solutions to these problems. So, the urban design and architectural style represents the evidence of these solutions (Tavassoli, 2002).

Climate condition has influence on the design of Iranian traditional houses. Hot and dry climate has a relationship to winter condition; building form can spread toward the east - west axis. But as a result the summer conditions houses were designed in compact shape, it's necessary to construct the houses in cubic form, and the general plan of construction in these areas will be focused toward inside. Some of the historical courtyard buildings are the best possible form to adjust in these climate regions and all the Rooms of these houses are opened only into one central courtyard (Behbood, 2010).

In Iran, in hot and arid climate, the most preferred plan type is the courtyard houses. In order to reduce the area affected by the solar radiation, compact forms are chosen. Shady areas can be obtained by arranging those forms with courtyards. In courtyards, with the help of plants and water for evaporative cooling, shady areas can be obtained, the floor temperature can be reduced by the high walls surrounding the courtyard, and the open areas can be used during the day, water Channels poured out from the pool are important elements for cooling (Behbood, 2010).

The recommended shape is a compact block detached to the other blocks, House plan and orientation should be directed towards the northwest-southeast. Two story buildings which also have basement are mostly preferable. The south side of the building can be transparent with shading elements in order to get the heat for winter time and block the summer rays of sun. There are trees or something that creates shade on the east and west to protect the building from the sun. In the north there is minimum opening to keep the warmth of winter time and let the cross-ventilation in summer time (Hyde, 2008).



Tab .1: Air temperature. Tamaki Fukazawa (Hyde, 2008)

To cope with these environmental conditions not only the buildings but also the overall layout of the cities in the region is developed with special characteristics. Ghobadian (2009) defines these characteristics as:

- 1- Urban spaces are enclosed
- 2- Buildings are adjoined
- 3- There are convex roofs
- 4-Ground floor is lower than natural ground level
- 5- Buildings are inward oriented
- 6- There are central courtyards
- 7- Construction materials are brick, adobe and mud

All these characteristics together with other means of using passive energy to acclimating the buildings makes the traditional Iranian architecture a sustainable one. On this subject Soflaee (2005) states that: Traditional architecture of Iran can be considered as a sustainable way of architecture. It is easy for dealing with the environmental problems in long period of time. Climatic factors as well as local construction materials of hot-arid regions and natural cooling systems are the area which the sustainability is obvious (Soflaee, 2005).

2.3.1.1. Traditional houses in the Central Plateau Region

Typical traditional houses in will be analyzed in order to find out if there is a relation between the climatic condition and buildings' form and material. In the hot and dry region of the central plateau, the urban place of traditional cities like Esfahan, Yazd, Kerman and Kashan was compact with attached buildings. The reason was to protect buildings and urban spaces against harsh climate and frequent sand storms. These buildings were inward oriented which means except the entrance door, all the doors and windows open to one or several courtyards. In this way the interiors of buildings were protected from sand storms. The houses in this region are referred to as houses for four seasons. Because the northern wing of such houses which receives direct sunlight was used as family living quarters during the cold months of the year, while the southern wing which is always in shade was used during the summer months. Wind towers were usually built above the summer wing for ventilation during the hot season.



Fig .3: The Arial view and summer living quarter of the Brujerdiha House in the city of Kashan – between Tehran and Esfahan (Ghobadian, 2009)



Fig .4: City of Kerman (Ghobadian, 2009)

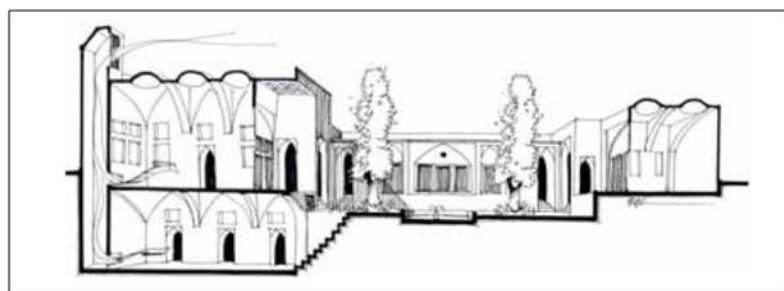


Fig .5: Schematic section of a “house for four seasons” with a one sided wind tower above the summer living quarter (Ghobadian, 2009)

The overall forms of the traditional houses in this region were as follows:

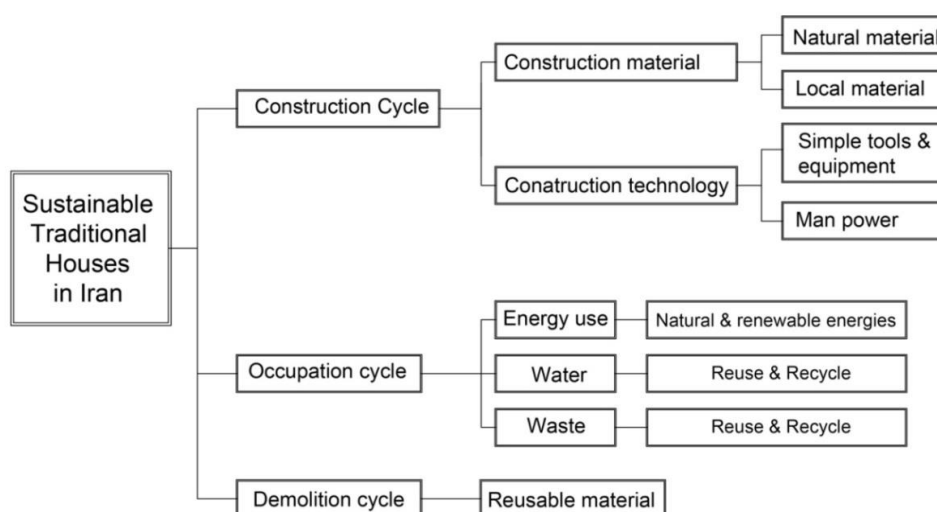
- Ground floor and courtyard lower than entrance and street level
- Buildings were adjoined
- Houses were inward oriented with a central courtyard

- Most buildings had basements, verandas and often wind towers
- Brick or adobe vaults or domes - convex roofs
- High ceilings, especially on the southern side of courtyards
- Thick walls

The only material that is abundant, cheap, and readily available in this region is clay. The three common building materials of mud, adobe, and brick are made with clay. Almost every part of the building fabric – walls, ceilings, and roofs- were made with these materials. The main climatic advantage of these building materials is that they have a high thermal capacity and minimize temperature fluctuations inside the building between day and night (Ghobadian, 2009).

2.3.1.1.1. The Shape of Traditional Houses

The research finding is that the forms of traditional houses varied in respect to the different climatic regions of Iran. In each region, climatic conditions had a direct effect on building form. Diagrammatic drawings of typical traditional houses in different climatic regions demonstrated that in the sustainable traditional houses in Iran, form followed climate. Because of the difficulty of transporting building materials in the past, there was one general rule for this. The materials had to be whatever that was readily and easily available in any particular area or region. For this reason, wood was used in forest areas, stone in mountainous areas, clay in desert, and materials made of plants in the fertile plains Iran (Ghobadian, 2009).



Tab .2: Sustainable traditional building practices in Iran (Ghobadian, 2009)

2.3.2. Traditional house's elements used in vernacular architecture in hot and dry climate

In order to create harmony in this climatic condition the vernacular architecture has implemented some strategies and presented a series of logical solutions for human comfort in response to such weather and his design is based on the environmental concerns and the sustainable interaction between the human and the environment. A principle for the existence of building is the need for better environmental conditions. Early men built houses to keep out the elements – rain, wind, sun, and snow. Their purpose was to produce an environment that is necessary for their survival and even favorable for their comfort. This attribute draw a connection between the architecture and climate and demonstrates a physical and architectural characteristic in a particular region. These elements are the tools which make life easier in such climate. The elements which deal with hot and dry climatic conditions in traditional architecture of Iran can be categorized as (Soflaee, 2005):

- *Wind Catcher (Badgir)*
- *Walls*
- *Windows*
- *Cellar-Shabestan*
- *Material*
- *Khishkhan*
- *Courtyard*
- *Roof*
- *Planting*

These elements and the way they are developed to reduce the effects of the harsh environmental conditions in the residential spaces are explained below.

2.3.2.1. Wind Catcher (Badgir)

Wind catcher is one of the main elements in Iranian traditional architecture. Wind catcher can be seen in hot, hot-dry and hot-humid climates. Wind towers are like chimneys in the sky line of most of the ancient cities in Iran. Wind catchers are vertical shafts with vents on top to guide the wind to the interior spaces. Windcatcher as an architectural element shows the compatibility of architectural design with natural environment. There is a conversion of energy and it is an example of sustainability in Iranian architecture (Ghaemmaghami & Mahmoudi, 2005).

It is necessary to mention that the wind tower examples can be seen in the other countries with the similar environmental conditions. Wind Catcher has been used for centuries in several countries of hot arid and hot-humid climates, mainly in the Middle East countries. Usually a wind catcher contains a tower and a head projecting above the roof of the building. The tower head have vents on the side which is facing the predominant wind. Though, two or four sides of the tower can be open to let the wind in all possible directions. The tower can be divided into two or more groups of shafts. This division let the air move separately up and down the tower all at once and provides more surface area in contact with the air. Soflaee (2005) also states that the breeze from the roof top goes to the summer living zones and on the other hand the hot air of the house goes up and changes its place with the breeze. The structure in the bottom of the wind catcher makes the wind cooler by the means of humidity sometimes the temperature would be 25 centigrade in the summer time (Soflaee, 2005).

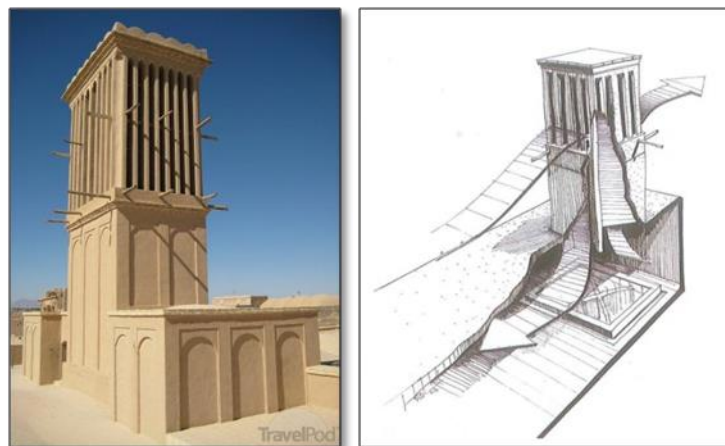


Fig .8: Four-sided wind tower (Gazzeh, 2009)

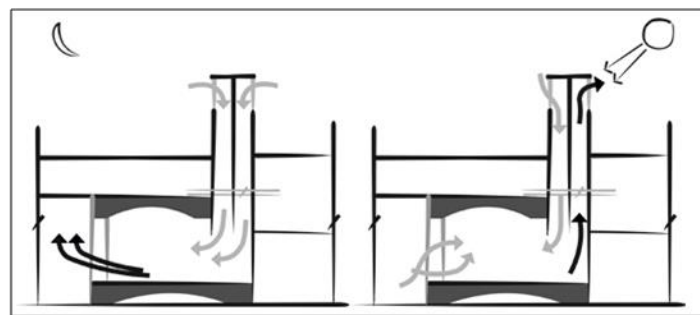


Fig .9: Wind catcher function during day and night (Gazzeh, 2009)

Salehipoor and Azami (2005) describe that “in most of the houses of hot-arid regions of Iran, wind catcher has a direct connection to parch and this space is used for diversity of functions from morning to noon and inhabitants use the underground in the afternoon and roofs at night, which have colder weather, for sleeping. In fact, this act of changing daily space is called local-regional correspondence” (Salehipoor & Azami, 2005).

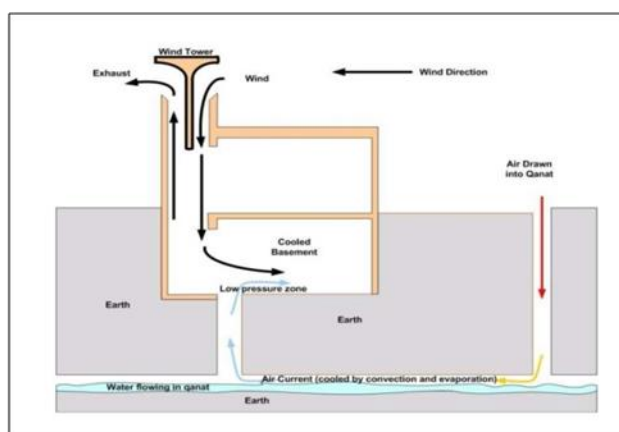


Fig. 10: Ways of wind-catcher function for ventilation (Salehipoor & Azami, 2005)

2.3.2.2. Walls

One of the most important elements of architecture in the hot-dry climate region is the wall. The walls with the thickness of one meter make the heat transferring difficult. In this way, the heat from outside cannot easily transfer to the interior space of the building during the day time. At the same time, the heat of the interior cannot transfer easily to the outside at the cold time of nights and provides enough comfort for the users (Salehipoor & Azami, 2005). Constructing these thick walls by materials with high heat capacity provides enough comfort for residents. Constructing thick walls in hot and dry climate was very common in Iran. For example in Arak city that is located in the center of Iran and has hot and dry climate, people make their homes cool in hot summers without using electrical cooling systems, and heat their homes in cold winters just by using a small heater (Ahmadkhanmaleki, 2011).



Fig .11: Thickness of traditional walls in hot and dry climate (by the author)

2.3.2.3. Windows

External walls do not have many windows and there is enough number of windows which are facing to the yard. Ventilation Passing is done by these windows as same as wind catcher which also helps to the internal ventilation (Salehipoor & Azami, 2005).



Fig .12 :.Window's frame (by the author)

2.3.2.4. Cellar-Shabestan

In all Iranian vernacular houses basement (Shabestan) could be seen, it can be called semi basement but with some differences. A basement (Shabestan) covers with the entire surface below the ground floor of the building. It has a ceiling about one meter higher than the surface of courtyard and the rest of it is designed to be underground (Soflaee, 2005).

2.3.2.5. Material

The common used material for constructing the huge wall in hot & dry regions are mud, mud brick, stone, brick, mortar, lime and wood. The thermo-physical specifications

of these materials are the important issues in hot & dry regions. 'These materials have thermal resistance, high heat capacity and they absorb the sun radiation by their external surfaces. The microscopic and many pores of the mentioned material, which are filled with air, change them to a material similar to thermal insulator' (Salehipoor & Azami, 2005).

2.3.2.6. Courtyard and introversion

Iranian traditional architecture makes the condition suitable for an introvert and hospitable society that its most important way is having inner spaces which are in the form of courtyards .So by using courtyards the general organization of the spaces in Iranian traditional architecture in hot – arid climate is introvert (Daiiallah & Anjom Shoaee, 2014).

Courtyard is a kind of yard that is surrounded by rooms or at least by walls in four sides. It means that at least in one side there are rooms and other sides are closed by walls or in four sides there are rooms (Soltanzadeh, 2010). Fig. 13 shows a courtyard that is surrounded by rooms. Sometimes there are two or even more courtyards in residential houses. In big houses with two courtyards the large courtyard is used by family members and their immediate kin and the smaller one is constructed for male guests. Between these two yards there is a large room and because of the connection of this room with two yards it was called a two- sided room (Soltanzadeh, 2010)

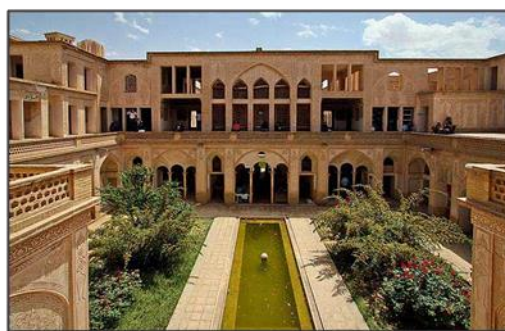


Fig .13: A large courtyard that is surrounded by rooms (by the author)

Courtyard is a social space with an environmental function. It is the heart of the building spatially, socially and environmentally. Courtyards are the main core of social gathering in Iranian culture. It provides outdoor activity and privacy. Family members can gather in the evenings and water the garden and enjoy the small environment and beauty provided inside their houses in a private and comfortable atmosphere. Courtyard

makes buildings a comfortable place for living in hot and dry climate. Water in the courtyard not only freshen the air but also creates a good view. Sound of water and the reflection of light on it can add dynamic quality to the space, while water and light are two aesthetical parameters in Islamic architecture. A courtyard can provide security, privacy and a comfortable place in the house (Zandkarimi & Hosseini, 2012).

Almost all of the houses in hot – arid climate have at least one courtyard and the rooms and other spaces of the house are around the courtyard and have openings to it. The courtyard functions as an element to unite different spaces of the house. So the courtyard is surrounded by very high and thick walls that can provide shady area inside the yard. The long and narrow form of the courtyard provides enough and needed shade for this space during the hot days of summer and it is wide enough to receive solar radiation in winter. Almost in all of the courtyards the ratio of length to width is between 1 and 1.6 (Zandkarimi & Hosseini, 2012).

Usually the whole building and specially the courtyard is lower than the ground level. In some cities buildings are even about 1 meter lower than the surface of the alleys and streets. It causes the building to be more resistant against the earthquakes. By placing part of the building under the ground the heat transfer between inside and outside of the building decreases and reduces the fluctuation of day and night temperature. In dry climate access to water resources was an important parameter in design. In desert regions the rate of planting depends on the amount of water and way of accessing to it. In hot and dry region the green space has lots of effects on the small surrounding regions such as decreasing the direct radiation of sunbeams, shading on ceiling, walls, windows and yard spaces, increasing the humidity in dry regions and decreasing the temperature in building. The courtyard where it is usually planted with trees, flowers and shrubs not only provides comfortable condition and beautiful setting but also supplies some shade and increase the relative humidity of the courtyard space. The humidity provided by the water and the plants and in addition the shade provided by high walls can increase the relative humidity of the air and cool the air in order to create a suitable microclimate in the center of the house. The air passes through the courtyard and upon the water in the pond enters the space of the house and make it cool. Even without modern mechanical heating or cooling systems the courtyard provides a comfortable living environment through seasonal usage of different sections of the structures (Daiiallah & Anjom Shoaee, 2014).

An appropriate explanation can be provided by considering the thermal properties of the air and the material of the courtyard. As the thermal capacity of air is very low the temperature of the courtyard air follows the temperature of the surrounding surfaces. As the thermal capacity of the courtyard walls and floor is so high, these elements save the sun heat during the day hours and radiate it by long waves during night hours. Because of the low thermal capacity of air surrounded in the courtyard and following of the surrounding surface temperature, the air deposited in the courtyard does not get as much hot as the air out of the building during day hours. In the morning the courtyard air gets warm slowly because the walls and floor of the courtyard serve as a reservoir of coolness. So the air receives the coolness of the floor and walls of the courtyard and the coolness remains until the direct radiation of the sun to the courtyard. Therefore the courtyard air is cooled in contact with the surrounding surfaces and makes a person feel cool during the day hours (Zare & Naghizadeh, 2011).

According to (Ratti & Raydan, 2003) , courtyard is introduced as the best urban built form in hot – arid regions. Four parameters were studied: surface to volume ratio, shadow density, day light and sky view factors. The larger surface to volume ratio of courtyard, in comparison with pavilion, in combination with its thermal mass is a positive advantage in the thermal performance of the building. Shadow density that is the average number of hours of shadow on the ground, for courtyard is higher than the pavilion and shows that courtyard provides protection to pedestrians. Day light distribution that is the direct day light availability for courtyard is lower than pavilion. Sky view factor is low in courtyard so during day time hours it insures an increase in direct shading and a reduction in reflected radiation. So courtyard form presented characteristics that when considering in an integral way can significantly improve the environmental performance in hot – arid climate (Ratti & Raydan, 2003) .

2.3.2.7. Summer sitting portion

Spaces located in the southern part of the courtyard are called summer sitting portion. Since these spaces face the north direction receive less sunray and are shady so can provide cooler places. In Persian they are called Nesar. The height of summer sitting portion is often more than the height of winter sitting portion thus the hot weather goes up and the cooler one replaces it in the lower levels. Wind catchers and air vents are mostly located in the southern part of the building. There is also a very big room, saloon (in Persian it is called Talar), on the main axes of the courtyard and in the southern part. By its ornaments, mirrors, paintings on the wood and paintings on the

plaster, this room becomes very beautiful and it is the most noticeable room in comparison with other simple rooms (Arjmandi & Mohdtahir, 2011).

2.3.2.8. Winter sitting portion

Most of the traditional houses are constructed along a specific orientation in such a way that their lengths are from east to the west. This orientation is called the orientation of north to south. This allows the house to be divided into a part in the north and a part in the south. There is a yearly use of space in these houses and for this reason all of the spaces located in the northern part of the courtyard are called winter sitting portions which face the south direction, receive more sunray and heat and become warm so can be used during the cold seasons. The winter sun ray which isn't intense enters into the rooms that are located in the northern part of the courtyard so these rooms become warm during winter. This orientation maximizes the benefit of sunray for cold winter (Ahmadkhanimalaki, 2011).

Seasonal function: The inhabitants of the house move to the northern part of the courtyard in winter and to the southern part in summer to adapt themselves to the changes of climate conditions. This seasonal movement to different spaces in the house is one of the human responses to the climate condition (Ahmadkhanimalaki, 2011)

2.3.2.9. Roof

If the flat roofs are used in hot and dry regions and paved with square shaped bricks called paved bricks, since these bricks receive the most radiation of sun, in the early morning temperature increases and in the late afternoon it decreases gradually. This makes the building to be heated during the day and to get cold at night. The domes which were used as covering roof for mosques, water reservoirs (in Persian called Ab Anbar) and shopping centers (in Persian called Bazar) are suitable types of roof in hot and dry regions. The domed roofs of buildings in this region have some thermal and physical advantages. Because it has convex surface each part of it always remains in shade during the morning and afternoon. The hot air that gathers under a curved roof is above the living area of the room. In this way the room is kept more comfortable. A curved roof is more effective when it incorporates with an air vent. The operation of an air vent depends on the fact that when air flows over a cylindrical or spherical object, the velocity at the apex decreases. If there is a hole at the apex of a domed or arched roof the difference in pressure makes the hot air under the roof flow out through the vent (Ahmadkhanimalaki, 2011).

According to a research that was done about domed roofs by using ECOTECH software, the temperature changes out of the building doesn't have significant influence on the temperature inside the building if it has domed roof. In addition the amount of radiant energy that is absorbed through flat roofs is twice more than it is absorbed by domed roofs (Vafamehr & Sanaieeian, 2012).

Figure 14 presents a domed roof of a mosque. This element is seen in Iranian Bazars (traditional shopping centers). In hot and dry regions the roofs are domed and arched and there are high ceilings but in cold regions the ceilings are short. What's more arched roofs can be observed in house too. For example in vestibule (in Persian called Hashti) the roofs are domed and sometimes there is a vent on the roof that makes the sunlight to enter into the vestibule and illuminates inside that place (Daiiallah & Anjom Shoaee, 2014).

In residential buildings in summer and spring nights, flat roofs were used for sleeping, having dinner and spending free time. For this reason walls were often constructed around the roofs. These walls were made of brick and were grid and were about 1.5 meters height, so the air could ventilate and people could have a private place without the sight of their neighbors. During the day hours these walls could even provide shade on some parts of the roof so they had a secondary climatic role during the day hours (Soltanzadeh, 2010).

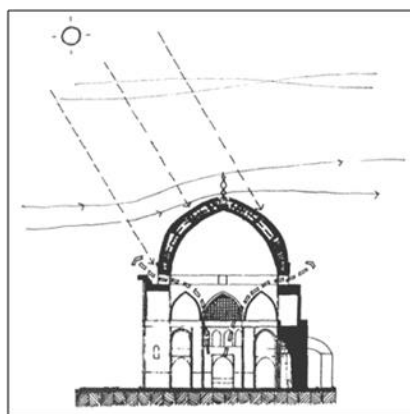


Fig.14.:Domed roof and the radiation of sunlight on it (Soltanzadeh, 2010)

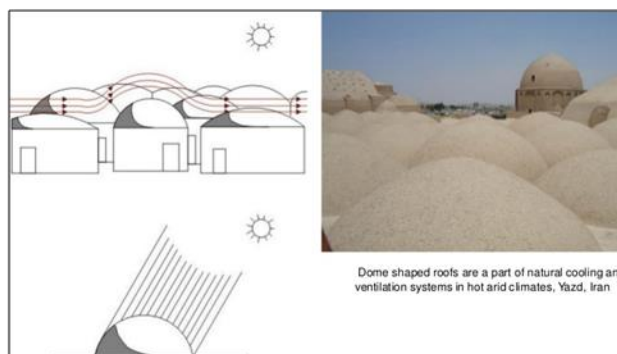


Fig .15: Roof shapes in hot and dry climate of Iran (Soltanzadeh, 2010)

2.3.2.10. Vestibule (Hashti)

In Iranian house the entrance was extremely important and sequence as well. The intention of the entrance was to block direct sight to the interior spaces. Nowadays the interior spaces of buildings are connected directly to the alleys, but in Iranian traditional houses there was a space called Hashti and a corridor between the alley and the interior spaces, so it avoided the direct sight of other people walking in the alley to the interior spaces (Zandkarimi & Hosseini, 2012).

Vestibule was a sheltered space out of the main space of the house that was designed in square, rectangular, octagon and other forms. It was a space between the alley and the house's yard, and was the common entrance for different houses. The residents of those houses were kin and use vestibule for speaking and spending time with each other and also vestibule helped them have their private lives (Zandkarimi & Hosseini, 2012).

2.3.2.11. Exterior and Interior spaces

The concepts of privacy and hospitality have had a great impact on the house formation in Iranian Islamic architecture. Iranian family needs to have privacy as well as social contact with neighbors. In order to achieve this aim the hierarchy of spaces starts with a public space, continues with a semipublic space, semi-private and at last a private space (Zandkarimi & Hosseini, 2012).

2.3.2.12. Sunken Garden

When a building is constructed without any excavation the contact surface of it with earth would be equal to its area but when the excavation is done the contact surface would be increased. In hot and dry regions to decrease the heat exchange of building with the outside air and to provide low expense and natural cooling and heating the buildings are constructed inside a pile of soil as much as possible. When the excavation is done in the center of the courtyard, the space that is made below the alley's surface and the building's surface is called sunken garden (Godal Baghche or Baghchal or Padiav). Sometimes Godal Baghche is one story below the surface of the courtyard. In some cases Godal Baghche occupies a considerable part of the courtyard so the courtyard was divided into two surfaces. This space was constructed in very hot and dry cities like Kashan, Naeen and Yazd city that are located in the center of Iran and are desert cities (Soltanzadeh, 2010).

Figure 16 shows a large sunken garden in Naeen city. The depth of the yard was more than normal to have access to Ghanat water or subterranean canal of water which was passing under the surface of the yard and was used to water garden and water and broom the courtyard. The floor of the yard was paved with square bricks called paved bricks which water and broom was used to clean them and it caused the yard space to become cool. Having access to flowing water that was passing under the surface of some parts of the house in desert cities was one of the main reasons for constructing Godal Baghche. In some cities like Naeen that had an advanced network of Ghanats having Padiav was really important. Water that flowed under the sunken garden filled the central pond and then its excess flowed out of the house toward other houses (Soltanzadeh, 2010).

There were some rooms around the courtyard. Godal Baghche was covered by planting with local trees like fig, pistachio and pomegranate. Upper yard spaces was almost cool and provided by fresh air due to plants and trees covering and evaporation effect of in Godal Bachghe which was smaller and lower than the courtyard,



Fig .16: Sunken garden in Naeen city (by the author)

2.3.2.13. Basement (Sardab)

In all Iranian vernacular houses Sardab is considered to be the same as basement or Shabestan or cellar. Since Sardab is an underground part of the house, thermal exchange between inside and outside of it decreases. Sardab is usually located in the southern part of the house or under the summer sitting part of it. In some cases all of it is under the ground and in some other cases it is an underground semi open space which has a ceiling about one meter higher than the surface of the courtyard and the rest was designed to be under the ground. Light and ventilation is provided for basement by this space. The cellar with its small illuminator under veranda takes a dim light. The vent holes conduct cool air blowing from the north into the cellar and produces good ventilation and cooling in hot summers (Zandkarimi & Hosseini, 2012).

The underground floors in houses are living places. Inhabitants use the underground in the afternoon and roof at night, which have cooler weather for sleeping. This act of changing daily space is called local – regional correspondence .Sardab was also used for preserving foodstuffs and as a living room for all family members. Sardab provided a cooler place in hot summers. It usually had a pond and sometimes had access to the underground water pathways which are called Ghanat. Sardab was usually cooled by Ghanat and wind catchers (Zandkarimi & Hosseini, 2012).

2.3.2.14. Water reservoir (Ab anbar)

Ab Anbar is a traditional water reservoir in Persian antiquity. Water reservoir is its equivalent term in English. To withstand the pressure the storage tank that reserves water, was built under the ground. The water reservoir is a place to a depth of 10 to 20

meters under the ground and is covered by a domed-like roof. The water is collected from Ghanats. So water reservoir is a container for storing water that is dependent on Ghanat. The water is accumulated during the winter, is kept cool in the reservoir and used during the hot summer days (Ratti & Raydan, 2003).

In the design of water reservoir the architects benefit from the changes of seasonal temperature in desert regions and the isolated nature of the ground. In the summer the domed- like roof of the water reservoir and the upper layer of water gets warm. Therefore the upper layer of water evaporates and exits from the reservoir with the air flowing in the air trap. The water reservoir can be divided into two groups: 1- Public water reservoirs that are in villages and cities. These are individual buildings in public places. 2- Private water reservoirs that are in the houses (Daiiallah & Anjom Shoaee, 2014).

In order to access the water people have to go through the entrance (Sardar) which would always be open, traverse the stairway and reach the bottom where there would be faucets to access the water in the storage. Figure 17 shows the entrance of a water reservoir (Daiiallah & Anjom Shoaee, 2014).

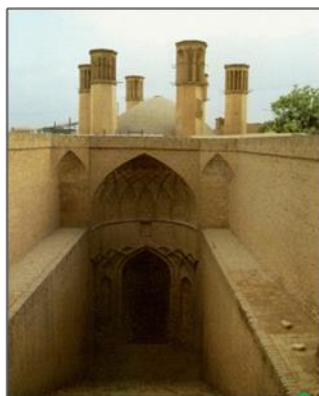


Fig.17: The entrance of a water reservoir toward the storage tank(by the author)

Around water reservoirs there are usually unidirectional or bilateral wind catchers. Wind catchers are located around the water reservoirs and their directions face the appropriate wind. Figure 18 shows the domed roof of a water reservoir and four wind catchers around it. By putting the wind catcher hatches toward the wind or appropriate winds they are led into the reservoir to prevent the growth of microorganisms, by passing it over the water in an environment which there is not air circulation. After the wind hits the water it goes up from the opposite side of the wind catcher (Daiiallah & Anjom Shoaee, 2014).

Figure 19 shows how prevailing wind enters the storage tank of a water reservoir throughout the wind catchers around it.



Fig.18: A water reservoir and wind catchers around it (Daiiallah & Anjom Shoaee, 2014)

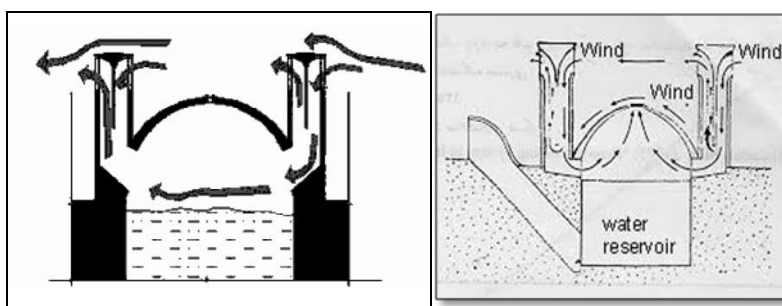


Fig .19: The flow of air in a water reservoir throughout the wind catchers (Daiiallah & Anjom Shoaee, 2014)

2.3.2.15. Sabat

One of the important elements of urban planning in cities with hot and dry climate is Sabat. Sabat is the linked arches between two walls of an alley or it can be defined as the roofed lane. Sabat is designed in order to keep human safe in desert from direct radiation of sunlight in shade for some moments and makes the hot temperature of the city more tolerable. In fact these linked arches have been multifunctional structures, particularly over the long days of hot summer these structures with narrow alleys and tall walls of residential buildings create shade and prevent sunlight falling directly on pedestrians and make air to be cooled. It is such a way that any pedestrian under it is positioned in shade and light repeatedly. These structures also protect pedestrians from the cold wind in winter and make the weather warmer. (Ahmadkhanmaleki, 2011).

Figure 20 shows Sabat in a hot-arid city in Iran. As it can be seen alley is not wide and Sabat doesn't cover the alley completely. Iranian architects in some instances built houses up to somewhere lying on the lane and began to build one or more protruded rooms with same eaves above the passage all commuting was made under these rooms called Sabat. In some cases they are as single rooms over the narrow alleys. Sabats improve the stability of the houses and make neighbors more close to each other (Ahmadkhanimalaki, 2011).



Fig .20: Sabat in a hot-arid city

2.3.2.16. Qanat

The most important problem in hot and dry region is water. Therefore people had to find a way to bring water to the city without any kind of modern technology or pumping system. Ghanat or Kariz is a passive system that was used. Ghanat is a canal that is dug under the ground which connects mother-well to the other wells. Water flows in this canal. A mother-well was dug in a place far from the city where they could reach the water table maybe 100 meters under the ground. Other wells were dug to direct water toward the city with minimum possible gradient. By using the slope of the earth they could bring water to the surface near the city (Ahmadkhanimalaki, 2011).

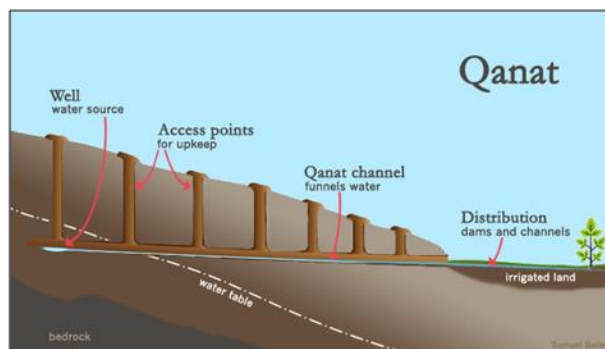


Fig. 21: Elements of Ghanat system (Ahmadkhanimalaki, 2011)

At the present time although Ghanats have been replaced by the modern deep wells, the agricultural lands of many Iranian cities in the central part of Iran are still benefited from Ghanats. By comparing with today's wells, Ghanat is cheaper and it has a longer period of life. But in flat areas or where the area doesn't have enough slopes and in the sandy area it isn't possible to dig Ghanat. In addition the flow of Ghanat water is permanent. (Ahmadkhanimeleki, 2011)

2.3.2.17. Yakhchal (Yakhdan)

Yakhchal is a traditional natural refrigerator that means storage of ice. It was often used to make and store ice, and sometimes to store food. Each Yakhchal was made of a pond, a tall wall that was called Hesar and a dome. The wall was constructed in such a way that during all hours of the day there was shade on the pond and it prevented the water to be warmed. This structure was a buried big space (up to 5000) which had thick walls of at least 2 meters at the base, made with a special mortar called Sarooj, composed of sand, clay, egg white, lime, hair of goat and ash in specific proportions and which was resistant to the transfer of heat. This mixture was impermeable. The ice was carried from surrounding mountains during the winter or was made in the Yakhchals pond in the winter and was stored in Yakhchal, which was a specially designed and naturally cooled refrigerator. Then the ice was used during the summer. Yakhchal was often connected to a wind tower which could refresh the temperature during the summer days. These structures were specially built and used in Iran. Among those which have been remained today, many were built hundred years ago (Ahmadkhanimeleki, 2011).



Fig .22: The form of Yakhdan in hot and dry climate (Ahmadkhanimeleki, 2011)

2.3.2.18. Planting:

In desert regions the rate of planting depends on water the accessibility to water. In hot and dry region the herbal space lots of effects on the small surrounding regions because of the following issues: (Maleki, 2011)

<i>Decreasing the direct radiation of sunbeams in the yard space.</i>
<i>Shading on ceiling, walls, windows, and yard space.</i>
<i>Decreasing the dust in the surroundings of the building</i>
<i>Decreasing the undesirable wind speed in building surroundings</i>
<i>Concentration of wind blow and increasing its speed in a desired direction.</i>
<i>Increasing the humidity in these regions.</i>
<i>Decreasing the temperature in building surroundings.</i>

Tab .3:Planting (Maleki, 2011)

2.4. Contemporary Architecture

In the 20th century, International Style was a very practical and economical way of building design and construction. In this style, form followed function. Climate, environment and regional concerns were not important issues.



Fig .23: Bird's eye view of contemporary Tehran, with many highways and modern buildings(by the author)

Nowadays, many buildings in Iran are built in this style. Almost all buildings are cubic shape and built mostly with metal, concrete and glass. They look the same in Iran as other international styles in other countries. But as traditional houses in Iran, contemporary buildings should be designed for human comfort with regard to the climate of each region. This would be one of the best ways to reduce energy and resource consumption and also reduce pollution, waste and greenhouse gases (Diba, 2015).

To understand and evaluate the contemporary architecture of Iran, it is necessary to look briefly at the evolution of socio-cultural phenomena over the last hundred years. Since the Qajar dynasty of the last century, a break with the long chain of traditional customs has emerged. Iran, whose culture is based essentially on Islam and metaphysical concepts, is being confronted with new Western values: scientism, rationalism and new political and economic considerations. This confrontation has, throughout history, led to an erosion and disintegration of traditional forms and customs (Diba, 2015).

In the West the rationalization of knowledge, followed by demythologization, led to the secularization of thought and, consequently, the crumbling of metaphysical values. This movement in human thought, bolstered in the twentieth century by its scientific and economic supports, is becoming the reference, model and point of convergence for most third world countries. The history of architecture in Iran over the last hundred years reflects the political viewpoints of a country which found wealth in oil and other resources, the desire for cultural and economic references and a cycle of international relations which have plunged the country into the most traditional form of colonialism, overshadowed by the importation of an inappropriate culture (Diba, 2015).

In 1941, following the abdication of Reza Shah in favor of his son, Mohammed Reza became the country's leader. Educated in Switzerland and instilled with new Western values, Mohammed Reza Shah sought to shape the image of Iran. A new modern Iran, with its strength in oil, became the goal of a monarch who was little versed in the social and cultural affairs of a country which, throughout its history, has been deeply impregnated with its own religious and metaphysical concepts, and during this same period (1955 -1978) socio-cultural values began to change. Modern Iran had to embrace modern architecture and the various movements tending in the same direction: functionalism, constructivism, technological rationalism, speculation and site economy. A cubic form of architecture with picture windows and travertine became predominant in the great cities (Diba, 2015).

At a time of economic boom when Iran's frontiers were opening up to multinational companies, and oil was being exploited, property speculators made much use of this easy-to-build cubic architecture. With its light metal structure, flat roofs, and thin walls, this architecture became the powerful, reliable trade of a country in which property was becoming almost the only economic element of stability and investment. The besaz-o-beforush (build and sell), a group of small-scale builders, became masters of the cities.

Architects were divided, out of their depth, overtaken by events and by the impact of a whole society that wanted to build mainly in order to secure its capital in a region where political tranquility had never been the order of the day. Organized into consulting architects' practices and others, they mostly attached themselves to the centers of economic power and became the professional tool of growing speculation. Only rarely did they produce anything innovative. (Diba, 2015)

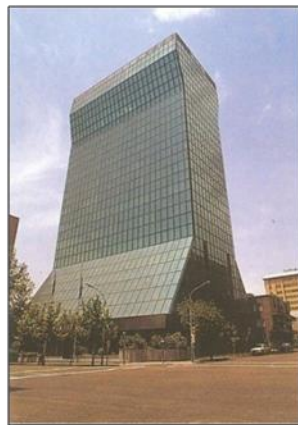


Fig .24: Tejarat Bank, Tehran (Diba, 2015)

This bank Work began before the Revolution and was completed in 1979. Constructed in concrete and glass. One of the series of prestigious projects of international economic relations. This is the most modern bank in Tehran and the whole of Iran. (Diba, 2015)

After Islamic revolution Most individual architects and most of the major practices are being forced to abandon their work. The Planning and Budgetary Organization is setting out new regulations to manage new architectural practices. These new regulations concern only the quantitative aspect of architectural production and do not in any way provide a response to the cultural and artistic aspirations of an evolving society. Islamic architecture is being discussed and sought out, but its interpretation is usually in the form of a pastiche of Islamic elements such as the dome, the arch, the inner garden and the stained glass window. In Tehran, the city has exploded in spatial terms. Initially, all the rules for controlling architectural production were eclipsed, and people took advantage of this period to build houses on plots without title deeds, making illegal use of urban infrastructure (water, electricity, gas, etc.) (Diba, 2015)

For the last ten years, social permutation on a huge scale has disrupted property speculation. Two councils often have control only over the surface area of plans proposed. No one discusses forms, facades or quality of the environment. In the schools of architecture (there are four in Tehran), teaching is mainly theoretical and it is difficult to shake off the influence of modern architecture. In practices, different trends coexist: modernism, post-modernism, high-tech, traditionalism, and so on. There is a range of experience with differing views amongst teachers and students who, in spite of their talent, find it difficult to grasp or develop this eclecticism. However, new programs developed after the revolution are more appropriate to the country (Diba, 2015)

There is few great quality architectural production in recent Buildings. The problem lies in socio-political factors and level of technical and labor skills. In common with many countries in the developing world, Iran is experiencing a rupture with the major traditions and achievements of the past. Iradj Kalantari, a well-known Iranian architect, considers that the reasons for architectural disintegration lie in the fact that political instability has fractured the progress and evolution of techniques and technology. This weakness in the technical field and in our resources has often obliged us to restrict ourselves to unchallenging and unambitious projects. Building workers are, on the whole, peasants from the countryside and small towns. Both workers and foremen have learnt their trade from experience but have seldom been able to participate in major projects. Kamran Safamanesh, whose house in Vanak has become a landmark, feels that only the architect's constant, committed presence on the site can produce an acceptable finished product. A site left in the hands of the workers, progresses by dint of patching and hybridization where the intermediate techniques and methods essential to harmonious completion are omitted. According to Safamanesh, This desire to work fast and cut out the intermediate phases of construction techniques, led to a decline and real cheapness in our buildings. Hossein Sheikh Zeyneddin, a highly talented theoretician and architect who runs the best-known architectural practice in Tehran, feels that the decline of today's architecture is due to a cultural transformation and economic chaos (Diba, 2015).

According to him, there are two essential elements to a harmonious concept of architecture: order and discipline. Without discipline in thought and execution, there can be no work of quality, and professional discipline and accuracy are factors which have almost completely disappeared from our culture. To achieve something of value therefore requires a constant struggle on the part of designers, at all levels and all degrees of execution. The Iranian architect works in an atmosphere of constraint which is incomprehensible to a Westerner. Architectural plans, even the best drawn and most

explicit, are followed and understood only very approximately on site. . In recent construction, the most frequently used materials are metal and concrete for the structure with brick cladding. The metal structure is usually chosen because it can be erected fast and because, in comparison with concrete structures, it is possible to make a saving in the area envisaged on the plans, giving greater profits from the space. Façade usually is covered with brick or stone. After the vogue for stone and travertine between the 1940s and the 1970s, we have now moved on to a fashion for brick (Diba, 2015).

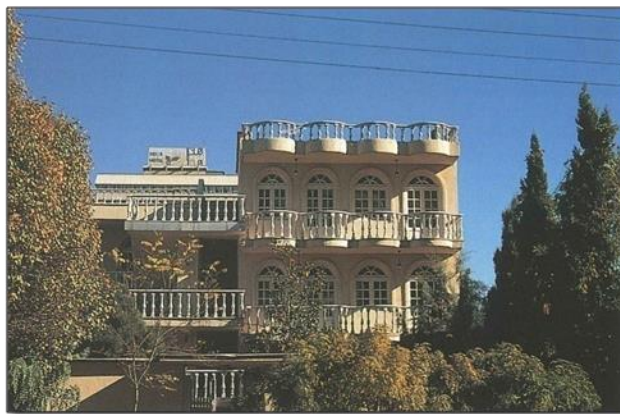


Fig .25 : Housing block (Diba, 2015)

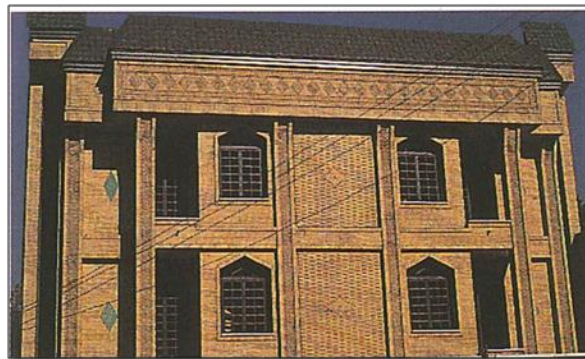


Fig. 26 : Housing block (Diba, 2015)

Figure 26 shows Housing block with 3 floor apartments in Tehran which was completed in 1987. The style is bourgeois/nouveau riche. This is the great fashion in Tehran and other towns in Iran: 3cm beige/light brick on the facade. These buildings could be housing blocks or offices. The structure is usually metal or concrete. In the travertine/stone style of the 1940s-1970s one can see that the brick imitates traditional techniques even in its finishing. It is well received by the various social classes.

The most fashionable cladding material is pale (light beige) brick which gives buildings a link with traditional architecture. An important phenomenon in the housing field is the construction of small, three or four-story housing complexes, each for three to four families, designed under the auspices of government-supported co-operatives. In the typology of their plans, these apartments generally reproduce a modern Western concept that is fairly close to the low-rent building constructed in Europe after the Second World War. Facades are generally no more than functional. This affordable housing is designed to a standard plan, made to fit the plot. Uniform and repetitive apartment blocks have begun to destroy the general appearance of the city and overshadow any landmarks and individuality. Public buildings are undergoing a similar process. Structures are of concrete or metal with cladding materials. Although the government might desire buildings whose level of construction and quality is high, the existing technical resources, labor and local technology allow only for simple construction methods (Diba, 2015).



Fig .27 :TavonMasan. Tehran (Diba, 2015)

These are the housing construction co-operatives intended for employees and members of government institutions on a 15 year loan.. For economic reasons and construction time deadlines a standard design will continue to be used (Diba, 2015).



Fig .28: Tehran. Complex of 17 (Diba, 2015)

Concrete structure covering with brick and mortar and was completed in 1989. This project is an innovation for Iran by changing from usual production. (Diba, 2015).

The current context of regulations, trafficking of influence, quantity-based evaluations, property speculation, excessive cost of sites, lack of labor and supporting technology, all act against the appearance of human, healthy, high- quality architecture. There is no institute or union of architects, and professional lobbying and only very rarely find its way into legal channels (Diba, 2015).

2.4.1. Current energy consumption of building sector

Iran consumes about two percent of the world's oil products while it has about one percent of the world's population (Farhanieh & Sattari, 2006).

Research has shown that 38% of the total energy consumed in Iran is in the construction sector. Almost 39% of this amount of energy is from petroleum products, 50% is from natural gas and near 11% from electricity (Farhanieh & Sattari, 2006).

The housing and construction sector is one of the main sources of pollution generation, accounting for 26.4% of carbon dioxide emissions (Nasrollahi, 2010).Energy consumption in domestic and business units in Iran is 40% of the total energy consumption of the country. According to the data provided it increase by 1.6% annually which will become one of the world's leading importers of energy in the near future. (Nasrollahi, 2010).

Selection of materials and their application in the building should be made according to the climatic conditions, which leads to saving and optimizing energy consumption. Unfortunately, this issue is not considered to be enough critical for architectures, engineers and designers in the construction sector. Given the great value of fossil fuels and the massive loss of this national capital, the need to reform the consumption structure and provide the best patterns for energy consumption is essential (Behyar & Khozani, 2002).

Building walls and insulation layers, lighting systems and home appliances and equipment are the reasons why domestic energy consumption in Iran is three to four times the world average. According to 2015 static, the intensity of energy in Iran is 0.8 tons, while in Japan it is 0.1, in South Korea 0.2, in China 0.27, in Saudi Arabia 0.4, in the United Arab Emirates 0.12. In general, the world average is 0.18. In other words, energy intensity in Iran is 4.5 times to world's average. ([https://www.isna.ir/news/\(19.08.2018\)](https://www.isna.ir/news/(19.08.2018))).

2.5. Sustainability

2.5.1. Concepts and Aspects

Rapid developments in different fields: industry, transportation, communication and construction have caused environmental and visual pollution. This affected the atmosphere and in living vegetation and life in its forms. This may change the balance of natural environment and human future on earth. These issues have brought together disparate activists from developed and developing countries. All these issues come within the remit of debates on sustainability .Sustainability became the “Buzzword” or as Lele (1991, P. 607) describes “watchword” for international aid agencies, the jargon of development planners, the theme of conference and learned papers, and the slogan of development and environmental activists. No wonder that the present climate of urgency to find solutions to the now unavoidably obvious repercussions of years of long-term abuse of the environment, sustainability has become not only an attractive and fashionable phrase, but also a “comfort word” that is prone to being viewed with suspicion (Berardi & Ghaffarianhosseini, 2014)

Sustainability, as Bell and Morse (1999, P.3) think, is widely used nowadays as a way to get support or justify policy: “Few development interventions or research initiatives these days can successfully attract funding unless the words “Sustainability” or

“Sustainable” appear somewhere in the proposal to the funding agency. Indeed, if one listens to speeches by politicians or reads articles by economists, policy-makers or scientists the word sustainable appears with a remarkable regularity”. Nevertheless, “sustainability” as a concept is becoming more important every day. Investigating the subject needs understanding the essence of sustainability as a way of living not just high-priority issues included in government policies and development strategies (Berardi & Ghaffarianhosseini, 2014).



Fig .28: Literature Review Structure (Berardi & Ghaffarianhosseini, 2014)

2.5.2. Sustainable Architectural Design in Hot Climates

This section of the literature review seeks to provide an examination of the crucial role played by architectural solutions and style in reducing energy consumption and CO2 emissions. Low energy buildings can be achieved through the use of renewable natural energy resources (e.g. solar energy and wind energy), as well as by reducing the energy demand of buildings. Sustainable architecture is the result of an environmentally conscious attitude towards designing, implementing and maintaining buildings and is based on local requirements and needs, construction materials for buildings and reflection on local traditions (Niroumand, 2013)

Williamson et al. (2003) state that these approaches to sustainable architecture are concerned with two main issues: firstly, they, “embody the notion that the design of buildings should fundamentally take account of their relationship with and the impact on the natural environment”; and secondly they are “concerned with the concept of reducing reliance on fossil fuels to operate a building” (Williamson et al., 2003)³³. The reduction of energy and natural resource consumption depend on such architectural principles as building shape, shading device strategies and external landscaping, natural ventilation,

lighting in buildings and ground heat exchangers (Figure 29) (Williamson & Radford, 2003)



Fig .29: Architectural Design Solutions Structure (Williamson & Radford, 2003)

2.5.2.1. Shape of building

Considerable number of Studies proved that building shape is a key factor regarding energy consumption (Ourghi, R et al, 2007). Thus, is necessary that building design to be done by optimal shape with attention to local climate and environment. Energy received and Heat Transmission through solar radiation attraction can be reduced by shape of building through whole exposed area in design process (Feist, 2009).consequently the total energy consumption for Colling in summer and warming in winter varies according to building shape and outside surface.

During building design phase, it is essential to recognize design variable, specifically items which is related to temperature transition, and climate- physical component which is has effect on energy demand. (Bektas Ekici & Aksoy, 2011). Table 4 illustrate their studies.

Physical–environmental parameters	Design parameters
Daily outside temperature (°C)	Shape factor
Solar radiation (W/m ²)	Transparent surface
Wind direction and speed (m/s)	Orientation
	Thermal–physical properties of building materials
	Distance between buildings

Tab. 4: item affecting energy demand of building (Bektas Ekici & Aksoy, 2011)

The previous Table shows variety of design items which influence building energy behavior.

Building shape coefficient through heat transfer by building envelope influence the energy demand of building (Oral & Yilmaz, 2003). Also, many studies mentioning area of windows to outside surface and solar radiation heating factor affect building shape factor (Ourghi, R et al, 2007).

2.5.2.2. Shading and Landscaping

In hot regions, by decreasing the building surrounding temperature, the need of energy for cooling will decrease consequently and it is proved by many studies. One way is implementation of trees and its shadows in building surrounding to decrease cooling demand of building. Udagawa report shows shade of deciduous and broad leaved trees on building will reduce air conditioning energy yearly up to 20 % (Higuchi & Udagawa, 2007)

The other case study shows by absence of shadows through the architecture design, windows design and appropriate landscaping, yearly cooling energy rose by 24 % in the same case (Farrar- Nagy & et al, 2000). By implementation of fixed or flexible windows shading like venetian blinds, solar heat absorption can be reduced which is considerable during summer (Feist, 2009). Another research represent facade louver, which is implemented for shading production, reduced indoor air temperature and cooling energy preservation as well (Palmero-Marrero & Oliveira, 2010)

2.5.2.3. Natural Ventilation

Natural ventilation significantly is important in sustainable design. Nowadays considerable amount of energies in different type of water, electricity, gas, fossil fuel are consuming for heating, cooling and ventilation. Implementation of these technics to naturally provide air circulation is a low cost and eco-friendly respond which can be used as a passive technique or as complementary of element of HVAC systems .

Considerable researches prove many advantages of natural ventilation or a combination of it with new technics. More specifically an extensive number of studies have focused on solar chimneys and the associated concept of absorptivity by Lee and

Strand (2009), for example report that improvements to airflow rates can reach 57% by increasing the solar absorptance of the absorber wall of a solar chimney from 0.25 to 1.0 (Lee & Strand, 2009). The temperature of the surface of the absorber wall can be increased significantly by increasing solar absorptance. They therefore suggest the highest absorptance possible for the absorber wall should be used, to maximize the levels of ventilation in the building (Lee & Strand, 2009). A solar chimney can promote natural ventilation using a top sloping roof to harvest solar heat and transfer this heat into the air via a sloped channel inducing a flow of air (upward) (Deblois & Bilec, 2013).

Natural ventilation is an energy saving measure capable of further improving the effects of various sustainability measures (Wong & Behnia, 2008). In new construction projects, the concepts of passive cooling and heating were employed to enhance environmental awareness (Deblois & Bilec, 2013). In domestic settings, using a sloped roof or a solar chimney was the subject of earlier studies (Aboulnaga, 1998).

As was mentioned previously, cooling a house can be achieved with natural ventilation. However, in some cases, a cooling system that relies on energy use is necessary. Energy can be used for either a mechanical cooling system or a passive cooling system (Feist, 2009). Raman (2001) tested passive solar systems that provide cooling, heating and ventilation in hot arid climates and in cold climates. He states that a passive system effectively moderates the temperature variation in a room (Raman, 2001). A system comprising of a collector positioned on a south wall, and a roof duct involving an evaporative cooling surface, was found to maintain an indoor temperature of approximately 30°C when the ambient temperature reached as high as 42°C during the summer period (Raman, 2001). According to Verma and Bansal (1986), the performance of a passive cooling system, using an evaporative cooling technique on the roof, was found to be effective, significantly reducing the air temperature in a room (Verma & Bansal, 1986).

An alternative option is offered by Maerefat and Haghghi (2010), who propose enhancement of passive cooling and natural ventilation in a solar house, based upon low-energy-consumption techniques by employing both a solar chimney and an evaporative cooling cavity. They reported that in the event of decreasing relative humidity to below 50%, the system was effective for air-conditioning in hot conditions (i.e. 40°C), delivering a better performance with a concurrent configuration (Maerefat & Haghghi, 2010).

Diverse methods are available to ensure that the indoor temperature remains low in the summer without active cooling. Some methods are simple, well-known and widely distributed, whereas others are exotic. Whilst some of the methods employed are passive, they may still require auxiliary energy for pumps, fans, etc. These methods are called hybrid cooling strategies and require much less energy than standard air-conditioning units. (Feist, 2009).

Mechanical ventilation can be applied to an entire building to reduce heat flows. This can be achieved by using a simple system, such as an attic fan, which removes solar heat from the attic (Feist, 2009).

On the other hand, subsoil heat exchangers cool down transferred external air. Soil cooling is a method which uses the evaporation enthalpy of water. This approach can be applied in a building to cool shaded ground located around, under or on top of a building. Different types of ground coupling can also make use of relatively constant ground temperatures (Feist, 2009).

2.5.2.4. Lighting

Lighting is an imperative factor to consider during home design process, according to lighting energy reduction by proper implementation and its effect on human health. Recently, there has been an increased interest in integrating natural lighting (day-light) with electric-lighting to reduce the energy consumption in buildings (Li & Lam, 2002). Many studies have reported the benefits of natural lighting, e.g. daylight promotes householder health benefits and plays a significant biological role in controlling the physiological and psychological rhythms of human beings. According to Feist (2009), the sun can be both a friend and an enemy to buildings. There is a need for caution, since buildings with poor climatic design can overheat in hot and even in cold climates. The use and manipulation of the energy advantages of the sun have an important role in sustainable design: solar energy must be exploited in passive solar designs as a pollution free alternative to burning fossil fuels (Feist, 2009).

Daylight and sunlight affects the form of buildings and cities, and the provision of electric lighting is one of the biggest electricity consumers. Occupant perception regarding daylight in a building is a key factor when controlling the use of electric lighting (Richardson, 2009). Mahapatra et al. (2009) have studied the performance of electrical lighting and proposed solutions that promote better levels of light, keep energy consumption to a minimum, and as a result lower rates of CO2 emissions.

2.5.2.5. Ground Heat Exchangers

To improve ventilation through a natural cooling system, the use of an earth to air heat exchanger (EAHE) is considered a viable architectural solution. This technique can also contribute to a reduction in a building's indoor temperature (Hollmuller & Lachal, 2001). As the ground exhibits high thermal inertia, the temperature at a certain depth remains stable throughout the year, which is potentially helpful in summer as a heat sink and in winter as a heat source (Hollmuller & Lachal, 2001)? The former option is applicable in hot climates for cooling purposes. Application of the EAHE technique requires an in depth understanding of the heat and humid dynamics at work in an earth to air heat exchanger (Kumar, Kaushik, & Garg, 2006). Different analytical and numerical models have attempted to examine thermal behavior and cooling, and the preheating potential of EAHE (Kumar, Kaushik, & Garg, 2006).

Maerefat and Haghighi (2010) have investigated the techniques for passive cooling, by using an EAHE in conjunction with a solar chimney (illustrated by Figure 30). They conclude that the performance of this system depends on the exterior temperature of the air, solar heat (radiation) and the configuration of both an earth to air heat exchanger and a solar chimney. They also claim that when cooling demand and external temperatures are high, suitable configurations can provide good internal conditions (Maerefat & Haghighi, 2010).

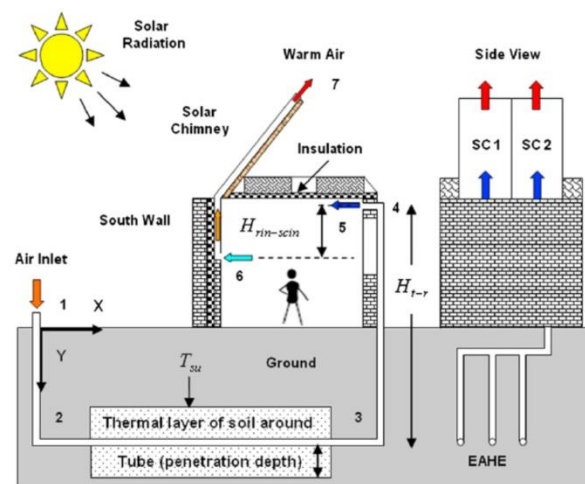


Fig. 30: External Air Temperature, Solar Radiation And The Configuration Of Both An Earth To Air Heat Exchanger And A Solar Chimney (Maerefat & Haghighi, 2010)

Another study has developed a theoretical model of heat exchange through the earth, for hot and arid climatic conditions, to calculate the cooling potential of these devices, as well as the outlet air temperature. They found that an EAHE can reduce the demand for cooling energy in a typical house by approximately 30% (Al-Ajmi & Loveday, 2006).

2.5.2.6. Efficient External Walls Design in Buildings

Most energy loss of building is through the building envelop. Therefore walls as a main item of building envelop play important role in this aspect. Al-Homoud (2004) evaluated the effectiveness of thermal insulation in different types of buildings in the Saudi Arabia. The result shows, the higher the internal heat gains of buildings, the lower the energy conservation level reported. This can be improved by the application of thermal insulation into the external walls.

Several investigations have been conducted to determine the most appropriate thermal insulation thicknesses (Li & Chow, 2005). For example, Zhu et al. (2009) have stated that thermal mass in an external wall can enable heat to be saved during the daytime and released during the night (Zhu & Hurt, 2009). However, in desert climates, with high 24-h ambient temperature and strong sunlight, more heat will be saved than can be subsequently released, resulting in increased energy demand for cooling (Zhu & Hurt, 2009).

In the context of the Bahrain region, Radhi (2009) reports that thermal insulation in an external wall offers a 25% reduction in energy consumption with regard to skin load-dominated buildings (Radhi, 2009). Radhi (2009) claims that energy consumption in the Middle East can potentially be reduced to approximately 7.1% and those CO₂ emissions can be reduced to approximately 23.4 million metric tons (Radhi, 2009).

Another strategy resulting in efficient external walls is the double wall technique. Utama and Ghee Wala (2009) have assessed life cycle energy (kWh/m² year) in an apartment in Indonesia (city of Jakarta) (Utama & Gheewala, 2009). They used clay bricks as a constant material but varied the configuration of the external walls; that is they first used a double wall and then they used a single one. They found that, a double wall is more efficient in terms of energy performance, by about 40%. Another study was conducted by Utama and Gheewala (2009), who examined cement and clay in single houses in Indonesia. They found that, the energy performance for clay houses was better, than cement house (Utama & Gheewala, 2009).

Other studies have focused on the employment of mud as a construction material and have illustrated its efficiency for energy performance. For example Coffman et al. (1980) confirm that mud external walls have a natural cooling effect (Coffman & Duffin, 1980). Similarly, Duffin and Knowles (1981) identify mud construction as a means to control indoor temperatures but they add that suitable proportioning of double or triple layers of different construction materials would further improve both comfort levels and energy efficiency (Duffin & Knowles, 1981).

Considerable research has also been undertaken regarding the thickness and configuration of insulation. Bolatturk (2006) stated that energy savings can be achieved by using a suitable thickness of insulation in buildings. Moreover, the thicknesses of an external wall can play a significant role in energy saving. Fang and Li (2000) suggest that the best structural thickness in passive solar-heated residential buildings is 37cm for brick, 40 to 45cm for high concrete walls, and 35 to 40cm for low concrete walls (Fang & Li, 2000). Clearly the construction of thicker external walls is a costly proposition. However, the long term reduction of operational costs resulting from such construction eventually leads to both economic and environmental benefits (Sisman, Kahya, & Aras, 2007).

Cavities within external walls have also been extensively researched, as they play a primary role in heat transmission. A study conducted by Najim (2014) confirms that, improving thermal performance of the external load-bearing wall of a domestic building can be the best option in terms of reducing energy consumption to run a cooling system. Moreover, the study also confirms that, compared with other approaches, the incorporation of air-cavities in external walls will have a greater effect on their performance (Najim). When cooling is the desired effect, a cavity insulation must be installed so that it confines heat storage in the external leaf of the wall and consequently forces the stored energy to be released to the outside (Byrne, 2013). These studies display how far these strategies can be applied in regions with a hot climate, in order to save energy via efficient external wall design. Additional techniques (cavity depth and cellulose insulation) can be applied when designing external walls, to increase the efficiency of the house envelope.

2.5.2.7. Efficient Roof Design

The roof of the building is the second part of the housing envelope that determines energy performance. The results of recent studies into roof design and insulation

materials will be discussed in this section, which will be divided into three main areas; green roof design, white roofs and reflection, and roof insulation. One of strategies when designing an external roof with the aim of achieving energy savings is the Green Roof. Green Roofs which are also called roof gardens, eco-roofs, or living roofs include planting on the external surface of the roof (Parizotto & Lamberts, 2011). The external roof of buildings is an envelope component offering significantly advanced solutions in terms of energy conservation for cooling the inside of buildings or improving the internal thermal conditions in non-cooled buildings (Zinzi & Agnoli, 2012). In addition, adding cool materials to the roof of a building will maintain a low temperature, even under hot conditions, such as when facing solar heat (sun). They function by reflecting the sun's heat (solar radiation) and radiating it away during the night. Examples of vernacular architecture from Northern European countries have been employed in research to demonstrate the benefits of green roofs (Coutts & Daly, 2013). The materials, including the vegetation, used in green roofs act as thermal insulation and they result in energy efficiency (Zinzi & Agnoli, 2012).

Furthermore, they offer increased insulation due to the soil and evapotranspiration, thus keeping the external roof of the building cool under solar radiation (Zinzi & Agnoli, 2012). At the same time, the incorporation of green roofs has additional benefits, such as, improvement in the quality of water runoff (Bates & Sadler, 2013). Many existing studies note that different types of Green Roofs are used in different locations (countries), confirming the advantages of selecting different building features to suit different climates (Williams, Rayner, & RaynorK.J, 2010).

However, because of the complexity of installing and maintaining a proper green roof, simpler alternatives have been explored. Selecting a light coloured external roofs surface has been proposed, due to the supposed efficiency of lighter colours in reflecting the sun. There are important differences in heat gain between lightly colored and dark roof surfaces (Bates & Sadler, 2013). A roof which is designed to be highly reflective, such as a white roof surface will be cooler during sunny periods, minimizing the demand for energy to cool the building . Both weathering and ageing, however, play a role in minimizing the solar reflection from cool roofing materials (Akbari, 2002).

Suehrcke et al. (2008) conducted a study in hot climate conditions, and proposed the classification of roof colours into, dark, medium, light and reflective ones. According to their calculations, a dramatic reduction in downward heat flow could be achieved if a

reflective or light coloured roof surface were used. This reduction correlates with a reduction in energy consumed by a cooling system (Suehrcke & Peterson, 2008).

Based on the results of a numerical simulation, Suehrcke et al. (2008) argue that a roof with a light color delivers approximately 30% reduction of internal air temperature and heat gain when compared with a dark coloured roof .

For hot climate conditions, according to Suehrcke et al. (2008) “it is widely recognized that a reflective white roof surface instead of a dark one can be of great benefit” (Suehrcke & Peterson, 2008). Roofs that are white in color can improve occupants’ comfort in the home and reduce the load on air conditioning systems.

2.5.2.8. Windows and Glazing Design

This section will investigate the results from recent studies, relating to window design and glazing. It will be divided into three main areas: the importance of windows, window design, and glazing.

It is well known that, external window design (glazing) is one of the most important elements considered by a designer when designing low energy homes for hot climates. It is common practice in modern dwellings to use large windows which result in high rates of heat transfer. Moreover, windows allow daylight into a building providing sufficient lighting during the day and meeting at least some of lighting needs in internal spaces. A suitable design for windows, offering natural lighting can improve appreciation of the indoor atmosphere. A study was conducted by Askar et al. (2001), and showed that recent building designs in the Middle East involved large areas of glazing . However, this creates high electricity demand to run a cooling system (Askar, 2001). A suitable design of windows is one way to reduce this demand.

A study carried out by Larsson (2002), has explored possible modifications to external window designs. According to Larsson (2002), the current trend in the reduction of heat loss at the base of building components has resulted in a number of important modifications to window design (Larsson & Moshfegh, 2002).

Another study by Askar (2001) has investigated ways in which to reduce energy demand in hot climates in the Middle East through the efficient design of external windows (Askar, 2001). They propose triple glazing to minimize solar radiation

transmission from the ambient environment. Moreover, this triple glazing system can maintain adequate levels of natural lighting inside the building (Askar, 2001).

Concerned by the influence of window size on energy consumption, Persson et al. (2006) note that minimizing the size of south facing windows, while increasing the size of northerly oriented windows, influences the energy consumption and maximum energy-load needed to maintain internal temperature comfort. Their results indicate that while energy efficiency influences 'cooling' in the summer, it does not significantly influence heating energy in the cold season . Therefore, they conclude that the enlargement of windows facing north would be of benefit, as they also improve lighting (Persson & Roos, 2006).

In order to reduce the impact of solar heat and slow down the heat transmittance from the outside to the inside through glazing, insulated glazing was reportedly the best option for external windows. Many techniques can be used to improve the efficiency of external glazing in terms of reducing buildings' energy consumption. Recently researchers have illustrated energy performance using different multiple panes of glazing in external windows (Manz, 2008).

It is common to use a system of double glazing in external windows in buildings today, but the insulation performance of such a system is affected by many factors, including, (a) type of glass used, and (b) the inclusion of a thermal breaker in the frame (Song & Jo, 2007). There have been many attempts to improve the efficiency of the insulation performance of double glazing systems; such as, using a low-e coating on the glass surface; filling the gap between the panes of glazing in the windows with gas, inserting a thermal breaker made of polyurethane (Song & Jo, 2007), sealed-air, coatings, evacuation, phase change materials and airflow (Chow & Li, 2013). Song et al. (2007) reported that using insulation "made of thermally broken aluminum and thick walled plastic" will raise the temperature of the lowest inner surface substantially and satisfy required minimum temperature (Song & Jo, 2007).

In a study, Oliveira Panão and Rebelo (2013) discussed the minimum amount of energy that would be required by near Zero-Energy Buildings (nZEB) in Mediterranean domestic buildings. They found that there is a direct correlation between the thickness of thermal insulation and the energy efficiency of the adopted solutions. Moreover, they specified the thickness of such insulation to be between 0.04 and 0.06 m (Oliveira Panao & Rebelo, 2013). Also the researchers noted that double glazing is one of the most

important energy saving solutions and asserted that its thickness should be 6/16/6mm, according to U-values. Finally, they discussed what level of energy consumption should be used in a near Zero-Energy Building and concluded that the energy demand is strongly dependent on the primary energy indicator assumed, which could significantly differ from country to country.

Multiple technologies have impacted energy saving as mentioned above. First, "Sealed- air" technology, where air is sealed in the cavity of external windows, offers efficient thermal insulation as well as a simple and economical design (Chow & Li, 2013). In addition, using an advanced low-e coating in the external glaze can reduce the solar heat exchange between glazes significantly (Singh & Garg, 2008). In different climatic conditions, it is necessary to place a coating on a suitable surface to decrease indoor heat gain (Chow & Li, 2013). Another technique when using natural airflow in the windows is to use double glazed windows installed with a semi-open cavity between the glazes to permit natural airflow; the thermal performance of the windows can then be improved through fluid heat removal (Gosselin & Chen, 2008).

Many studies have been conducted to address and establish the benefits and importance of the role played by glazing in maintaining comfort in the indoor climate for the longest possible duration. Studies have explored the environmental, technical, economic, and internal comfort implications of the current technologies associated with emerging glazing, for the energy conservation of highly glazed buildings in hot climate conditions in the Middle East, which is one of the world's harshest climates. Predictions have been made involving two examples of buildings, through the employment of thermal simulations to assess the influence of electrochromic glazing, holographic optical elements (HOE), aerogel glazing and thin film photovoltaics. After assessing the potential for reductions in cooling demand, their study of fixed glazing concluded that reflection in the form of HOE can be expected to minimize the comparable air conditioning energy use of buildings. It is claimed that light transmission in this kind of glazing would be approximately 85% of the equivalent standard (low-e glazing) solution applied. The more significant air conditioning load reduction can be attributable to the lower light transmission (James & Bahaj, 2008).

2.5.3 .Renewable Energy

Currently utilization of Renewable energies in different sectors caused huge energy conservation. It is important to pay attention to implementation of renewable energy in building industry as it is huge energy consumer sector. Implementation of any type of renewable energies for buildings can be an advantage specially buildings which are located in the regions with available and active source of energies.

Developing and designing with the distribution of suitable technologies for renewable energy is essential to meet the increasing energy demand for both the growth of the economy and to improve the quality of people's lives cited in. Developing renewable energy technologies and disseminating them on a large scale has been the priority in a large number of countries around the world, in order to promote sustainable options and insure that environmental energy supply can meet energy demands, Historically, in the mid-1970s, considerable progress was made in terms of renewable energy, such as; wind energy, solar radiation energy through (photovoltaic) and thermal applications (Kandpal & Broman, 2014)

However, the recent trend toward energy management in the residential sector of the smart grid paradigm involves: (a) distribution renewable generation, (b) distribution energy storage possibilities, and (c) demand-side load management. Adoption of multi-generation systems to generate renewable energy results in significant benefits in terms of higher energy efficiency; minimising CO2 emissions rates and enhancing the economy (Chicco & Mancarella, 2009).

This section will discuss recent studies that have been conducted into the use of natural resources, as an alternative to burning fossil fuels. this section will be divided into three main categories: (i) Solar Energy; (ii) Natural Energy resources(iii) natural energy resources

2.5.3.1. Solar Energy for Buildings

Passive solar design techniques have been practiced for thousands of years; they were essential prior to the development of modern mechanical cooling or heating. When designing passive solar buildings, it is important to consider the local climate conditions. Hence, the scientific design of passive solar buildings is based on factors that include

local climate, solar heat gain or loss and human thermal comfort (Delisle & Kummert, 2014).

According to Delisle and Kummert (2014), in the near future (the next 5 years), within the solar industry, building integrated photovoltaics will become one of the quickest growing segments across the world. This increase of interest in “building-integrated photovoltaics” has arisen because many countries are currently establishing specific goals related to zero energy buildings. To achieve this aim, building designs are expected to incorporate three important concepts: (i) energy efficiency; (ii) energy saving; and (iii) optimal use of technologies for renewable energy to generate electricity naturally. For this reason, building integrated photovoltaics has significant advantages; such as, it generates electricity acting as an active component of the building envelope. The application of photovoltaic technology (PV) is most common in on-site energy generation units (small scale). Photovoltaic technology has huge benefits for consumers and utilities (Delisle & Kummert, 2014).

It is widely recognized that on-site energy generation using PV techniques and wind energy is a “cost effective” method that can be applied in the countryside “suburb areas” as an isolated power system. Moharil and Kulkarni (2009) pointed out that solar photovoltaic systems provide a competitive option and are acceptable to people in terms of commercial operation and quality of energy supply (Moharil & Kulkarni, 2009). The strategy of vertical facades is an efficient renewable energy technique to consider. A study was conducted by Ordenes et al. (2007) to discover the impact of domestic building integrated photovoltaics on energy consumption. They analysed multi-family houses in multiple locations (three different cities) in Brazil. They found a large amount of energy can be generated through vertical facades (Ordenes & Marinoski, 2007).

Employing a Photovoltaic panel (PV) system on a roof top, or using other renewable energy sources normally creates a balance between consumed and generated electrical energy, thus achieving a zero energy building. In addition to their environmental benefits, photovoltaics can also have aesthetically pleasing effects. A study of surveys conducted by building professionals and architects points out that the integration of a PV system into a building facade can improve its features (Ordenes & Marinoski, 2007).

Garcia (2002) outlined potential energy reduction and noted that more efficient performance is achievable with the careful use of different passive solar strategies, such

as: (a) skylights; (b) clerestory roof windows; and (c) roof monitors, as well as intelligent element measures on the roof. The implementation of solar passive strategies can significantly reduce heating load and improve ventilation and lighting in spaces where there is no equator-facing (Garcia Hansen & Esteves, 2002).

Davidsson (2010) developed and evaluated building-integrated multifunctional PV/T solar windows, based upon a construction of PV cells laminated on solar absorbers and placed in a window behind the glazing (see Figure 32). He found that a solar window produces about 35% more energy in the form of electricity per unit cell area every year, compared with a vertical flat PV module (Davidsson, 2010).

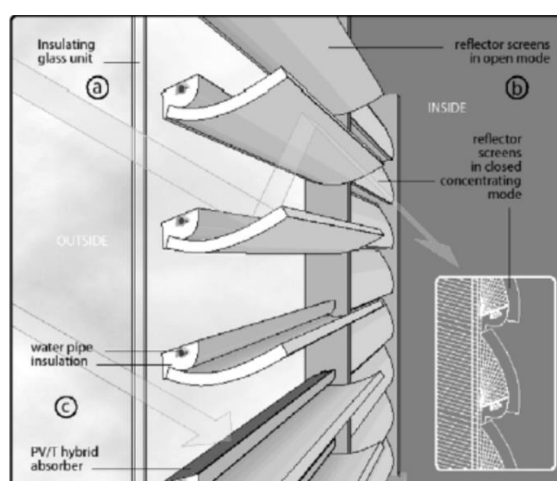


Fig .31: Solar Absorbers Placed In A Window Behind the Glazing (Davidsson, 2010)

2.5.3.2 Clean energy requires technology

Before the Industrial Revolution, energy used by humans was fundamentally renewable. The shape and design of cities based on the existing climate were designed to provide maximum use of solar and wind energy for citizens. This issue is well seen in Iranian cities, especially desert towns. The industrial organization after the industrial revolution was dominated by steam energy using coal fuel instead of wood burning. This technology has met with increased demand for more energy. The industrial revolution was in fact a revolution in fossil fuels, and although it was a rapid progress, there were serious consequences, such as urban air pollution, which was effective in the health of the inhabitants. Considering that energy from fossil fuels can be extinguished, the use and calculation of energy efficiency and energy efficiency have been greatly expanded. One of the important aspects of increasing energy efficiency is to ensure proper use of the type of energy for specific purposes. For example, the cost of generating electricity in

the transmission lines is much higher than the cost associated with it. The wasted energy in this process is capable of heating all American houses (Byrne, 2013).

It is important to move energy to renewable energy, and in fact, the transition from fossil-based hard technology to soft technology, such as those that are environmentally compatible and ecologically and future technology returns to nature and compatibility with nature (Byrne, 2013).

2.6. Investigating Sustainable Architecture in Iran

2.6.1. Sustainable Systems in Iranian Vernacular Architecture

Sustainable architecture, framed by the larger discussion of sustainability having to do with the pressing economic and political issues of our world, seeks to minimize the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy, and development space (Nicol & Raof, 2007).

Due to lack of access to modern heating and cooling equipment in ancient times the architects were obliged to rely on natural energies to render the inside condition of the buildings pleasant (Raof, 1982).

Iran is basically divided into four climatic regions. One of these Regions is the dry and hot region, which consists of the most parts of the Iranian plateau. In this part we will focus on various solutions and different sustainable systems which were used in hot and dry region of Iran.

2.6.2. Iran and Energy Sources

Iran has vast reserves of oil and natural gas and is one the most important centers of these energy sources in the world, but because of its extensively use, at the present rate of use, it will be hard to export any oil in the next few years and not only in Iran, but also in all over the world lack of energy will be the most important problem. So we have to think about the new sources of energy and in order to keep the world clean and also to reduce oil extraction, it is better to think about the natural environment and energies and reestablish the disturbed relation between man and nature, the thing that Iranian traditional architects did many times ago.

Nowadays, we bring comfort in our buildings with the use of expensive energy sources and mechanical & electrical equipment and if they stop working life would be hard in these buildings and as the cost of these equipment and energies is becoming more, the world is becoming more directed toward the use of renewable resources like solar, wind, geothermal and hydro energy. In Iran, the traditional designers had to present environmental elements as their buildings would have been very cold in winter in some regions and very hot or humid in summers in some other regions. So, the way of their design was based on the region they were going to do and according to this we are going to talk more about the regions and their sustainable systems used in each region.

2.6.3. Coordination between Iranian vernacular architecture and the principles of sustainability

Iranian traditional and vernacular buildings, based on the principles of sustainable architecture are formed in the way that they would provide the maximum amount of sunlight in the winter and maximum amount of shadow in the summer to provide natural ventilation and to create welfare for their residents (Qasemi & Geranmaye, 2013):

- **Principle 1.** Saving energy: Iran's traditional architecture is designed and constructed based upon non-fossil fuels and renewable energies.
- **Principle 2.** In coordination with the region: Iran's domestic architecture is in harmony with the region and the devisal of spaces for summer and winter.
- **Principle 3.** Reduction of the utilization of new materials: The best indication of this matter is the utilization of region-based materials in traditional architecture. These materials are renewable and recyclable and these are among the principles of sustainable architecture.
- **Principle 4.** Satisfying the needs of the residents: In traditional architecture, all the actions and designing are ways to achieve the needs and welfare of the residents.
- **Principle 5.** Coordination with the sight: Traditional houses in Iran do not have a harmonious geometry therefore; the architect should try to construct the houses in a way that would coordinate with uneven contexts.
- **Principle 6.** Universality: Iran's traditional architecture tries to save the energy, fossil fuels and non-renewable sources to utilize the renewable sources alternatives like the wind, the sun, etc. Therefore, it can be said that the principle of universality in sustainable architecture which is respect to environment and

cultural and regional factors, is applied in Iran's traditional architecture (Qasemi & Geranmaye, 2013).

- **Principle 7. Static sustainability:** Iran's traditional buildings with structures based on geometry have a great amount of functions. The use of accumulative solid geometries in the heights, like arches, domes and minarets was in a way the only possible method for enduring the brunt and natural forces in its time. Geometry creates an expansive array of beautiful techniques and forms that in coordination with beauty, add to the building's durability (Qasemi & Geranmaye, 2013).

The spatial hierarchy of traditional buildings of Iran, interchangeable and accumulative sections of the walls, lightening the higher levels and spatial geometrics that different parts become alternatives for their lines find the structural function for enduring the side loads and create a relatively great hardship for the function of the structure which the set of these methods lead to the durability of the building and its sustainability during different centuries (Qasemi & Geranmaye, 2013).



Fig. 32: Lightening the higher levels and spatial geometrics in domes and arches to endure the load (Qasemi & Geranmaye, 2013)

In buildings, the sustainable structure (building) is considered as a part of the sustainable architecture if it is based upon geometrics, through the eyes of the beholder will imply beauty, peace and balance and these lines are in fact paths for the transportation of loads and forces (Qasemi & Geranmaye, 2013):

2.6.3.1. Vernacular architecture elements for use in contemporary Iranian architecture

2.6.3.1.1. Central courtyard

The central courtyard is in the heart so that it is better used than air curtain. In every space, opening windows in the courtyard is transmitted through the ventilation and the

heat is reduced. On the other hand, the successive placement of empty spaces of various proportions can create a breeze by using the shadow and sunlight properties and the central enclosure of the central courtyard makes this outdoor space, such as the air conditioner, work for indoor spaces and cause the exhaust of hot air (Shahin, 2010).



Fig .33: The central courtyard of the Kazerooni Seigniory, the current location of Bushehr's Cultural Heritage Organization (by the author)

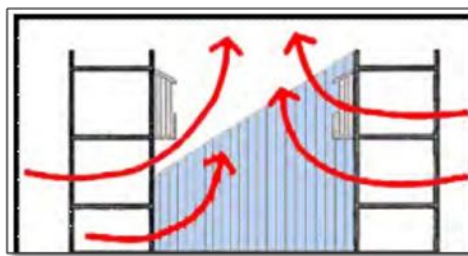


Fig .34: A segment of the central courtyard, the intense confinement causes the formation of shadows and air transportation (Shahin, 2010)

2.6.3.1.2. Tarmi

An unoccupied and open space is considered in the floors and surrounded by wooden shutters and wicker sunshades. Tarmi is an autonomous semi-open space that is exposed to a constant air curtain and cooler than other parts of the building. In addition to allowing the desired wind to enter the building spaces (Shahin, 2010).

2.6.3.1.3. Wooden shutters : The direction and amount of air entering the space is determined.

2.6.3.1.4. Aperture: It is located above the entrance of the house and is involved in the ventilation and lighting of the entrance (Pirnia M. , 2006).

2.6.3.1.5. Chamber (SARDAB)

In hot and dry Iranian houses, there is an underground with a roof above the central courtyard and usually located in the summer houses. The windows lead between the courtyard and the ceiling of the central courtyard air into the cabinet, and the underground or aqueduct that passes through this space causes it to cool and humidify it (Pirnia M. , 2006)

2.6.3.1.6. Ceilings higher than usual :Another solution is to cool the interior space so that the warmer air moves upwards and the fresh air from the openings enters the lower alignment to the inside, which causes the air to move (Pirnia M. , 2006).

2.6.3.1.7. Wind catcher (BADGIR) :Badgir ventilators are amazing and are a typical example of the traditional Iranian architecture adapted to the severe weather conditions by natural cooling. In a general category, the air venting function can be divided into two ways by creating air displacement (Pirnia M. , 2006).

- directing the wind into the building (when the wind is blowing)

- Exit air inside (when the wind does not blow)

The wind catcher function is basically blow air into the building and as its reaction hot and contaminated air will be sucked. At the tip of the pencil there are pores that are generally perpendicular to the dominant wind blowing. When the wind turbine is placed in the wind direction, the vents are placed under positive pressure, and vice versa, negative pressure is created in the back portions of the wind (Pirnia M. , 2006).



Fig .35 : A reservoir with two pools and seven Yazdi wind catcher in Hussein Abad close to the city of Yazd (by the author)

Wind catcher are not only effective factors in the sense of welfare and peace, but are also considered as a determining factor in the city's beauty. The utilization of the wind wards and water to cool the buildings not only utilizes and optimizes the consumption of renewable energies and has no environmental pollution, but also are in the direction to reach sustainable urban principles (Lashkari, 2011).

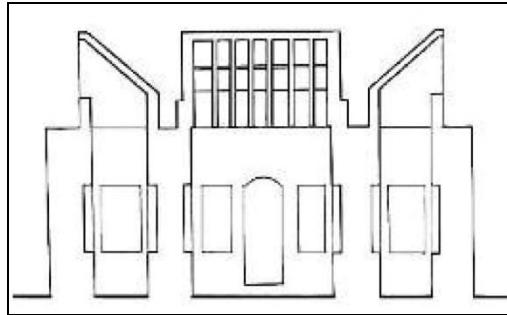


Fig .36: The synoptic schema of the three-sided windward of the house of the barrack's commander in chief, Arg-e Bam (Bahadorinezhad & Dehghani, 2012)

2.6.3.1.8. Air's syndrome or transportation

The transportation of energy through syndrome and also the creation of air transportation in the building in necessary times have always been in the attention of architects. Iran's traditional architecture, based on experiences, also used this physical property of air in different methods and we will discuss some of them here. Utilization of single-layered space Rooms that have view over the courtyard on the one side and to the open space of the outside from the other side and can open in different fronts with the capability to use the transportation of air . Because of the importance of creating air transportation, each space should have a hatch for the air to enter in the pressure area and a hatch for going out from the suction area (Pirnia M. , 2006).

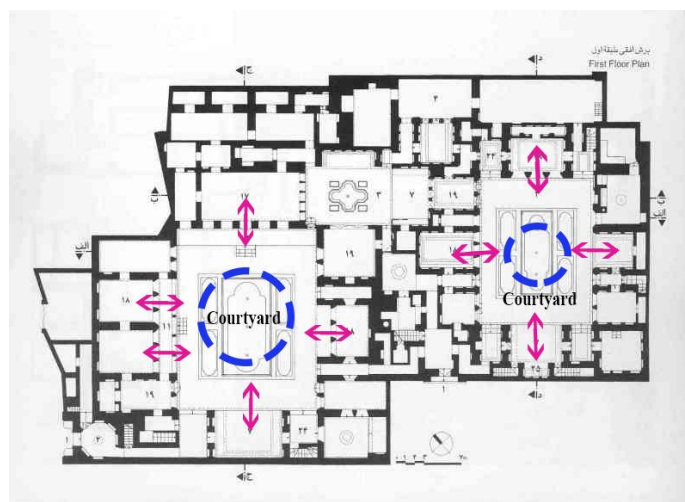


Fig. 37 :Plan of the operable in different sides (by the Author)

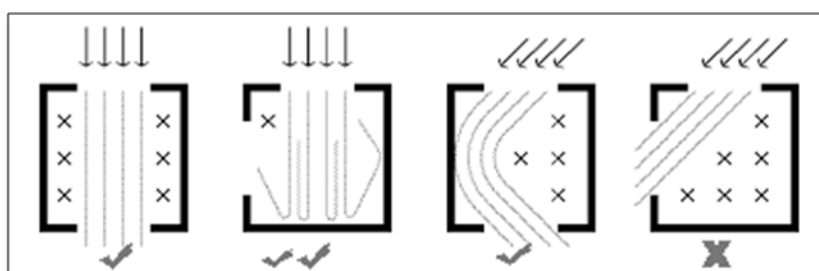


Fig. 38: Utilization of windows facing the wind and those back to the wind (confronting each other)

2.6.3.1.9. Molecular transportation

Wall's thickness: The thickness of the walls in regions of Iran is about 1 meter. The high special capacity of the bricks causes the heat to stay inside the wall and this means that minor heat changes are not significant. During the nights, the walls lose their heat through transportation and radiation and their temperature during the day is kept at a low level so that they will provide the welfare of the residents . In this way, the soil acts as a heat insulator and because of its high heat capacity, it leads to the independence of the temperature of the inside from that of the outside. Two factors can be mentioned for the reasons of the thickness of the walls (Rahimi Etani & Ghachkoub, 2011):

A) Reduction of heat transportation from the space outside the houses to the inside and also the increase in the delay for the transported heat

B) Increase in the durability and solidity of the building.

Double-flake ceilings: Another method for coordinating the hot climate is the double-flake ceiling. The heat capacity of the air is very low and the air between the two flakes acts as a heat insulator and therefore, less heat will be transported to the inside and during the summer, the interior flake will be cooler than the exterior one. Arch and domes: Another way for reducing the heat absorption by the buildings especially in hot and dry regions of Iran is the utilization of arches and domes. This form not only is in coordination with the available materials and structural logics, but also is a proper choice for the reduction of transported heat because of thermo-physical reasons. First, its convex spherical shape is very desirable for streaming heat radiations and also facilitates the cooling process during the night. Secondly, during the day and in morning and afternoon time, half of the dome is in the shadow of the other half and this fact plays a vital role in reducing the temperature. Also, the dome-shaped roof, because of its projection, is exposed to the wind and therefore, the heat radiation has less effect on it (Rahimi Etani & Ghachkoub, 2011)

2.6.3.1.10. Use of material

A) *Thatch:* Thatch is used for the exterior and interior walls of the buildings. This mixture is a suitable cover for keeping the interior space of the building from the intense heat of the summer and the coldness of the winter. The conductivity of the thatch is very low because of its hollowness. Thatch prevents the cracking of the wall and therefore, stops the transportation of intense heat through the cracks to the inside of the building and causes the safety of the building from the intense heat of the summer and the probable coldness of the winter (Espinani, 1999).

B) *Bricks:* Among the advantages of the bricks, it can be mentioned that because of the thickness of the walls and in some cases, their covers, heat and coldness insulators are made. In contrast, the thick walls of the central courtyard have high special heat capacity and work as stores for heat in which the coldness is saved during the night and during the midday when the weather is hot, this coldness is gradually released. In this way, the thickness of the brick walls causes the insignificance of minor changes in the heat (Zamarshidi, 2012).

2.6.3.1.11. Evaporation

As one of the ways for transformation, change and transportation of energy and heat has received special attention in regional architecture. The following items can be mentioned as examples: *Waterfronts and fountains:* The waterfronts and fountains cause

subtlety of the air. In regional architecture the water is used as an important factor for changing, transforming, transporting and saving energy. Green trees in the central courtyard: With the evaporation of the water by the trees, the relative dampness of the environment will also rise. This matter helps the cooling process of the interior spaces around the central courtyard, as the scientists have stated that evaporation by trees affects the cooling process as much as an air conditioner that has been working for 20 hours for 1 million BTU for 10 regular rooms. On the other hand, the existence of the trees with leaves and shadow help a great deal in reducing the amount of the surfaces that receive direct sunlight in the courtyard and the neighboring walls. Also, green surfaces by absorbing sunrays prevent the reflection of the rays and the unwanted rise in the heat. Sometimes, these trees also play the role of carminatives. The choice of the type of the ever green trees is also different based on each type of region (Nasrollahi, 2010).

Architectural design and optimization of energy consumption One of the easiest and cheapest things to do for increasing the productivity of energy in a building is to pay attention to the type of the architectural design of that building in order to reduce energy consumption. This matter has been used in the past by the architects and urban planners in the best way possible. They were used so efficiently that now, when we look at the work that still exists after all these years, we see that without heating or cooling systems and only through the use of the properties of an architectural design, including orientation, coordination, etc, they have been able to provide temperature welfare for their residents. Some of the studies done in the field of productivity of architectural design for reducing energy consumption in some cold and hot and dry regions in Iran indicate that the potential for energy saving with the help of the architectural design in the city of Tehran for instance is 48 percent and this number for the city of Tabriz is 64 percent. These will cause the sustainability in modern houses (Nasrollahi, 2010).

Therefore, with regard to the above mentioned items, paying attention to the region and a proper architecture in coordination with it and the utilization of architectural methods that would decrease energy consumption, should become necessities in architecture and urban planning policies in the country.

CHAPTER 3: DISCUSSION

(A Comparative Study of the Principles of Sustainable Architecture in Iranian Native and Contemporary Architecture)

3.1. Introduction

As we know, considerable world's energy consumption is used in the area of architecture and creates a large part of environmental pollution in buildings. Therefore, by correct implementation of architecture principles and methods, buildings must be constructed to minimize damage to the environment. Architecture must coordinate its elements for sustainable development goals to promote quality of life.

As mentioned, in the traditional Iranian architecture and construction, five principles have always been observed (Humanity, avoiding futility, introversion, stagnation, and the use of vernacular materials). The principles mentioned in their simplest form appear in Iranian architecture, especially in the architecture of Iranian homes. Iranian architects had invented traditional architecture principles and methods which prepared comfortable and healthy living condition without using mechanical methods in different climates much as possible (Ghobadian, 2009).

In this section, first principles of sustainability in traditional Iranian architecture briefly are examined and then implementation of technologies in contemporary architecture is represented. Then Comparison of energy efficiency in the traditional and native architecture of Iran and Iran contemporary architecture had done.

3.2. The principles of sustainable architecture

The principles to be followed to classify a building as a sustainable building include (Razmkhah & Joudi, 2012):

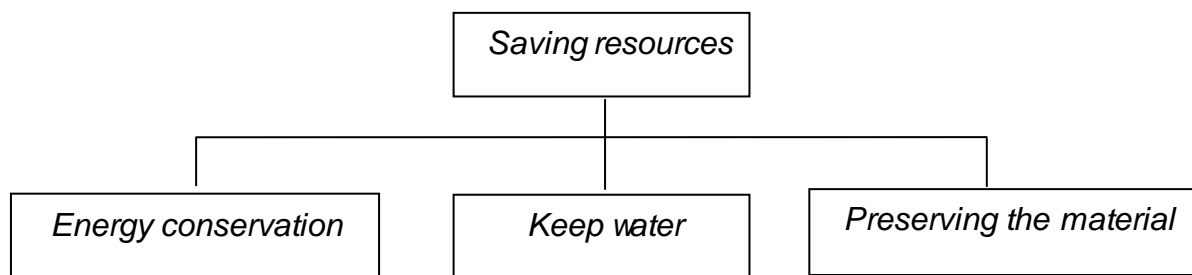
- Saving resources*
- Design to return to the life cycle*
- Design for man*

Each of them has their own special strategies. Recognizing and studying these measures will make the architect more aware of the environmental design.

3.2.1. Saving resources

In order to save resources, On one side, proper exploitation of non-renewable resources and energy, such as fossil fuels is important to reduce consumption and pollution, and on the other side, being conscious to implement renewable and natural source of energies which shows using of sustainability idea. For example, sunlight is an environmental friendly and widespread source of energy in many climates (Razmkhah & Joudi, 2012).

By proper usage and conservation of resources during building lifecycle like energy, water and materials, reducing and control of resource is possible.



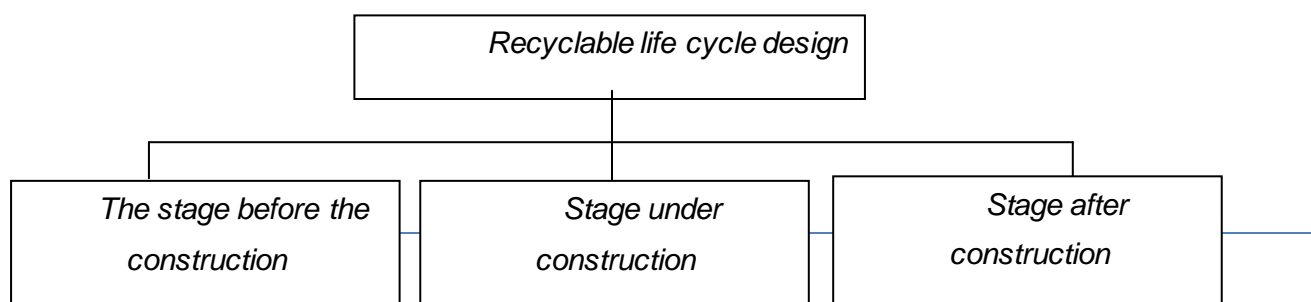
Tab .5: Saving resources in construction of building (Razmkhah & Joudi, 2012)

3.2.2. Recyclable life cycle design

Another sustainable architecture principle can be applied according to utilization of material in a usable form, without adversely affecting its usefulness. Due to this principle, one of the designer's duties must be to prevent environmental contamination. To achieve this goal this theory need to implement in building life cycle in below steps.

- The stage before construction (development phase)
- Construction phase
- Stage after construction (operation phase)

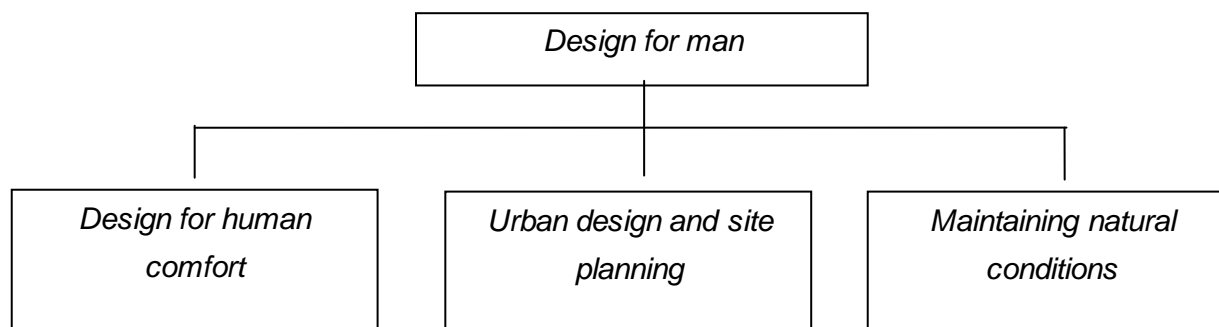
It should be noted that these are inter related steps and all must be work during building lifecycle. For instance, remained material in one building life cycle phase can be reused or recycled for other phases or in other projects (Razmkhah & Joudi, 2012).



Tab .6: Stages related to the life cycle in the construction of buildings (Razmkhah & Joudi, 2012)

3.2.3. Design for mankind

Design according to people needs is a critical subject to achieve sustainable architecture. This method is rooted base on preservation of ecosystem chain elements that will guarantee human survival instead. There are few main strategies to conserving natural resources which include design according to urban and site condition and fulfilling human comfort, which its main goal is bringing harmony between residence, building and environment (Razmkhah & Joudi, 2012).



Tab. 7: Design principles for humans (Razmkhah & Joudi, 2012)

3.3. Traditional Iranian Architecture

As mentioned in the previous chapter, in traditional Iranian architecture, the buildings are shaped with respect to Iranian identity, culture. Therefore in construction of these buildings is also ultimately taken care, using local materials and proper use of the land and environment. From an economic point of view, according to religious and cultural beliefs in the prevention of waste, extreme care and diligence to act, it is said that no additional work or expense should be imposed on the owner of the work. What is important in this section is that most of the principles that have emerged in the modern sustainable architecture of the present century have been respected in the country's local and climatic architecture, which itself confirms the proper impact of the culture, religion and traditions of the Iranian people on How construction and architecture have been in the past centuries. To some extent these principles have been forgotten in the present era. Somehow can say that one of the symbols of sustainable architecture is traditional Iranian architecture that has been accountable for ecological and energy efficiency consideration both in terms of low initial price and low operation cost and functional price of the building. So with the reintroduction of these principles, in line with contemporary architecture, a new approach to contemporary Iranian architecture can be created.

3.4. Comparison of Principles Used in Traditional Architecture and implementation in Iran's contemporary Architecture

3.4.1. Buildings orientation design for optimal use of natural energies

The orientation and position of a building is crucial subjects influence quality of the thermal and environmental conditions of the external and internal space and in some aspect affect many design goals and thermal requirements. The climate and environment in two sides might affect the orientation of the building:

- 1- The sun's radiation and the effect of its thermal energy on the spaces in different directions*
- 2- The flow of air and the effect of its direction on the orientation of a building.*

The final decision is the result of a quantitative or analytical assessment of these two factors in the area of human comfort in each region. The proper orientation of the building for proper interaction with the sun is one of the first and most important inactive

design solutions. IN traditional buildings, the application and implementation of local resources and natural energy is one of the basic principles for organization and spatial planning. This climatic design orientation has provided comfort conditions for summer spaces and winter rooms to find their place in the design of biological spaces on a regular basis. The proper orientation of the buildings, in addition to protecting residents from direct sunlight, also prevents inappropriate winds from entering. There are three orientations in traditional Iranian buildings (Namazian, 2010):

- 1- Straight direction (Northeast - Southwest orientation)
- 2- Isfahani direction(Northwest - Southeast orientation)
- 3- Kermani direction (East-West orientation).

The proper orientation of the buildings in the city context with regard to the direction of the sun in the sky, as well as the proper placement of the interior spaces for use in the warm and cold seasons for the use of natural energies and natural ventilation reduced the use of renewable energy. In the current architecture of Iran, like its traditional and vernacular architecture, the orientation and form of the building plan are designed and implemented base on the radiation and sun direction and the pleasant or disturbing winds, in order to satisfy both the comfort conditions for humans as well as the energy consumption reduction to Save natural resources (Asadpour, 2006).

In addition to create the best thermal conditions inside the building, hot air in the winter and cool air in the summer should be the mainly enter from south facade of the building. Although southeast and south west orientation absorb more sunshine, but in the summer Warmer and cooler in the winter than the southern view. The eastern and western walls are warmer in the summer and colder in the winter than the southern, southeast, and southwest walls (Asadpour, 2006).

According to above-mentioned aspects about the building direction and the sunlight, the direction of the south is the most energy efficient direction for the building, and if the placement of the building be in the western eastern axis direction, the area of the eastern and western walls decreases and the most energy and Light radiation to the southern walls of the building can be very effective in saving energy.

3.4.2. Design of spaces in the basement

Earth is an almost unlimited source of energy. The construction of spaces in the basement for the use of soil thermal capacity is one of the climatic techniques. The existence of basements in warm and dry climates is an appropriate response to climatic conditions and creates a comfort environment for living (Asadpour, 2006).

Therefore, the use of summer and winter spaces and the use of depth of land and live in the heart of the soil have been associated with the consequences that the predecessors have known and correctly used it. Unfortunately, in contemporary Iranian architecture, these technic are less important and there is not enough concern due to economic problems caused by excavations and rarely used in contemporary buildings. And if designed and implemented, they will only be used for parking and service spaces.

3.4.3. Proper use of green space with respect to climate

Gardens and trees compensate lack of environmental humidity while providing shades and producing and creating beauty as well. These green surfaces absorb radiation from the sun to prevent redundant reflections and unwanted intense heat rise. Planting proper plants with regard to the climate of the region and planting evergreen trees and bushy trees Due to the obligation of shading or sunlight in different seasons and creating diversity and color in the space, had been the wisdom of the ancestors in the use of plants to improve the human Comfort conditions. But Between 1290 and 1350s, with the unintentional migration to cities and apartment life style, removal of these green spaces like garden pits and central courtyards had seen in the contemporary Iranian architect.

Today, with the advent of technology to Iran's architecture, and the energy crisis and water scarcity, architects are on the way back to the idea of linking the architecture to nature. Green roofing technology brings a wide range of environmental, economic and social benefits. In terms of environmental sustainability, green roofing is a static cooling method for buildings by covering the ceiling with vegetation which result increases in thermal mass of the ceiling and this increase leads to a decrease in volatility to absorb the heat of the sun in the interior. The vegetation cover acts as an insulation that cools the roof in the summer and keeps the roof warm in the winter. Green roofs in a warm and dry climate in the summer are between 20 ° C and 60 ° C cooler than ordinary roofs with brick and concrete materials. Also, these roofs absorb carbon dioxide and produce oxygen for air purification.

Despite the fact that these roofs make energy saving for buildings and reduce the heating and cooling needs, But in a hot and dry climate only a few people interested to implement these technic due to:

- *High cost performance*
- *Facing the water crisis and using technology in watering system.*
- *Extreme sunlight due to the warming of the globe and the use of canopies*

3.4.4. Central courtyard

Open space in the traditional architecture of Iran has played a significant role. In addition to the obvious role in shaping the geometry form, various functions have been accepted

.In modern contemporary Iranian architecture, high buildings create a barrier against direct sunlight and, consequently, create shadows on low-altitude buildings, makes it necessary to use artificial lighting fixtures and increase their power consumption. While, according to the Iranian religious beliefs, it is forbidden to build high-rise buildings that prevent sunlight and fresh air in other residential areas. The vertical development of construction complexes limited the light, the heat of the sun and the fresh air for the adjacent inhabitants(Sadeghzadeh, 2003).

The contradiction of architecture and materials used in high-rise buildings with the climate of different regions of the country greatly affects the increase in energy consumption. Because it requires the use of temperature adjustment (heat and cold) that require high energy consumption. There is always a difference in temperature between the upper and lower floors of high-rise buildings. This phenomenon can be a factor in the loss of energy resources in the long time .Towers are heavily influenced by external temperatures and heat from radiation. The design of the courtyard and outdoor space in high-rise buildings in contemporary Iran's architecture provides the possibility of communicating the enclosed spaces with the outside environment and taking advantage of beautiful landscapes in the highs. In the high-rise building order of the yard, there can be rear-facing terraces with high-rise glass doors or partitions opening from the interior spaces to the outside. These terraces have a distinct role with the green architecture prevalent in other countries. Deeper terraces can lead to a spatial relationship between the private and public fields of each unit, and the same role played by the central courtyards in the form of terraces (Sadeghzadeh, 2003)

3.4.5. Materials according to the climate

The use of native and vernacular materials with appropriate thermal capacity according to the climate is one of the tricks used in traditional Iranian architecture. The implementation of suitable materials and climate-compatible materials has no reason other than the proper functioning of these materials in relation to the climate of each region. Not only is it suitable for every climate that is compatible with its environment and resilient to environmental factors, but is also used for energy and additional costs, such as transportation.

In contemporary architecture, due to the economic conditions, in many cases, because of the beauty and imitation architecture of other areas, materials are used that their thermal coefficient is not appropriate to the hot and dry climate. As mentioned, in the vernacular architecture of Iran, brightly colored materials, or materials with high thermal properties, such as clay and mud brick, and sometimes materials that reflect the sunlight, have been used in the outer cover of buildings. Along with the traditional Iranian architectural methods, the following methods have been used to save energy in modern Iranian architecture:

A: implementation of bright colors in the roof covering: *Since the roof is exposed to the sun from other surfaces of the building, the roof paint must be bright to prevent sunlight absorption, or use glossy gritty on the surface of the roof. In another way, they have used pigments inside the roof to protect the roof, although the colors of these pigments are dark, but they have the reflectivity of infrared rays from surfaces, these pigments usually consist of chromium oxide and cobalt (Kasmai, 2003)*

B: implementation of materials reflecting heat: *When the sun's rays collide with the building's surface, it reflects a part of the heat outside, and partly absorb. Since all radiation is absorbed or reflected, and its result is always constant, it must be used in dealing with energy optimization with respect to the properties of materials in the reflection or absorption properties. In aluminum and galvanized steel, they have the highest reflectivity and the lowest heat emission factor. Materials that have bright, polished colors also have a high reflectivity, which can be used in external shells, especially in the eastern and western side, to reflect excess heat (Kasmai, 2003)*

3.4.6. Insulation

Iranians have long been familiar with the insulation and, using available building materials and increasing the thickness of the walls, they built their homes that have the least need for heating and cooling. Insulation in the summer causes less heat absorbed to internal area, and in the winter it also prevents heat exit from the building and keep building cools. In traditional buildings, the use of two-layer ceilings, and double-layer walls were used as insulating elements (Pirnia M. , 2001)

However, in the contemporary architecture of 1910-1960, the construction of houses destroyed by blind imitation of other climatic zones , As well as the economic conditions and the speed of execution, thick walls, double-sided and thick coatings disappeared and replaced with panels and blades. But after 1970 onwards, and faced with the energy crisis, Iran's engineering organization approved measures to prevent the loss of natural energy and heat transfer from internal and external spaces in compliance with these principles , Listed below (Pirnia M. , 2001) :

First method: two layers walls that external wall usually brick and internal wall are usually made with brick, concrete block or concrete, and these two shells are attached to the robust fasteners. Between these walls, there is an air-tight layer that works for energy preserve, better ventilation and sound control, and is a perfect thermal insulation for the wall. The atmosphere of the two layers can have a chimney effect on hot days and warm up the air, one of the problems with buildings being designed in this method is that in the upper floors is a colony of excessive heat over the interior space which can cause fire. This problem can eliminate by creation of valve at the top to exhaust the hot air and at the bottom of the valve for entering and circulating the air in this compartment (Pirnia M. , 2001)

Second method: applying appropriate thickness Insulating layer on one side of the wall, inside or outside of it. This method is one of the most suitable methods for reducing energy consumption in the building. The use of these insulators in winter reduces consumption of electricity, gas, or other source of energy and in the summer causes the environment to be healthy and prevent the introduction of excess heat into the interior and need of energy consumption for cooling (Pirnia M. , 2001).

According to the company's fuel efficiency optimization by building insulation an average saving of 35% in annual heating and 65% in annual cooling is achievable. Types of common insulators used to heat exclusion in building shells are as follows:

- *Fiberglass: Fiber from the fused glass*
- *Mineral wool (rock wool): The melting rock is a bit glassier.*
- *Cellulose fibers: made of wood or paper and cardboard with the help of chemical compounds resistant to fire and water, their resistance is like fiberglass, But then it gets corrupted and loses its resistance*
- *Plastic plates: made of polystyrene and polyurethane. These materials are flammable and should be kept away from the fire.*
- *Lightweight Concrete: conductive cavities formed in the concrete, which makes it insulate, which eliminates the need for separate use of other insulators (Pirnia M. , 2001).*

As mentioned above, in traditional architecture, two-layer walls were also used. This method is also used in the modern Iranian architecture with the same function as the Trump Wall. These walls are responsible for collecting and storing heat indirectly. These walls, known as the walls of the trump, are built with a little distance behind the glass surfaces facing the south of the building. The thickness of these walls is between 33 and 66 cm and can be of brick, stone, concrete or clay with a high thermal capacity (Pirnia M. , 2001).

This wall is a kind of solar wall that can be controlled at the top and bottom of the ventilation valves, so that heat transfer can be achieved through convection. When exposed to the wall by the sun, the heat is blocked in the space between the wall and the glass and it increases the absorption of heat by the wall. At night, the valves are closed and, due to the time delay, the radiation from the wall to the inside space takes place Due to the slowness of the heat transfer.

3.4.7. Performance of openings and windows

Traditional Iranian homes in hot and dry climate have windows called ORSI, which are commonly used in main spaces or high ceilings. Orsi covering the whole surface of the wall were generally located adjacent to the central courtyards and were responsible for controlling the entrance of light into the spaces in different seasons. The size of these openings varied in different side of the building. These openings have been instrumental in the air conditioning of indoor spaces (Askar, 2001).

Today, choosing the right window and canopy is very important for reducing energy consumption. The windows are more vulnerable than any other element of the building's shell to unwanted heat transfer, so the exact explanation of the properties of the glass and window systems is essential to save energy, energy efficiency, and comfort in all buildings. Selection of the glass and window should be considered as fully comprehensive, and in the design process, the following should be evaluated (Askar, 2001):

- *Interest and thermal effects*
- *Visual Requirements (privacy, light and landscape)*
- *Control of shadow and sunlight*
- *Thermal comfort*
- *Condensation control*
- *Ultraviolet control*
- *Sound control*
- *Color effects*
- *Lighting and daylight*
- *Energy requirements*

And finally, the optimal selection of window and window systems depends on many factors, such as physical, local weather, building occupancy period, and the amount of facilities. And that's precisely must being observed in modern Iranian architecture. According to Iran National Organization of Building Regulations.

3.5. Case studies (sustainability in traditional and contemporary architecture)

3.5.1. Analysis of Traditional houses in hot and dry Climate

3.5.1.1. The effect of sustainability factors on traditional buildings in Yazd

Yazd Province is located in central Iran, between geographical latitude of 29°48' to 33°30' north and longitude of 52°45' to 56°30' east of the meridian origin. The area of Yazd Province is approximately 72,000 square kilometers, or more than four percent of the total area of the country (Kasmai, 1984).

Logical formation of architectural texture in Yazd City in accordance with climatic issues. In examining the architecture of cities and villages in hot and arid areas, climate is an important logical factor that must be considered in the architecture of urban areas, and it has always had a major effect on the decision making of the people who live in these regions. The oppressive climate made it necessary for people to search for solutions over thousands of years, and they have managed to have great success in reducing the annoying aspects of the oppressive environment and in putting its favorable aspects to beneficial use. The major problems that forced the people of Yazd Province people to search for effective solutions were the burning sun, excessive heat, high temperatures during the day, and low temperatures at night (especially during the summer), hot summers and cold winters, the arid weather that results from very little rainfall, dehydration, and frequent sand storms. One valuable solution for dealing with the climate issues in the hot-arid regions of Iran, especially Yazd Province, is described below. The architectural plan is to make buildings dense and complex, providing maximum protection from the weather in the winter and in the summer and casting the most shadows on the houses and across the streets (Tavassoli, 2002).

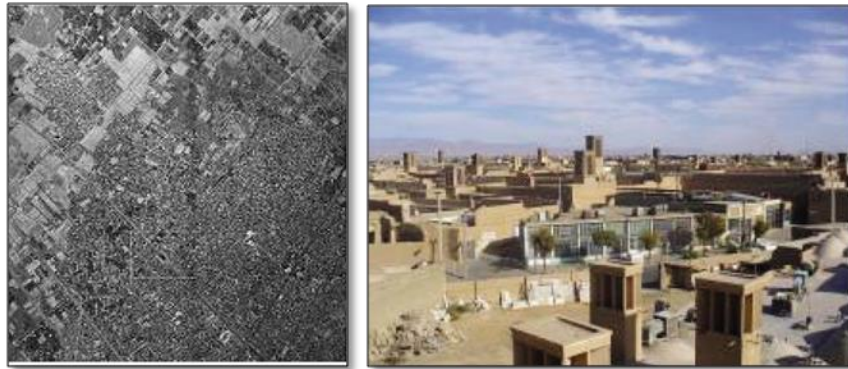


Fig .39: (a) urban texture; (b) The historic core of Yazd city (Tavassoli, 2002)

- **Sidewalks:** To protect people from the heat, streets and sidewalks are constructed mainly in the east-to-west direction. On hot summer days, the narrow sidewalks with high walls on both sides are completely in the shadows (Tavassoli, 2002).

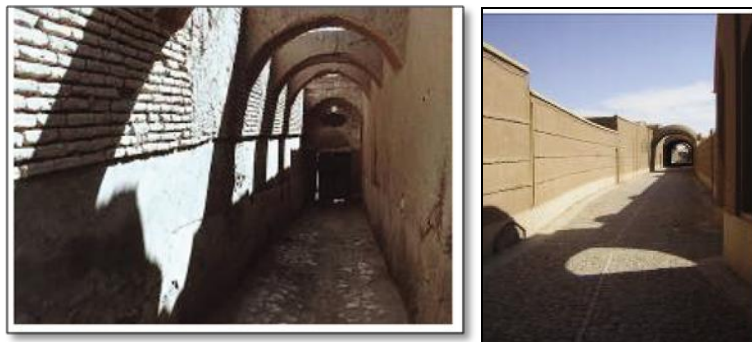


Fig .40: (a) The renovated street of Yazd ;(b) Sidewalk in historic core of Yazd (Tavassoli, 2002)

To prevent the hot air from flowing down the streets and sidewalks and entering the buildings, the sidewalks are mostly curved and narrow with high walls. Roofed sidewalks (Sabat) help keep the sidewalks in the shadows, and narrow sidewalks contribute to the density of nearby buildings. These narrow passages with high walls provide an effective solution for dealing with the harsh climate (Moradi, 2005).



Fig .41: (a)Sabat , Yazd; (b) renovated Sabat , Yazd (Moradi, 2005)

Openings: *The numbers of windows that open to the sidewalks are minimized to avoid having the unfavorable climate penetrate into the indoor area. To prevent dust and excessive sunlight from getting into the buildings, windows and openings are usually placed in the ceiling or high up the walls. Most of the windows open to the protected central courtyard area, which generally has less harsh conditions and a more favorable environment than exist on the outside of the buildings (Meamarian, 1999).*



Fig .42: House of Kolahdooz, Yazd (Meamarian, 1999)

Materials: *What attracts Yazd visitors at first is the role of mud and molded materials (especially mud brick) everywhere in the houses, on the sidewalks, and on the wind catchers. Everything in Yazd has been designed to use construction materials that are formed from mud. Because of the climatic conditions, the use of mud materials in the desert, and especially in Yazd, is feasible and practical. Nothing is as resistant against the burning sun in these regions as mud brick and mud, because rooms can be warmed with little internal heat during the cold-dry seasons. The main reasons for using these materials are that they are available and practical for applications in desert conditions. Mud brick and mud have high thermal capacity, which is important because it takes a long time for the heat outdoors to pass through the walls and get into the indoor spaces*

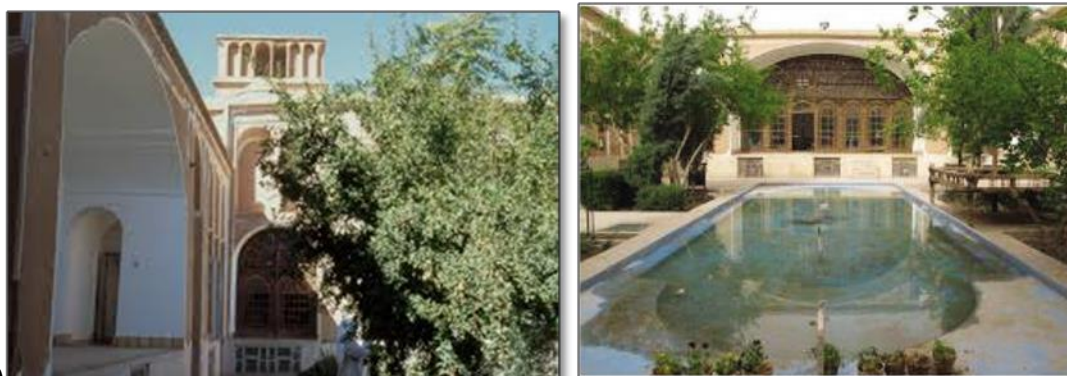
of the houses. Mud brick can delay the heat transfer from outside to inside for about eight hours, which means the heat that is accumulated in the walls during the day will warm the house at night when the outside temperature decreases. In critical conditions, buildings are built underground or in the heart of the hills so they will be less affected by the adverse weather conditions (Moradi, 2005).



Fig .43: (a) Traditional material, Yazd; (b) outside facade of traditional house, Yazd (Moradi, 2005)

Facade: Light colors are used for the façade of buildings because they absorb less heat. Smooth and glossy surfaces are also used to reflect light. Current practice is to use plaster, raw clay, and hay to coat the walls (Moradi, 2005).

Courtyard : In hot-arid regions, houses with courtyards are a time-tested and valuable design pattern. This approach has been used from pre-historic times in central Iran, in other dry parts of the Middle East, and by most ancient civilizations. Houses with surrounded central yards are the most beneficial form for decreasing the exposure to harsh weather conditions, especially in hot, arid regions and in deserts. The rooms that open to the yard are usually protected against the extreme heat of the summer, the cold of the winter, and from wind, storms, and sand in desert regions (Meamarian,



1999)

Fig .44: The house of Rasoulian, Yazd (Meamarian, 1999)

Summer area and winter area: Nature is an inseparable part of people's lives. It forces families to move to different parts of the house in different seasons. So, houses are divided into two parts, a summer area and a winter area. This feature can be seen in the houses in most cities of this region. In most houses in Yazd, the main part of the houses located in faces northeast. In the summer, the main part of the house is the summer area, which most of the time is in the shadows. Across the yard from the summer area is the winter area, which provides access to the warmth of the sunlight during the winter. The owner builds the two other parts depending on her or his financial status. Houses with yards in the middle and two other areas that connect the summer area and the winter area are called four-season houses. But the summer area best demonstrates the importance of the art of architecture in protecting people from adverse climatic conditions (Tavassoli, 2002).

The veranda is a part of the house that is used on summer evenings when the sun has passed below the front wall. It usually is elevated three or more steps higher than the yard, so it is slightly raised above the yard. The basement vent is under the steps of the summer area (Meamarian, 1999).

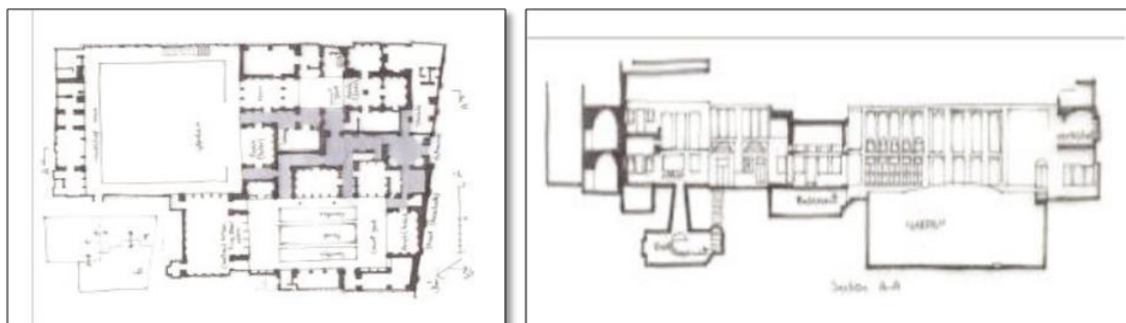


Fig .45: (a) The house of Zoroastrian, Yazd (section); (b) The house of Zoroastrian, Yazd (Plan) (Tavassoli, 2002)



Fig .46: The house of Kolahdooz (Meamarian, 1999)

Yazd Godalbaghche (deep pit yard):

In a traditional house, the yard is built very deep and is called Godalbaghche. Sometimes the depth of the yard is as much as 3-4 meters (Meamarian, 1999). Increasing the height of the walls of the yard increases the height of the shade and helps to keep the air cool air in the yard during the day. It also facilitates access to the subterranean canals that are used to water the plants and gardens in the yard. By building Godalbaghche, the access of people to the central yard, the branches and leaves of the trees, and the humidity and shade is increased (Moradi, 2005).

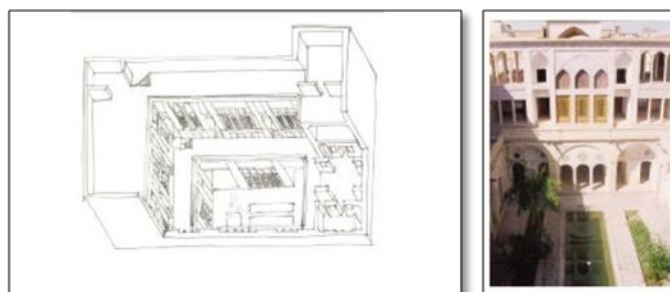


Fig .47 : (a)The house in Darband-e-lariha, Yazd; (b) A house with Godalbaghche (Moradi, 2005)

Roof cover :

The lack of rainfall and wood in Yazd are the reasons that roofs are made into arched or domed shapes using mudbrick and mud. Because the prominence of domed roofs means that they are constantly exposed to the flow of air caused by the wind, it is a useful way to reduce the heat of the roof due to severe sun radiation. At night, it helps the roof to cool faster as well. In the domed or cylindrical roofs, the sun radiation is not the same on all sides, because one part always receives less heat than other part .This is also useful in reducing the temperature under the roof (Moradi, 2005).

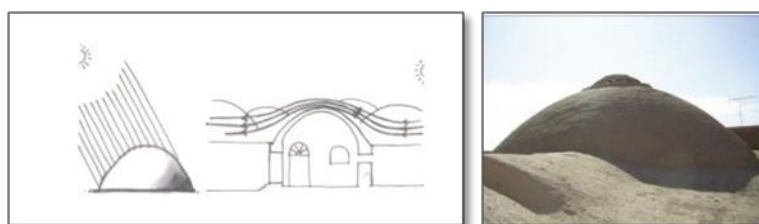


Fig .48 : (a)The Roof of traditional building, Yazd; (b) Diagram of roof function (Moradi, 2005)

Badgir(Wind catcher) :

Natural features of Yazd include harsh, high-speed winds and sometimes sand storms. That's why architects must consider favorable and unfavorable winds. They use the favorable winds in hot seasons with the help of the Wind catcher. One of these favorable winds is known as the Isfahani wind, which moves in the northwest direction. Wind catcher is an architectural element that has a climate function (Mahmoudi, 2006).



Fig .49: wind catcher, Yazd (by the author)

The functions of air Wind catchers are primarily to receive the favorable wind for cooling and ventilation and to direct it to spaces such as the main room, basement, and water storage area. The open side of the Wind catcher, which faces the wind, has positive pressure, and the opposite opening side to the incoming wind has a negative pressure that is less than the ambient atmospheric pressure (Mahmoudi, 2006).

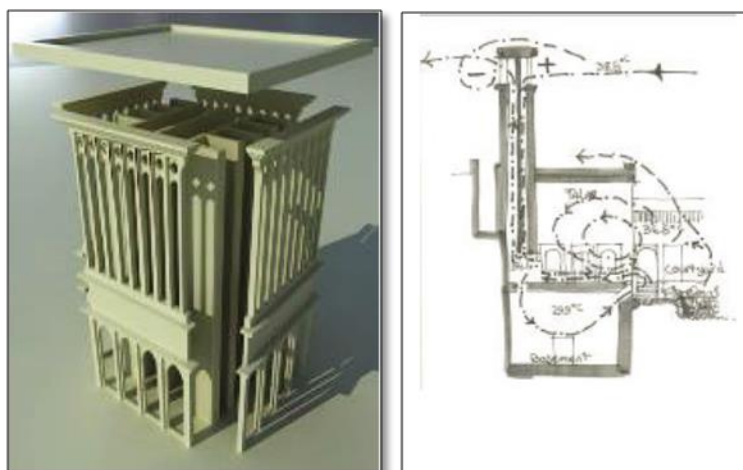


Fig. 50 :(a) 3D modelling of air trap; (b) Wind circulation (Mahmoudi, 2006)

The middle septum of the wind catcher separates the suction part from the pressure part. The wind that enters hits the vertical septum in the middle of the wind catcher and

directs the air to the indoors space through channels that face the wind. It should be mentioned that a group of wind catchers cool the indoor space just by convection, while others cool the air via evaporation in addition to the convection. A pool filled with water is built under the air trap channels, so the wind that enters through the channels passes over the surface of the water and cools the air by transferring some of its heat energy into the water to effect evaporation of the water. The increase in humidity that results from the evaporation of the water in arid regions is in great importance. The air that is used indoors absorbs heat from the environment, and the reduced pressure in the back channels causes the air to be rapidly removed, causing an inflow of air through the front openings to replace the used air inside (Mahmoudi, 2006).

- The effect of climate factors

Heat radiation (shining) ,heat, wind, humidity As an example in Yazd: To prevent the extra heat of summer, especially during the very hot afternoon period, the summer section (the part in which families spend more time) is built with its back to Qibla (back to the south), which is called "Nesar" in the native language. The other side, which is in front of Qibla, is perfect for the winter sunshine. The yard is a pit below the ground level, because the height of the walls of the rooms in all four parts of the house, so it is in the shadows on hot summer days. In addition, at night when the weather is cool, the deep (pit low) yard becomes cool and stays cool for several hours, until the sun is shining almost directly from above. The coolest part of the house is the basement, which is underground and cool even in the summer, so it is enjoyable to spend hot summer days in a place that is so cool that sometimes it can feel uncomfortable. There is a wind catcher located in the back part of the summer section, through which air flows into the house, and, in some houses, the air is directed to the basement as well. Having a pond in the yard and some plants or a little garden creates evaporative cooling, and, with the help of the wind catcher, the cool, humid air flows in the house, creating a pleasant environment. On summer nights, when people usually sleep on the roof or in the yard, the wind catcher gets the cold, night winds and spreads the cold air all over the house, and since the doors are closed, the house remains cool during the morning (Tavassoli, 2002).

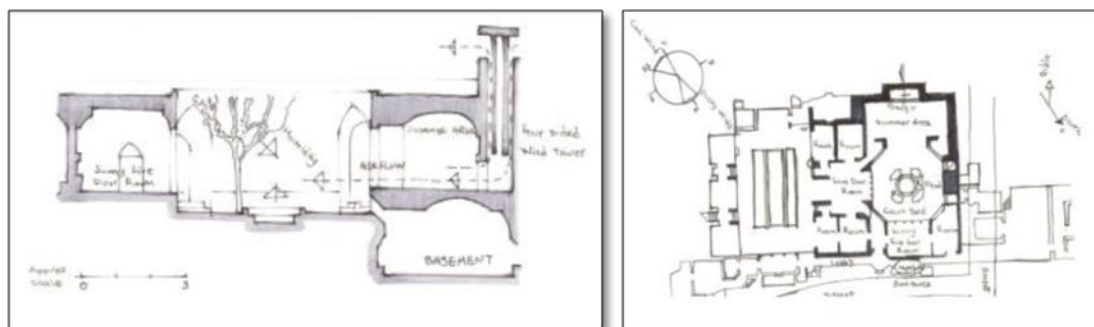


Fig .51 : (a)The house of Arabha , Yazd (section); (b) The house of Arabha, Yazd (Plan)
(Tavassoli, 2002)

- Using vernacular architectural design directions in Yazd

The house of Ayatollahi in the Safaee quarter in Yazd was designed to be compatible with the local climate. This house faces southeast at an angle 27° in $13\text{m} \times 25\text{m}$ dimensions. Some modern architecture ideas are based on traditional, vernacular architecture. The area of the front yard is 150 m^2 , and there is also a backyard with tall walls to provide shade during the day and ventilation air in the summer. The Livingroom has a high ceiling and is connected to the bedroom on the first floor, which help the hot air rise and spread on the first floor. On sunny days the outdoor and indoor curtains are lowered, while, after sunset, they are raised. Hence, in summer, the process will be reversed. Two horizontal channels that are perpendicular to each other, one from the storehouse in basement and the other from the lowered yard that is connected to the small basin, have a way to the living room, ending at a well with a depth of 3 m at their interchange point. The channel that leads to the pool is half filled with water, and the overflow goes into the well, always keeping it damp. So the air gets humid at 24° C and streams into the living room (Gharehbolchian, 2010).

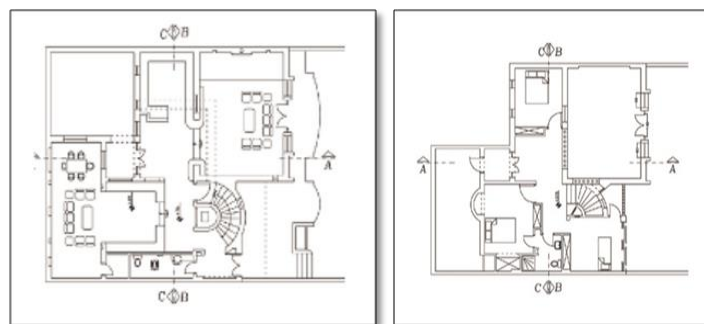


Fig .52 :(a) The house of Ayatollahi (ground floor plan); (b) The house of Ayatollahi (first floor plan) (Gharehbolchian, 2010)

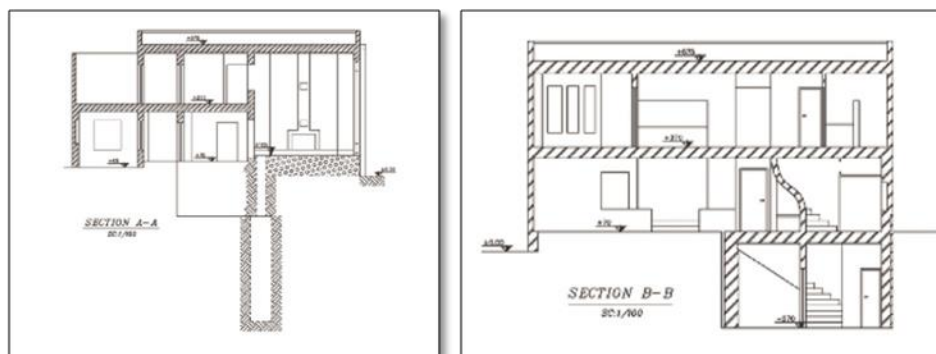


Fig. 53 :(a) The house of Ayatollahi (section A-A); (b) The house of Ayatollahi(section B-B)
(Gharehbolchian, 2010)

Fig. 51 shows the little pool (small basin) and the underground channel that leads to the lowered northern yard .It streams the cool air to the living room with the help of the air that has been cooled by giving up its heat to evaporate water. In the summer, the cool air of the basement comes up through the vertical channels, and, in the winter, the fan and the heater in the basement provide warm air to the bedrooms through this channel. Natural ventilation occurs when the north and south windows are opened during the evenings and nights in summer, and the cool air is saved in the house for the morning hours. In the morning, while all the windows are covered by the curtains to prevent light from coming in, the window of the main bedroom is open and acts as a chimney to remove the hot stream of air, and the cool air of the north direction and deep-ground yard replace the hot air (Gharehbolchian, 2010).



Fig .54 : The pond located in north yard (Gharehbolchian, 2010)

3.5.1.2. The effect of sustainability factors on traditional buildings in Isfahan

By Using Designer Builder software, a traditional home is simulated in Isfahan and then analyzed for energy consumption and compared with the results of contemporary house simulation to find out amount of energy reduction which is effect of implementation of sustainable architecture. It should be noted that with the attention to the wide range of input data, the simulation is related to the cold season. So the winter part of home is simulated. The aim of this research is to answer the question of how much the architecture of buildings can be reduce energy consumption by architectural design and appropriate selection of traditional architecture patterns (Sharifian & Chehrazai, 2016).

Initially, architectural and urban factors affecting energy consumption in buildings can be named, and items will be checked according to the importance and magnitude of these factors. These items are: orientation and elongation of the building, the number of windows on different fronts, the type and size of canopies, the layout and layout of the interior, the number of floors, the type of roof and the height of the floor to the ground level. For this purpose, the weather information of the city has been extracted in the last 14 years and has been entered as a file of energy plus into the design builder software (Sharifian & Chehrazai, 2016).

A- Study of traditional house (javaheri house)

This building was built in ghajar period about 150 years ago. The architectural space of the javaheri house is constructed in four square sides of courtyards. Southern side spaces are higher than other side areas. The eastern side has spaces such as a hall and rooms overlooking the courtyard and two verandahs on the sides of the hall (Sharifian & Chehrazai, 2016).



Fig .55: Isfahan Cultural Heritage, Handcrafts and Tourism Organization (Sharifian & Chehrazai, 2016)

B- Contemporary House in Isfahan

For house selecting had tried to match the condition with same jewelry house as much as can. This 551-square-meter house is located in the vicinity of a jewelry house, and is surrounded by three neighborhoods, like a jewel house. This building is constructed as a javaheri house in two stories but based on a contemporary house pattern. The percentage of openings to the external surface of the building is about 40 %. The building has a concrete structure and materials used in the construction include brick and sand cement mortar. Facade materials are stone and glass and brick (Sharifian & Chehrazai, 2016).



Fig .56: Ground floor and first floor plan and 3D model (Sharifian & Chehrazai, 2016)

Simulation of the buildings in the relevant software is a solution that allows for more accurate examination and estimation of the conditions and potential for the study and their effect in reducing the cooling and heating.

- **Assumption:** IN the modeling, building orientation, windows to wall ratio in south front was investigated. In the case of javaheri house, the materials are classified into two main categories of roofing materials and wall materials in the simulation process have tried to be implementing the materials used in the environment (brick, lime sand mortar). The structure consisted of load bearing walls with raw clay and bricks in later period. The ceiling was created from wooden beams, foundation from stone, internal walls covered by plaster and flat roof covering with clay and straw mortar (Sharifian & Chehrazai, 2016).

- **Traditional (javaheri) house analysis:**

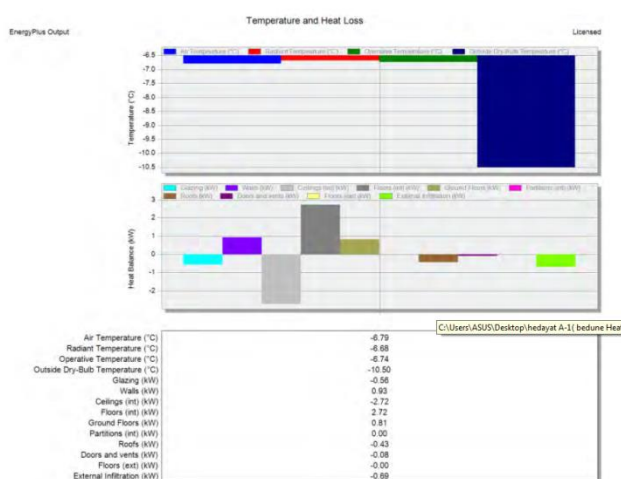


Fig .57: Temperature and degree difference chart in javaheri house from design builder

(Sharifian & Chehrazai, 2016)

Given the results of simulations, it is clear that the air temperature in the non-use of thermal equipment is always outside the comfort zone. So for having comfort living condition heating equipment is needed.

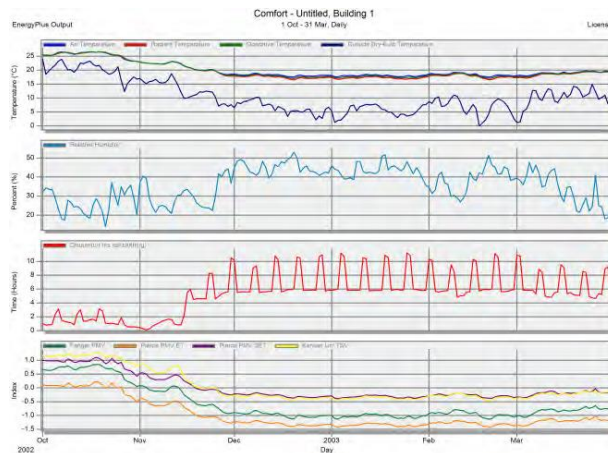


Fig .58: Comfort chart in javaheri house (Sharifian & Chehrazei, 2016)

Simulation done, amount of energy needed to achieve winter comfort is shown in above figure. Also, according to Comfort standards, the University of Kansas Standard has the highest ranges for indoor conditions. While the Fenner and Pierce standards set low level of living comfort. As a result it is possible to reach comfort level by using warm clothing to save energy with easier solution as shown in Figure 11, after the use of heating equipment, the comfort temperature of the residential unit has reach to 24 degrees throughout the year. Of course, the energy consumption is 11534 kilowatt-hours per year, which is a high amount. According to the table, respectively the highest energy losses are Exhaust air from inside to outside, cold air entrainment through openings, roof and ventilation through its doors and joints. Therefore, it is possible to reduce the amount of thermal loss in a year with small measures such as door and window seals (Sharifian & Chehrazei, 2016).

It is also clear in this diagram that the amount of generated thermal energy is approximately equal to the amount of absorption that is due to the sun. So sun as a potential for design can be used. It is also clear in this diagram that the amount of generated thermal energy is approximately equal to the amount of absorption that is due to the sun. Therefore sun can be used as a potential for design.

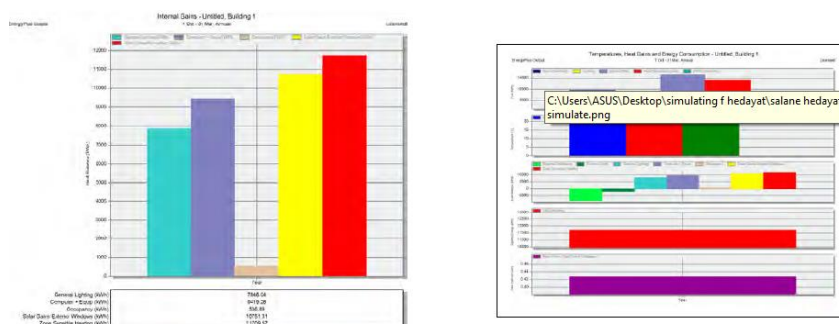


Fig .59: Direct absorption chart – energy consumption and energy lost chart (Sharifian & Chehrazai, 2016)

Figure 60 and 61 show the effect of direct absorption and radiation (14531 kWh). So Sun can be considered as an important factor in design because there is no need to heating by sun radiation and building heat absorption until November.

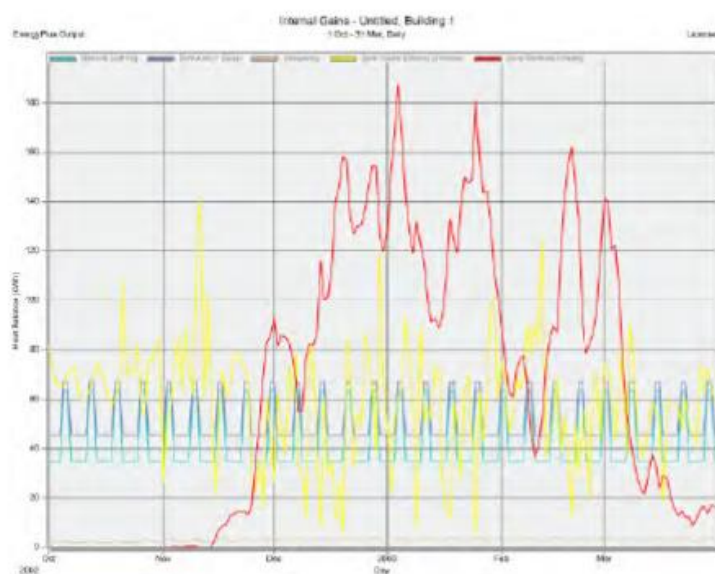


Fig .60: Internal absorption chart by design builder (Sharifian & Chehrazai, 2016)

-Contemporary house analyses:

Regarding the simulation results and the above diagram, it can be easily seen that the air temperature inside without using the heating equipment is, on average, lower than the comfort level. From this chart, the factors influencing heat lost can be assumed to be hot air exhaust from connections. The change in air and indoor air ducts causes excessive heat exiting from the sun's absorption. Also, windows, roofs, walls, and cold air

entrances from outside have the greatest impact on the internal heat lost (Sharifian & Chehrzei, 2016).

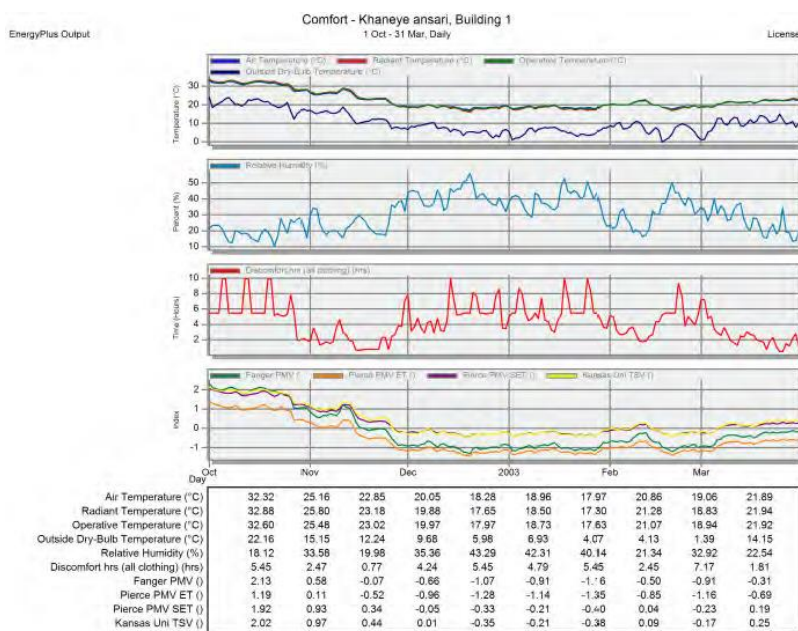


Fig .61: Comfort chart in contemporary house (Sharifian & Chehrzei, 2016)

The results of daily statistics during the cold seasons after the application of heating equipment, interior space is within the comfort zone (18-32c). With regard to the fenger comparative comfort level, people can have comfort level only by using appropriate clothing in this area. Figure 15 illustrate the amount of thermal energy required is 3357 kWh. Another interesting point is that the percentage of the building's openings is 36% on the southern side, while the absorption of heat from the sun is 17052 kilowatt-hours per hour which is a considerable amount near 5 times energy needed for heating. The proportion of 30%-36% for the southern side can be appropriate and the only necessary measures to use this heat are proper insulate and preventing heat loss (Sharifian & Chehrzei, 2016).

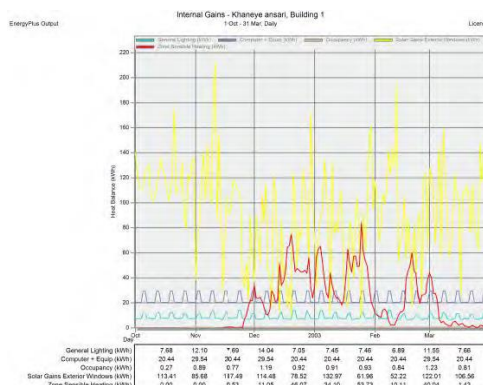


Fig .62 : internal heat absorption (Sharifian & Chehrazai, 2016)

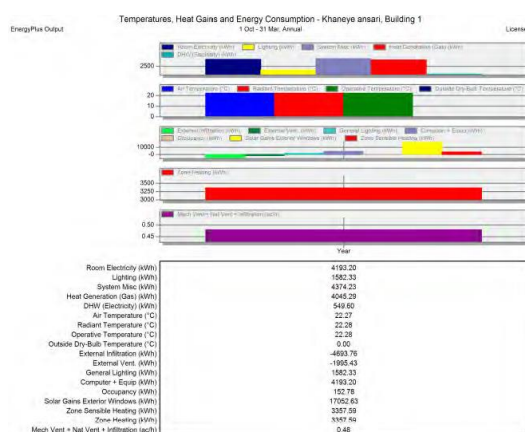


Fig .63: temperature, direct absorption, energy consumption (Sharifian & Chehrazai, 2016)

Figure 62 shows the amount of daily heat gain during the cold season as well as the effect of the thermal effect caused by it. This table clearly shows how much radiation can affect energy consumption, so that the input Solar radiation can reduce the energy consumption of equipment, so that from October to early December, the minimum use of Equipment. This is directly dependent on the proper building design (Sharifian & Chehrazai, 2016)

In this part, comparing a traditional home and a contemporary house in terms of thermal behavior, the results of this comparison are summarized in Table 8.

Amount of sun absorption affect heating(kw/h)	Window to wall ratio	Floor area	Energy consumption	Case study
17052	36	189	3350	Javaheri house
10751	40	368	11750	Contemporary house

Tab .8:Energy consumption and heat absorption comparison (Sharifian & Chehrazai, 2016)

-Conclusion:

As can be seen, the energy consumption of a contemporary home is approximately 3.5 times the size of a javaheri house, while the area of the jewelry house is almost twice as high. So, using traditional architectural patterns in contemporary homes can help reduce energy consumption. The most important way to reduce the heating load in this study is to optimize the reception of sun rays, which, according to the results of this study, is not limited to the level of the transparent surface of the South Front And factors such as the form of building, proper orientation and appropriate materials with the climate, affect the thermal performance of the building. All these factors must be taken into account in order to achieve the best results in terms of reducing energy consumption and this will not be possible except with the careful consideration of architects in the design as well as attention to climate issues such as the orientation, form and level of occupation of buildings.

The goal of energy saving in buildings is to reduce environmental pollution and reduce the heating-cooling costs of buildings and the use of renewable energy instead of non-renewable energies. With the increase in environmental pollution, the new technology of clean energy use has grown significantly. Considering the high consumption of energy in the construction sector, suitable designs for reducing energy consumption and designing buildings are highly important by architects. The use of renewable energies, in addition to reducing the use of fossil fuels, reduces environmental pollution.

Therefore, a comparison has been made between vernacular architecture and contemporary and modern architecture. The vernacular architecture is a kind of architecture in which elements used in it are shaped according to culture, climate and human comfort.

But contemporary architecture sometimes represents wrong imitation from western and modern style without consideration of climatic and cultural aspect, and moreover, with the rise of urbanization and the introduction of technology into architecture, some of the elements mentioned in the traditional architecture are removed or the same elements are used in modern building.

The following table represents sustainable technics, patterns and concepts had used in vernacular architecture in hot and dry region of Iran which can be implemented in contemporary architecture.

Elements	Description	Traditional Architecture	Alternative in Contemporary Architecture
Material and color	material used and color type for facade	- local material(straw and clay mortar) with low thermal conductivity with light colors	Implementation of alternative light color material or insulation layer with low thermal conductivity for facade instead of glass, aluminum and other non-local materials and dark colors materials
Buildings orientation design	- The sun's radiation and the effect of its thermal energy - The flow of air and the effect of its	-provided comfort conditions for summer spaces and winter rooms	-selecting optimum building orientation will optimize heating, cooling and lighting energy demand of building which will reduce need of active energies
spaces in the basement(Sardab)	use of soil thermal capacity	an appropriate response to climatic conditions and creates a comfort environment for living	Can be consider as a Strong potential to preserve energy in single family houses and private properties
Central courtyard	in this type of yard residential spaces or walls surrounding the sides of yard and yard located in center of building	- played a significant role for lighting , Air conditioning and Ventilation for indoor spaces by appropriate design and planting tree	Necessity to pay more attention to the design of the courtyard and green space and the selection of climate-friendly trees speciose and the use of suitable materials with low thermal capacity and bright colors to use cooling potential of the yard which will help cooling demand of building -Use the terrace in high-rise buildings instead of the central courtyard

<p style="text-align: center;">Wind Catcher (Badgir)</p>	<p>-work like solar chimneys for air circulation</p> <p>-this element used for air circulation during hot summer days</p>	<p>- The tower head have vents on the side which is facing the predominant wind.</p> <p>- Two or four sides of the tower can be open to let the wind in all possible directions.</p> <p>- let the air move separately up and down the tower all at once</p>	<p>- Implementation of this technic as a passive energy design will reduce building cooling demand in days which the temperature is not so high and can help as a complementary element of air-conditioning system</p> <p>-modern type of wind catcher equipped with solar panel and work without need of electricity</p>
<p style="text-align: center;">Walls</p>	<p>Walls with the thickness of one meter</p>	<p>- long wall thickness and material uses for walls (raw brick , clay mortar as filler and straw and clay mortar as a finishing layer)has very low thermal conductivity and works as an insulation layer and consequently reduce energy demand of building</p> <p>-</p>	<p>- Use of double-layer walls</p> <p>- Insulation of walls with materials with high thermal capacity to reduce thermal conductivity</p> <p>- using light weight and porous bricks which is built from local material and environment friendly</p> <p>- Use of decorative façade bricks made from native and local materials</p>
<p style="text-align: center;">Windows, canopies and veranda</p>	<p>- proper use of windows size and windows material to control the sun radiation and air conditioning</p> <p>- proper</p>	<p>- Use of wooden lattice windows with colored glass that reduces the intensity of light into interior spaces</p> <p>- The use of the canopy (the porch) and the deepening of the windows as a result of the decrease in the entrance of sunlight into the interior spaces</p>	<p>- Implementation of energy efficient windows frame and multi-layer glaze to minimize energy lost through windows</p> <p>- design and Selecting best size of windows according to site and climate condition in each direction by simulation for best energy optimization</p> <p>- design canopies with depths corresponding to the region's climate and direction and intensity of sunlight minimize sun light entrance in summer and maximize light entrance in winter</p> <p>-Placing the window in the depth of the wall</p>
<p style="text-align: center;">Materials</p>	<p>-The use of native and vernacular materials</p> <p>- mud, mud brick, stone, brick, mortar, straw mortar</p>	<p>- thermal resistance as an insulation layer</p> <p>- high heat capacity</p> <p>- use brightly colored materials prevent over</p>	<p>- using modern low weight brick with low thermal conductivity from local material instead of metal, concrete , glass, aluminum and other non-local material</p>

		<i>heating of building</i>	<i>-use brightly colored materials</i>
Summer sitting portion	<i>Spaces located in the southern part of the courtyard</i>	<p><i>-face the north direction receive less sunray and are shady so can provide cooler places</i></p> <p><i>- Wind catchers and air vents are mostly located in the southern part of the building</i></p>	<i>-Placement of main spaces (living space) on the south side of the building and the placement of spaces such as the kitchen on the north side and the service spaces in the east and west</i>
Winter sitting portion	<i>the spaces located in the northern part of the courtyard</i>	<p><i>-face the south direction, receive more sunray</i></p> <p><i>-heat and become warm so can be used during the cold seasons.</i></p>	
Roof	<i>Domed roof are suitable types of roof in hot and dry regions</i>	<p><i>Roof covered with straw and clay mortar or double layer ceiling work as an efficient insulation layer</i></p> <p><i>- less heat attraction by shadows in half part of dome</i></p> <p><i>- better air circulation and heat exhaust according to Spherical shape of roof</i></p>	<p><i>- use the two-layer ceilings</i></p> <p><i>- use glossy and light colored material to prevent heating in hot days to reduce cooling demand</i></p> <p><i>-Use of thermal layer insulation and moisture insulation in roof</i></p> <p><i>- Use roof garden in some apartments</i></p>
Vestibule (Hashti)	<p><i>a corridor between the alley and the interior spaces, so it</i></p> <p><i>- designed in square, rectangular, octagon and other forms</i></p>	<i>- an area between inside and outside of building work as an interior space which preserve heat and reduce energy lost in cold winters</i>	<i>- considering a lobby in plan in design phase to prevent energy lost</i>

<p>Sunken Garden</p> <p>(Godal Baghche)</p>	<p>the excavation is done in the center of the courtyard, the space that is made below the alley's surface and the building's surface</p>	<p>to decrease the heat exchange of building with the outside air and to provide low expense and natural cooling and heating</p>	<p>-It is recommend to use in single family houses or private places or the yards with enough free space to supply a comfort and pleasant outside space during hot summer</p>
<p>Cellar-Shabestan</p>	<p>-Located below the ground floor of the building</p> <p>-It has a ceiling about one meter higher than the surface of courtyard and the rest of it is designed to be underground.</p>	<p>- create cool and comfort place for resting during hot summer days without generating cooling energy</p> <p>-ventilation of the space by windows that connected to central court yard</p>	<p>-It is recommend to use in single family houses or private places to supply a comfort and pleasant space during hot summer with default comfort temperature</p>
<p>Sustainability</p>	<p>Designing compatible buildings with the climate, providing human comfort and reducing unreleased energy use</p>	<p>-using passive energy to acclimating the buildings makes the traditional Iranian architecture a sustainable one</p> <p>- Climatic factors as well as local construction materials of hot-arid regions and natural cooling systems are the area which the sustainability is obvious.</p>	<p>-form followed function. Climate, environment and regional concerns were not important issues.</p>
<p>Sustainable building life cycle</p>	<p>Low energy demand building – mostly help renewable type of energy and material</p>	<p>-passive design by help of Reusable materials such as natural and local materials and use of inherent environmental factors to provide comfort level</p>	<p>- The necessity to pay attention to the climate, use of local materials, climatic design compatible with environment, the use of the inherent potential of the environment and the use of clean energies, especially the sun energy</p>
<p>Construction Technology</p>	<p>At the same time as the Industrial Revolution</p>	<p>-Simple tools and equipment</p> <p>-Man power</p>	<p>Use of advanced technology to optimize energy consumption and generate energy from renewable source like sun and wind</p>

Planting		<ul style="list-style-type: none"> - Decreasing the direct radiation of sun in the yard space and consequently reduce temperature in building surroundings - Shading on ceiling, walls, windows, and yard space -Decreasing the dust in the surroundings of the building -Decreasing the undesirable wind speed in building surroundings -Increasing the humidity in these regions 	<ul style="list-style-type: none"> - green roofing increases in thermal mass - Use of plants on the terraces and balconies
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Tab. 9: Comparison of Sustainability Elements in Traditional and Contemporary Iranian Architecture (by the author)

3.5.2. Reducing energy consumption by new idea in elements

Traditional architecture in hot and dry region of Iran is a good sample of sustainable architecture which is achieved by use of creative techniques to reduce energy consumption and appropriate usage of environmental material and nature potentials. This had led to the minimal use of fossil fuels. Unfortunately, in contemporary architecture, imitation from modern architecture style without consideration in climatic design and the lack of attention of architects to sustainability aspect caused increasing use of fossil fuels. These crises not only cause huge energy consumption in building sector but also cause global warming, environmental contamination and Impose a huge cost to society.

Therefore, in today's architecture, we have to take consideration to environmental friendly, valuable concepts and modern technologies for optimum design concept which will lead construction to be more sustainable. By Finding, utilizing and updating valuable traditional architecture technics and concept which have positive potential be implemented in contemporary architecture, concept of sustainable development in the building industry can be achieved. The following studies will represented analyze and result of the implementation of most practical vernacular architecture concepts and provide them with new ideas and forms for implementation in contemporary architecture.

3.5.2.1. Windows and canopies in a warm and dry climate in Isfahan

- **Optimal window percentage:** Windows Because of their transparency, receive radiant energy as well as daylight through them, and this element one of the most important component of the building in terms of energy. Using the appropriate ratio of windows in each direction is one of the most important aspects of energy efficiency through architectural design. So in the first step, the window to the wall ratio is calculated without any canopies on each front of the building. Then area of optimal canopies found. The selected building has a stretch in the south-north direction. In determining the optimal percentage of windows, all the heating, cooling, and lighting consumption of the building considered together because the total impact of these items is considered to be the criterion for assessing the energy efficiency of buildings (Shiyasi & Karimi Yeganeh, 2016)

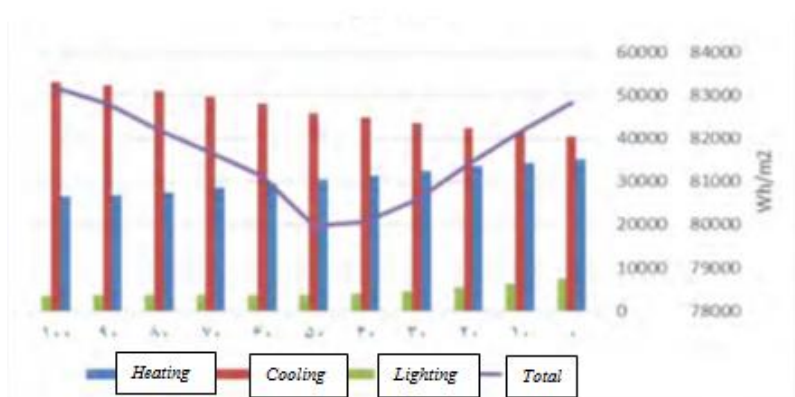


Fig .64: The primary energy consumption of office buildings without canopies with different levels of window to the surface ratio (kw/h) in south front of building (Shiyasi & Karimi Yeganeh, 2016)

The lowest point of this graph shows the best percentage of window to the wall in south front, which is in the range of 40 to 50%.

-Optional window percentage in other directions:

Modeling was done similarly for other directions, and the optimal percentage of the window for the north front was 40% and the eastern front was between 30% and 40%, and the western edge was 30%.

-Conclusion for optimal design of windows in each front:

After obtaining the optimal amount of window to the wall surface at different fronts and compare it with the previous states we see that the total energy of the whole building has fallen by about 7 kWh/m^2 , which is about 11% Reduce energy consumption per year. Then, in the next step and for further process of building optimization with a consideration of 50% The southern window, 40% of the northern window, 30% of the eastern and western windows, the canopy and the depth of the optimal canopy for this window Were discussed (Shiyasi & Karimi Yeganeh, 2016).

-Optimal canopy:

One of the most effective ways of controlling the amount of sun radiation is the use of a canopy. A canopy should be designed in a way to prevent sunlight interring inside during the warm year, and produce the lowest amount of shadow on the window or wall surface during the cold weather the year will. In fact, the canopy has the greatest effect on reducing the amount of radiation emitted by the sun.

-The horizontal canopies of the South Face of the building:

Based on the studies carried out in the previous section and determining the optimal window value for each side of the building, the depth of the canopy was determined, since the amount of radiation introduced through the windows with fixed canopies into the building is influenced by the depth of the canopy and minimized Total energy is very important (Shiyasi & Karimi Yeganeh, 2016).

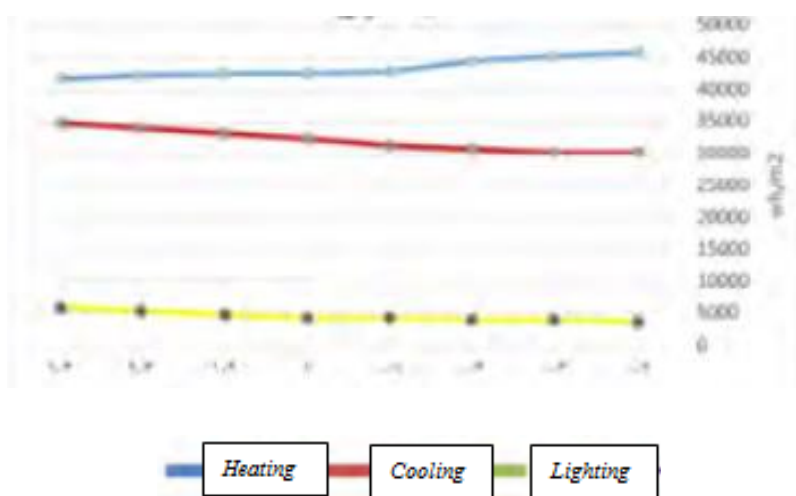


Fig .65: Energy required for cooling and heating Brightness with different horizontal canopy depths (Shiyasi & Karimi Yeganeh, 2016)

In order to select the proper canopy depth, the total energy consumption must be analyzed to achieve the desired result. According to fig 66, we observe that the total energy consumption has decreased by increasing depth of canopy from 0.2 to 0.8 and then begins to increase by more depth of canopy. As a result, the depth of the appropriate canopy for this front is 0.8 meters (Shiyasi & Karimi Yeganeh, 2016).

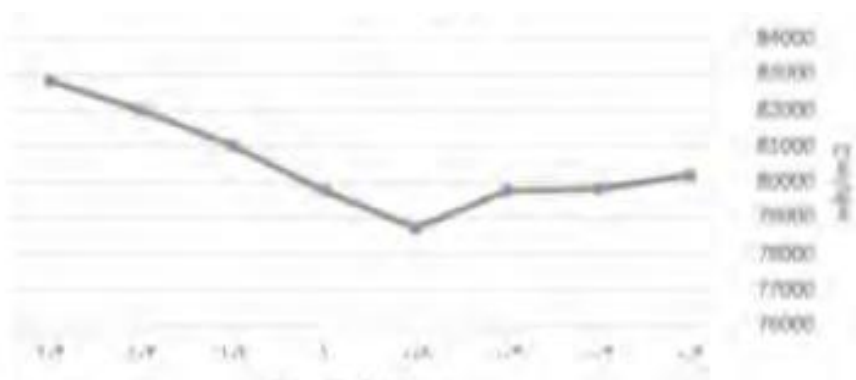


Fig .66 Total energy consumption with different canopy depths on the South Front (Shiyasi & Karimi Yeganeh, 2016)

-Optimum size of the canopy in other directions:

In the same way, the optimal size of the canopy was examined for other directions, which vertical canopies with depth of 0.6 meter was optimum. The northern front was not required canopies due to not radiation sunshine. Also According to information obtained from similar diagrams, the depth of the optimal canopy on the western front of the building is 0.6 meters. Also, in the corners of the northwest and northwest front, vertical canopies with a width of 0.6 meters are considered (Shiyasi & Karimi Yeganeh, 2016).

-Results of use and correction of shadows:

Considering the mentioned issues and the importance of the canopy of windows, adding and correcting the depths of the building canopies to the non-canopy mode by design builder software, the amount of energy savings is calculated as follows. According to diagram 11 and the comparison of the energy of the whole building in two cases without canopies and with canopies, we can see that if using external canopies, the total

energy consumption will be saved about 7 kWh / m² per year compared to the non-canopies mode. Which is about a total of 10% energy savings relative to the total energy consumption of the building, only with the appropriate design of the canopy depth on each front (Shiyasi & Karimi Yeganeh, 2016).

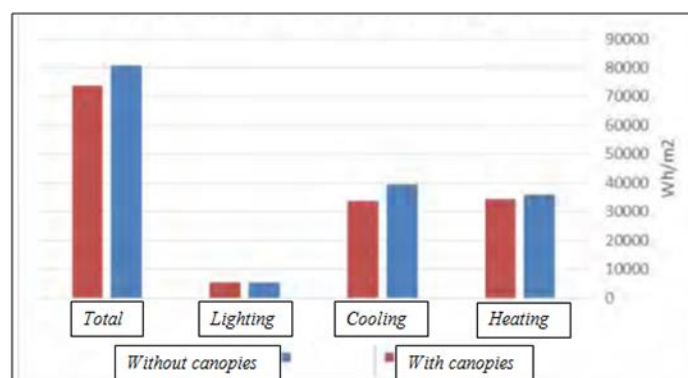


Fig .67 : Comparison of energy consumption of building with canopies and without canopies (Shiyasi & Karimi Yeganeh, 2016)

-Conclusion:

In this study, firstly, to obtain the optimum window percentage on each front of the building, the office building was modeled using the design builder software. And then the amount of lighting, heating and cooling and the energy of the whole building was analyzed. According to the results and comparing the energy consumption of the building, the optimum area of the window was calculated in different directions of the building. In the next step, considering the optimum window percentage for each front, the design and analysis of the depth of the canopy of each front was considered. The results of this study and the comparison of energy consumption of the whole building in two conditions with a canopy and no canopy, total energy of the building will be saved 10%. Considering the 11% energy savings found in the optimum window area design, it can be concluded that with the appropriate design of the windows and canopies of a building, energy consumption of the existing building will reduce up to 20% (Shiyasi & Karimi Yeganeh, 2016).

3.5.2.2. The effect of glass on reducing the thermal and cooling load of the building

The purpose of this study was to investigate heating and cooling performance of conventional windows in the Building Industry of Iran. For this purpose, 21 samples of these windows were modeled in the Designer Biller software and analyzed by Energy

Plugin Plus with the weather data of Qazvin. IN this study, the analysis of the performance of single-layer, multi-layers, colored glass and low-pass glass windows has been considered in reducing the cooling and heating load (Gorji Mahlabani & Mofared Boushehri, 2017)

-Simulation:

In order to analyze the thermal performance of the building, a monthly analysis is required throughout the year. This analysis is based on the climatic conditions and other effective factors in improving the thermal performance of the building, such as materials used in external walls. For this purpose, the Designer Builder software has been used which is powered by the Energy Plug plugins that has been carefully tested (Gorji Mahlabani & Mofared Boushehri, 2017).

For the software analysis of heating and cooling for, rooms with dimensions of six in four and a height of 3.5 meters were modeled. Also, in 21 samples, for more precise simulation the effective components in its thermal and cooling performance were kept constant and only window type was considered as insulation. Windows has 2 meter height and 4 meter width which installed one meter from floor and is located in south facade (Gorji Mahlabani & Mofared Boushehri, 2017).

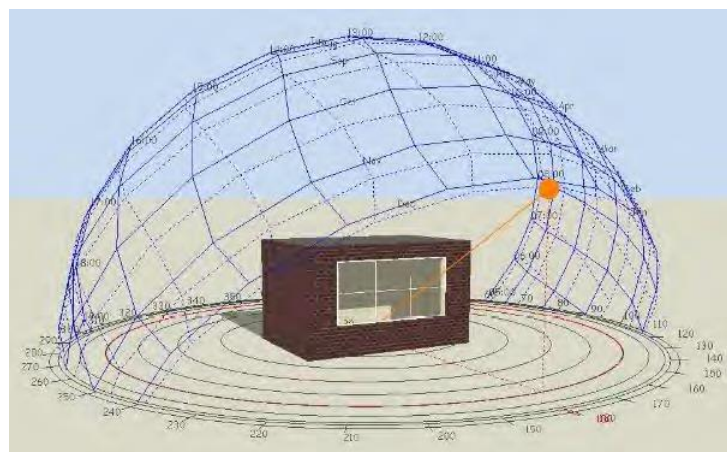


Fig .68: Place of window in simulated samples according to position (Gorji Mahlabani & Mofared Boushehri, 2017)

The walls from outside to inside consisted of a 10 cm brick layer, a 8 cm polystyrene insulation layer, and 10 cm layer of cemented concrete blocks and a layer of plaster with thickness of 0.6 cm. The thermal coefficient was constant.

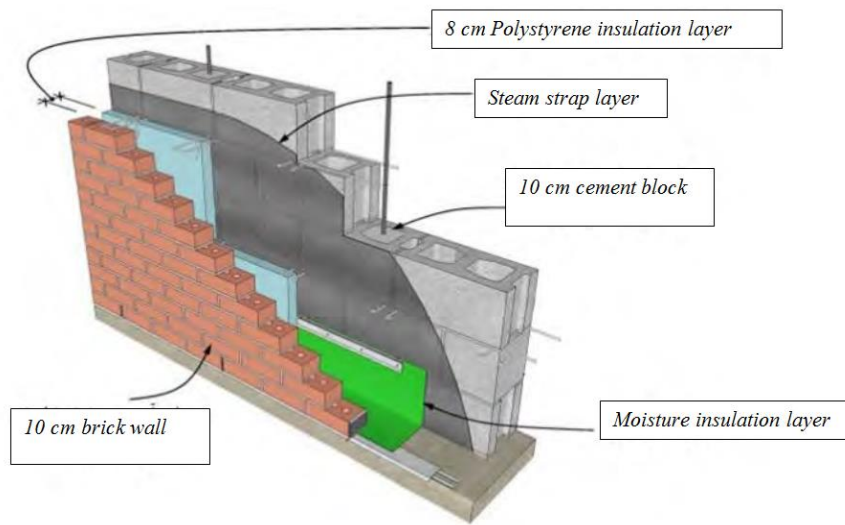


Fig .69: Wall detail (Gorji Mahlabani & Mofared Boushehri, 2017)

Since the glass was considered as the main variable for analyzing the thermal performance of the building, 21 different samples of glass that differ in terms of the number of layers, color, and the type of interlayer layers were analyzed.

-Single layer glazed:

In this section the comparison between single glaze windows with different color had done

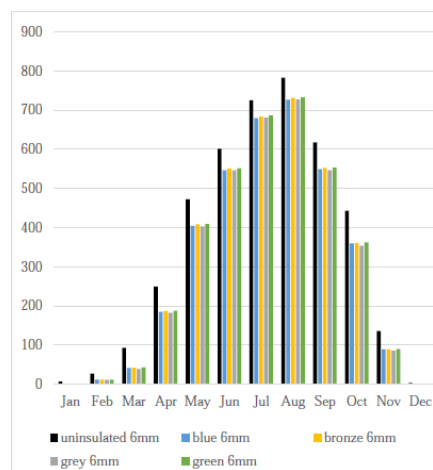


Fig .70: Cooling load in one layer glaze (kWh) (Gorji Mahlabani & Mofared Boushehri, 2017)

-Double glazed windows:

In this section air filled with different colors, argon filled with different colors and low-E windows in terms of heating and cooling load had compared.

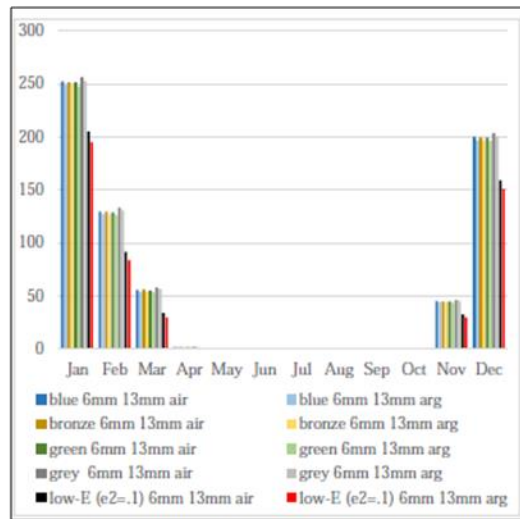


Fig .71: Heat load comparison in double layer windows (kWh) (Gorji Mahlabani & Mofared Boushehri, 2017)

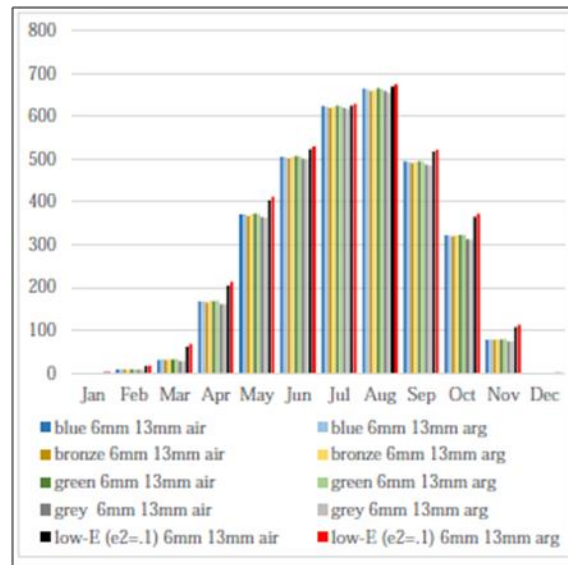


Fig .72: Cooling load comparison in double layer windows (kwh) (Gorji Mahlabani & Mofared Boushehri, 2017)

-Triple glazed windows:

In this section to investigate the performance of three-layer glasses, six samples were selected. Triple glazed air filled windows, Triple glazed argon filled windows, and two type of Triple glazed low-e which each type had studied with argon filled and air filled.

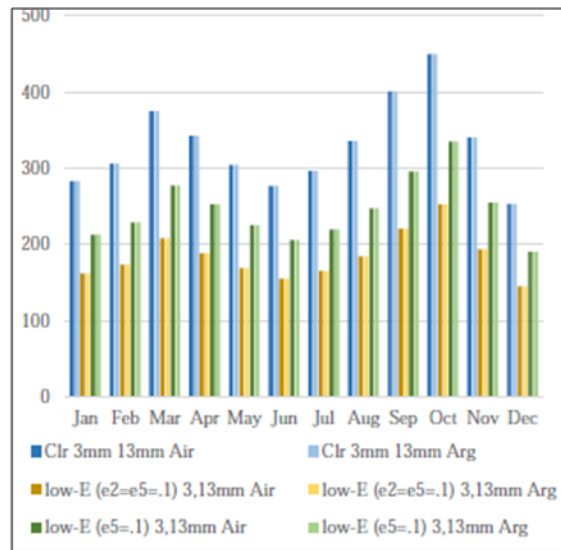


Fig .73: Heat load iteration from sun radiation (kWh) (Gorji Mahlabani & Mofared Boushehri, 2017)

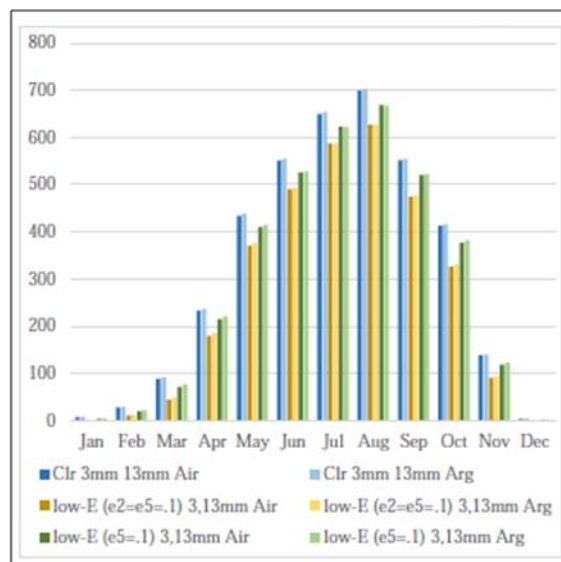


Fig .74: Cooling load comparison in triple layer windows (kWh) (Gorji Mahlabani & Mofared Boushehri, 2017)

-Conclusion:

The windows as one of the outer layers of the building can have a significant effect on the thermal performance of the building. In this study, the effect of some windows on the cooling, heating, and solar incoming heat coefficient was evaluated through computer simulation. The results show that under the same climatic conditions and the use of similar materials for external walls, the use of double glaze and triple glaze instead of single-glazed windows, the heating load of the building would be reduced by 17% and 39%. The cooling load of the building is also reduced by using double-glazed windows and three-wall windows instead of single-pane windows. Also, the use of low-E windows in hot climate of the country which often need cooling to achieve the comfort conditions will reduce the cooling load of the building.

3.5.2.3. Determine the best window frames to reduce energy consumption

The main factor indicating the amount of energy lost through windows is the u-factor. The smaller factor, shows better the insulation and the less energy lost. In this research, the effect of reducing energy consumption by replacing the metal frame with pvc, aluminum and wood samples is investigated (Naghdi & Vasigh, 2014).

Agha Hussein School in Ilam City has been studied for computer simulation. All factors affecting the thermal load of the building were considered. For this purpose, real information was used by the construction consultants such as wall layout, ceiling, cooling system, heating and climatic information of the city of Ilam (Naghdi & Vasigh, 2014).



Fig .75: South façade of the building (Naghdi & Vasigh, 2014)

-Study assumption:

Sky position, type of wall and ceiling layers, number of occupancy hours, metabolic coefficient for sitting, thermal resistance of clothing, window to wall ratio, glass type,

metal window frame and Lighting, heating and cooling settings were enter into the software (Naghdi & Vasigh, 2014)

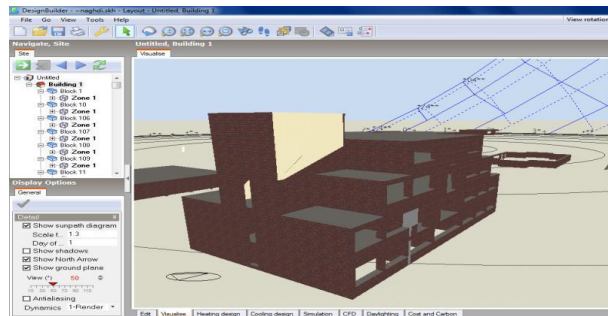


Fig .76: Simulated model (Naghdi & Vasigh, 2014)

As seen in the modeling building, the school building has an East-West stretch and classes are arranged linearly around a corridor. Windows on all fronts are made of metal frames.

-Building Energy consumption:

Diagram below represent building energy consumption of heating and cooling, lighting and other electrical appliances. As shown in the diagram, the most energy consumed in building is heating and second cooling and lighting is the least consumption. Therefore, it is necessary to provide indoor solutions to reduce this consumption by maintaining comfortable conditions (Naghdi & Vasigh, 2014).

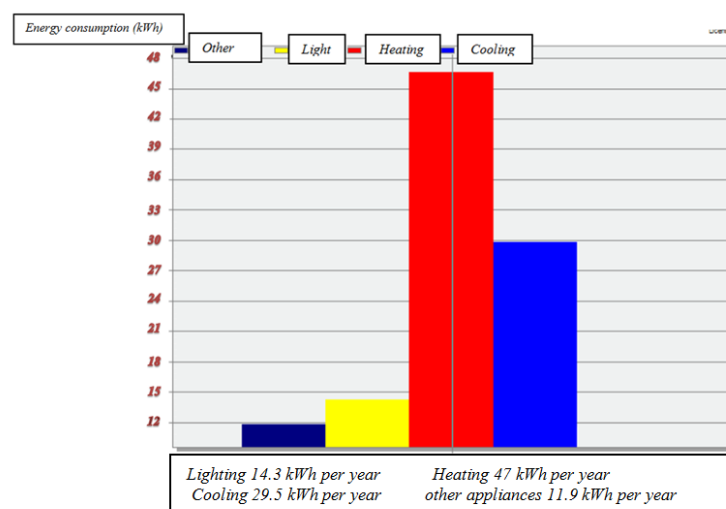


Fig .77: Energy consumption (Naghdi & Vasigh, 2014)

-Determine the optimized type of window frame:

In order to determine the best window frames for reducing energy consumption, PVC, aluminum and wooden frames for each building are modeled. The results of their energy consumption reduction are shown in the below diagram (Naghdi & Vasigh, 2014).

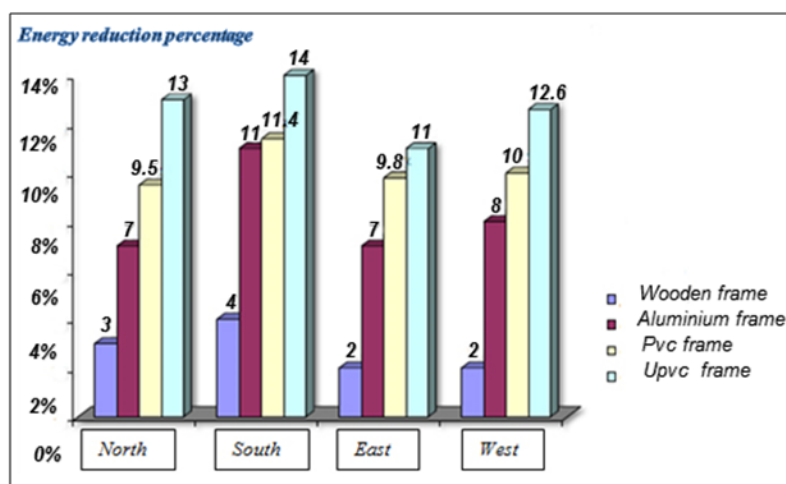


Fig .78: Energy in type of window frame (Naghdi & Vasigh, 2014)

From the review of the energy consumption reduction diagram for each windows frame, it can be seen that the best frames for all fronts in terms of reducing the energy consumption are UPVC frames. After that, the aluminum frames and, finally, the wooden frame have a weaker performance than U PVC and aluminum frames. The reason for the effectiveness of most UPVC frames is that the plastics have very low thermal conductivity and the air inside the profile provides the best structure for low thermal conductivity.

By replacing metal frames with UPVC type in all fronts, energy consumption in the north, south, east and west fronts fell down by 13, 14, 11 and 12.6 percent, respectively (Naghdi & Vasigh, 2014).

3.5.2.4. Investigating the effect of different materials on reducing energy consumption in residential complexes using Designer Biller software

In this part, modeling of a typical building in the climate of Tehran with the help of Designer Builder software has been studied and the cooling and heating energy consumption of the building under different hot and cold conditions has been investigated. Tehran is located in in warm and dry region. This software uses the Energy

Plus analyzer to analyze the heat transfer processes of the building. The modeling space of the building complex consists of three blocks, the right block of 11 floors, the left block of 13 floors and the middle block with 15 floors. In each block, one space is designed as atrium, and in each floor, in addition to the three residential units, a greenhouse is used to adjust the air temperature of the building. These greenhouses are interconnected on different floors through the green way which is showed in the form. The ceiling of the atrium designed in the middle of each block is made of glass and is closed in winter and open in summer. All windows used in the building are made of single-glazed with aluminum frame. Details of the common materials used in the wall are given in Table 1. There are 11 different modes for comparison with the sample building, and the difference between each of this alternative with the base, state in Table 2. First, four parameters of Low-E reflector glasses, smart electrochemical glasses, external wall insulation and roofing with polystyrene insulation have been studied separately And then these solutions are combined and their impact on the energy consumption of buildings has been investigated (Sobhan & Yazdanfar, 2016).



Fig .79 : 3D modeling simulation (Sobhan & Yazdanfar, 2016)

Thermal and physical properties of materials in the building				
Density m ³ /kg	Thermal conductivity coefficient w/mk	Thickness cm	Details	Element
2800	3.5	3	white marble	external wall
1800	1	3	cement sand mortar	
1800	0.8	30	pottery block	
1500	1.1	2	gypsum soil layer	
1100	0.57	2	white gypsum	
1100	0.57	2	white gypsum	internal wall
1500	1.1	2	gypsum soil layer	
1800	0.8	25	pottery block	
1500	1.1	2	gypsum soil layer	
1100	0.57	2	white gypsum	
1100	0.23	4	moisture insulation	ceiling
1800	1	5	cement sand mortar	
400	0.12	10	light mineral filler	
1800	0.8	20	pottery block	
1500	1.1	2	gypsum soil layer	
1100	0.57	2	white gypsum	
980	1.4	1	ceramic	
1800	1	5	cement sand mortar	external flooring
400	0.12	10	light mineral filler	
1800	0.8	20	pottery block	
1500	1.1	2	gypsum soil layer	
1100	0.57	2	white gypsum	

Tab. 10: Thermal and physical properties of materials in the building (Sobhan & Yazdanfar, 2016)

Case 2 + case 5	Case 7	External wall insulation	Case 2
Case 2 + case 3+ case 4	Case 8	Roof insulation	Case 3
Case 2 + case 3+ case 5	Case 9	Smart electrochromic glass	Case 4
Case 2 + case 3+ case 4 + internal wall insulation	Case 10	E-low glass	Case 5
Case 2 + case 3+ case 5 + internal wall insulation	Case 11	Case 2 + case 4	Case 6

Tab. 11: Different types of case study (Sobhan & Yazdanfar, 2016)

In this research, a sample of buildings in Tehran's climate has been modeled and different cases which causing Energy consumption reduction was investigated. Modeling showed that the use of polystyrene insulation in the walls and the use of electrochromic

and Low-E glasses could considerably reduce the energy consumption of the building (Sobhan & Yazdanfar, 2016).

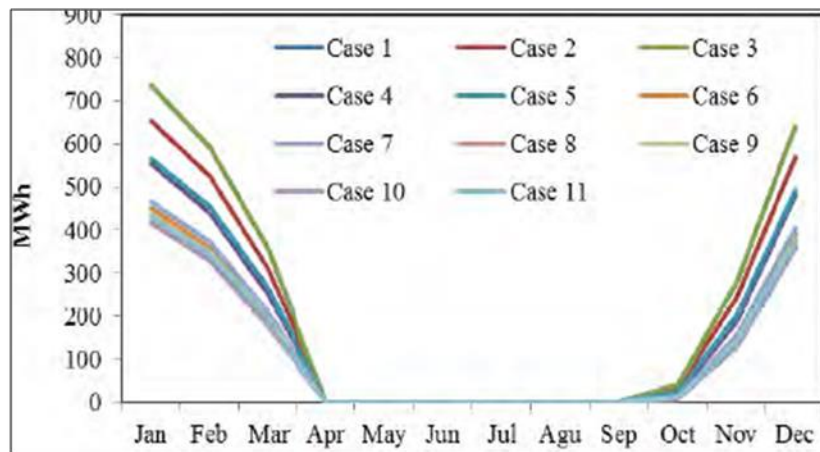


Fig .80 : Monthly heating energy consumption (Sobhan & Yazdanfar, 2016)

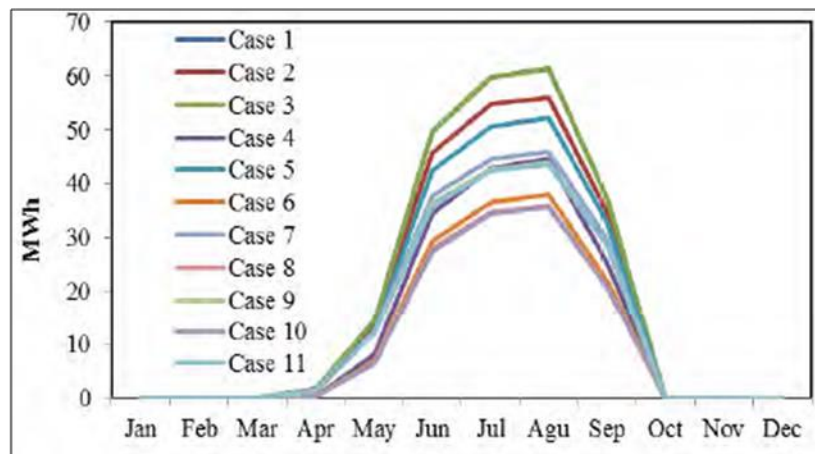


Fig .81 : Monthly cooling energy consumption (Sobhan & Yazdanfar, 2016)

Figures below shows, respectively, the annual heating and cooling consumption of the building. According to these diagrams, two important points can be found. First, the maximum demand for a building in the climate of Tehran is heating, and it is better to use the ways that attract the maximum energy of the sun or minimize the energy loss of the building. Based on these two above charts, the energy consumption of the building's heating can be reduced to 142 megawatts by running Case 10. Also by implementation of the same solution could reduce about 125 Megawatt the energy consumption of the building (Sobhan & Yazdanfar, 2016).



Fig 82 : Yearly heating energy consumption (Sobhan & Yazdanfar, 2016)

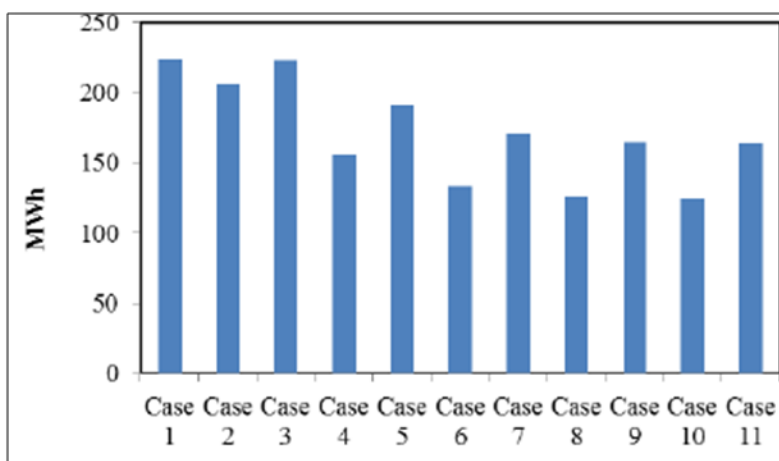


Fig .83 : Yearly cooling energy consumption (Sobhan & Yazdanfar, 2016)

According to Figures 82 and 83, it seems that the use of electrochromic glass in the building is more appropriate than Low-E glass. Figures 6 and 7 shows the total energy consumption of the building, which represents the energy consumption of the building's heating and cooling.

In this part, the effects of various optimization solutions such as wall and ceiling insulating and the use of smart electrochromic and Low-E glasses were investigated. The results of this study showed that, due to the low area of the ceiling relative to the exterior walls and windows, the roof insulation of the building will not have much effect on reducing the energy consumption of the building. The modeling showed that the by insulation of exterior walls, building energy consumption reduced by 11.7 and by

implementation of smart electrochromic glazes building energy consumption reduced by 27.3 percent (Sobhan & Yazdanfar, 2016).

Also, by simultaneously insulating the walls and using electrochromic glasses, the energy consumption of the building can be reduced from 287 megawatts to about 154 megawatts equal to 46.3%.(Sobhan & Yazdanfar, 2016).

3.5.3. Analysis of contemporary buildings in hot and dry Climate

3.5.3.1. The zero energy building

The design and implementation of the first zero energy building in Iran in 2012 was determined by the Materials and Energy Research Institute. Pure zero energy buildings refer to buildings with zero net annual energy consumption. The zero energy building of the Materials and Energy Research Center in Karaj has been designed as the first zero-energy building in Iran, with the view to reducing primary energy consumption and offsetting energy consumed through renewable energy production through clean energy sources and it was launched in 2014. The building is with a 2000m² infrastructure in two floors and with educational-research applications. In this building, the building energy demand has been reduced to a minimum and some of the energy needs of the building have been met by using solar energy, using building architecture and factors like wind catcher and atrium (<http://zero-energy.ir>)

The use of such strategies as passive solar design, orientation of buildings, location of spaces and insulation in the design of building architecture and the implementation of new design standards have caused energy consumption of this building to be reduced to 90% compared to an ordinary building and will reach 87kWh / m², which will supply by solar energy equipment (<http://zero-energy.ir>)

In addition to using the energy approach in the design of the building architecture, a variety of elements such as wind catcher and atrium are also used in the building, which representing the ideas of traditional architecture and its integration with the modern aspects of the building design. Also, the use of a wind catcher in buildings has reduced the energy consumption of buildings in the middle seasons. The use of modern control systems and BMS in the building has also led to a good control over the energy consumption of buildings. Ultimately, the use of solar and photovoltaic water systems to generate energy from renewable and clean sources has led the building to become a zero-energy building (<http://zero-energy.ir>)



Fig. 84. : The zero-energy building in Karaj (<http://zero-energy.ir>)



Fig. 85 : The zero-energy building in Karaj (<http://zero-energy.ir>)



Fig .86: Use of solar system to provide electrical charge of the building (<http://zero-energy.ir>)



Fig .87: Use Solar Water Heater (<http://zero-energy.ir>)

3.5.3.1.1. Architectural Properties and the factors affecting

Since the energy consumed in this building should be provided with solar energy, the greater use of energy in the building is equivalent to increasing the solar system and increasing operation cost, Therefore, in this building, the energy consumption of the building has been reduced to the minimum possible considering the heat load created by sun radiation on the building energy consumption and its optimal use. Hence, different initial design for the building carry out and standards such as ASHRAE 90.1 for buildings design with energy perspective, and ASHRAE AEDG standard, which is designing buildings with very low energy consumption and zero energy building had applied. Then, using simulation software such as IES VE, the energy consumption of the building was calculated for each design option and finally the option with the least energy consumption was selected. Once the design of the building has been determined, the architectural plans and three-dimensional design of the building are provided in Revit Architecture software and 3D model provided in this software is included in the IES VE software for accurate calculation of energy consumption. By specifying the electrical and heating energy consumption over a year, the solar water heating system of the building was designed so that it can as much as possible satisfy the heating needs of the building. Meanwhile, the system of photovoltaic panels has been designed in such a way that it can meet the building's electrical power requirements in one year and also maintain the energy balance of the building from the network (<http://zero-energy.ir>).

A: Stretching and orienting the building

The stretching of the building as well as its orientation has a significant effect on the thermal energy attracted through sun radiation and the use of natural light in the building. To increase the sunlight absorption during day, more space is dedicated on the south

side of the building. Project was built in two-story with eastern-western stretching so that most of the building spaces can use maximum solar heating and natural light.

For design of architecture plans, Spaces that are more user-friendly had designed on south side of the building in ground floor level. The placement of these spaces on the southern side, maximum sunlight had been achieved. IN addition, due to the increased traffic in these spaces, placing them on the ground floor will make it easier to access these spaces and prevent the loss of energy in other low traffic areas. Less use spaces are also designed on the first floor of north building side. These spaces require less energy and by placement on the northern side make it possible for users to access their energy only through the building system and at the time of use (<http://zero-energy.ir>).

B: Spaces lay out in the building

- 1-Placing spaces with high thermal requirements on the south side of the building
- 2-Placing spaces with low heat requirement on the northern side of the building.
- 3-Placing highly traffic spaces on the ground floor and close to the entrance to the building.
- 4-The placement of spaces with low traffic in the areas far from the entrance or the first floor of the building.

Given that the angle of the sun's radiation in different parts of the globe depends on the geographical coordinates of that point, the orientation of the building anywhere in the globe is also different for absorption of the maximum solar energy. The IES VE simulation software has been used to determine the best orientation of this building on the ground. In this application, the 3D model made from the building is rotated at different angles. At each building orientation, the energy consumption of the building and energy absorbed from the sun is calculated (<http://zero-energy.ir>)

Maximum Solar Absorption of Materials is a priority in building heating. According to the building conditions and priorities, the best orientation for the building is selected.

C: Insulation in a zero energy building

By increasing the amount of building insulation, energy consumption will decrease. In one hand by doing proper insulation the cost of the project will increase. On the other hand by increasing energy consumption, it is necessary to compensate higher energy demand by using larger solar systems, which will further increase the initial cost of the

project. Therefore, it is possible to determine the amount of insulation required by finding an optimal point for the insulation value of the building, in which the most energy saving is achieved with the least initial cost. In this project, by using proper insulation in terms of quality and cost, the energy demand of building reduced 40% in compare with normal building insulation requirement mentioned in section 19 of Iran national building regulation (<http://zero-energy.ir>)

D: Implementation of canopy on the south side of the building

The Implementation of canopies in hot and dry areas causes the cooling energy demand of the building decrease. Therefore, it is necessary to optimize the size of the shadows affecting building, in terms of the amount of solar heating energy absorbed during sun radiation. In this project with modeling of canopies in different sizes, it was determined that the use of vertical canopies on both sides of windows has no effect on building behavior. Windows located on the northern side of the building only in the early hours and end of the day are affected by sun radiation when mostly the building is not in occupied, therefore only horizontal canopies had implemented for south side windows (<http://zero-energy.ir>).

Studies show that the use of horizontal canopies with a depth of 40cm creates optimal conditions for the building. In warm summer months at different times of day, increasing the shadow depth of more than a certain amount does not have an effect on the emission of solar radiation. This value varies between 30cm and 50cm at different times of the day, with an average of 40cm at noon time. Also, during the cold months of the winter, only at noon and when the depth of the canopy exceeds 30 cm can have an adverse effect on the absorption of solar energy. Thus, the depth of the shade according to these graphs is 40cm. In the middle seasons, the increase in the length of the canopy is always effective in absorbing sunlight. However, due to the fact that building systems are not very active at this time, these diagrams are not involved in selecting the appropriate depth of the canopy (<http://zero-energy.ir>).

E: Use of the atrium to provide fresh air during the heating of the building

Providing fresh air during the warm-up period brings a great deal of heating to the building and makes it difficult to balance the energy consumption of it. Therefore, the atrium was used to provide some of the energy needed to provide fresh air during the building's heating period. In order to determine the atrium dimensions, the optimal supply needs of the fresh air have been considered. So that during the peak of the occupancy of

the building, fresh air can be provided only by the atrium. Due to the new air volume required for the building, the amount of energy required to provide fresh air during the heating period is calculated to be 16,450kWh / year. Based on the simulation results of IES VE software, if the atrium in the building is used, the amount of energy required to supply fresh air is reduced to 49% and equals 8.11kWh / year. This amount is equivalent to 30% of the total heating needs of this building over a year (<http://zero-energy.ir>).

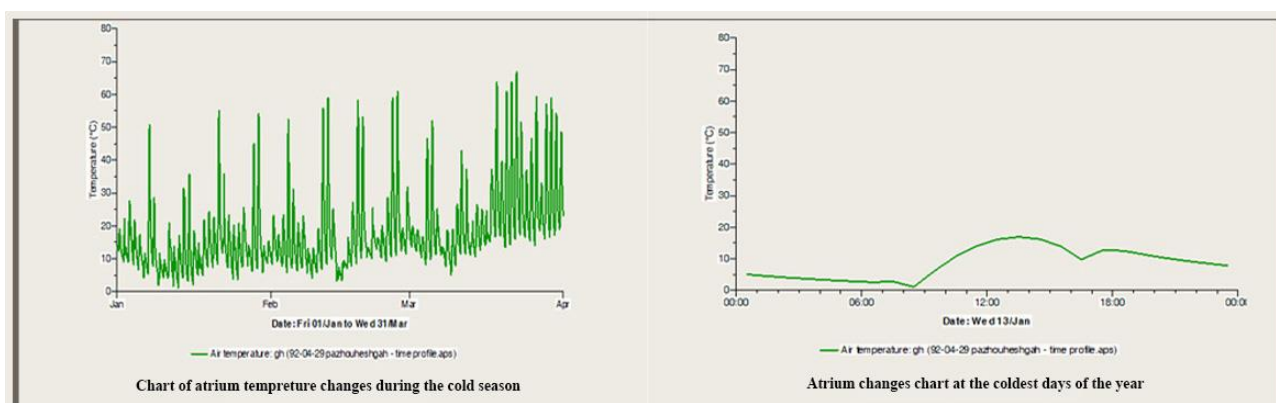


Fig .88 :Temperature changes atrium chart (<http://zero-energy.ir>)

In order to determine the useful volume of the atrium, it is necessary to select the dimensions so that the atrium temperature in the cold season is most often be in the appropriate range of 20 °C otherwise If the atrium enlarged too much, temperature will not increase as needed, so it is necessary to use the network energy to heat the inlet air into the building. Also, if the bigger size of the atrium is selected, more atrium ventilation fans will be needed in the summer. As shown in the diagram above, if the atrium drainage fans are not active in the summer, the temperature inside it is heavily raised and causes the plant species to disappear inside it (<http://zero-energy.ir>)

F: Use the wind catcher in the building

The use of wind catchers has been commonplace in Iran since ancient times. Wind catchers are made in different forms in central and southern cities of Iran, each of which is designed and implemented in terms of height and direction of the wind. The wind catchers were used in various residential, religious and service buildings, The remaining wind catchers can still be seen in the hot and dry climate of Iran (<http://zero-energy.ir>)



Fig .89: The use of traditional architectural elements such as wind catchers in the zero-energy building (<http://zero-energy.ir>)

In the zero energy building, the wind catcher as a symbol of a zero energy building was used to ventilate the corridors of the building in the middle seasons (spring and autumn) .Since there are two wind catchers in this building, one as input and the other as an air exhaust, Therefore, the winds of the area were investigated for designing the entrance to the openings of the dominant wind and the openings of the exit tower are closed in this direction. Also, the height of the towers and the openings of the openings are designed according to the amount of air flow required. Finally, the designed wind catcher model is simulated in Fluent software and their behavior in the building had investigated. The results of modeling wind catchers in Fluent software are presented (<http://zero-energy.ir>).

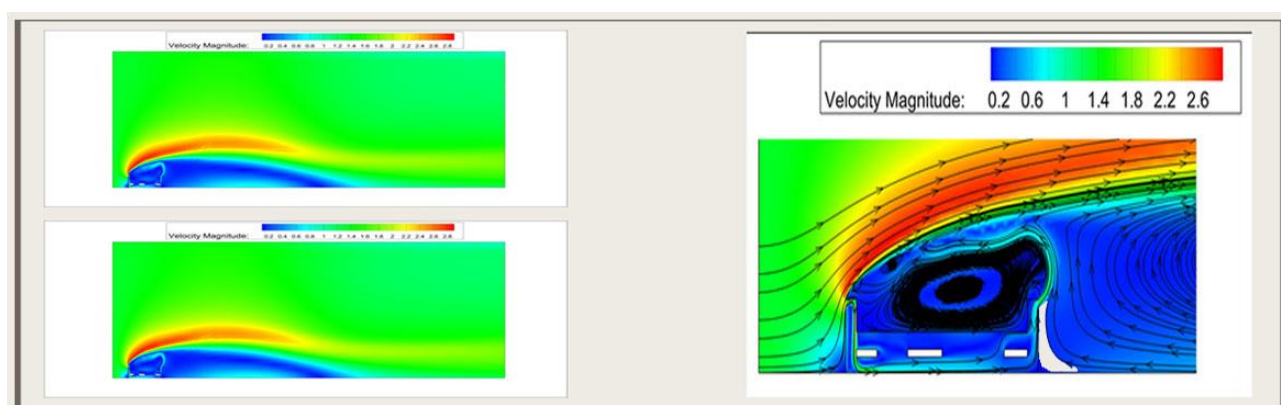


Fig .90: The results of building wind catcher modeling in Fluent software (<http://zero-energy.ir>)

3.5.3.1.2. Electrical Installations

The electrical design of building has been driven by a reduction in the demand of electricity and the benefit of renewable energy implementation. The building lighting

requirement has been reduced with the architectural design and there are requirements for the maximum benefit of natural lighting in architecture. Building lighting design is done with these considerations and using Dialux software by specifying the type of user. Based on this, the lighting power of the building is estimated to be 5.5 W / m^2 , which is approximately 50% less than the limits, set in the IECC code. LED lighting equipment is chosen, which in addition to reducing the power of light is compatible with photovoltaic equipment. Photovoltaic (PV) equipment is used to provide electrical power to the building. In addition to providing building support, the PV system also has the ability to sell electricity to the grid in the time of vacancy. By using PV syst software, the energy generated from solar equipment planned to be used in peak time and to be sold to network in low-energy demand time (holiday days, etc.) (<http://zero-energy.ir>).

Considering different type of building usage and the fact that the building's energy consumption is largely influenced by the operation, management and system performance, net energy consumption of the building, with having a 10% confidence coefficient is positive.

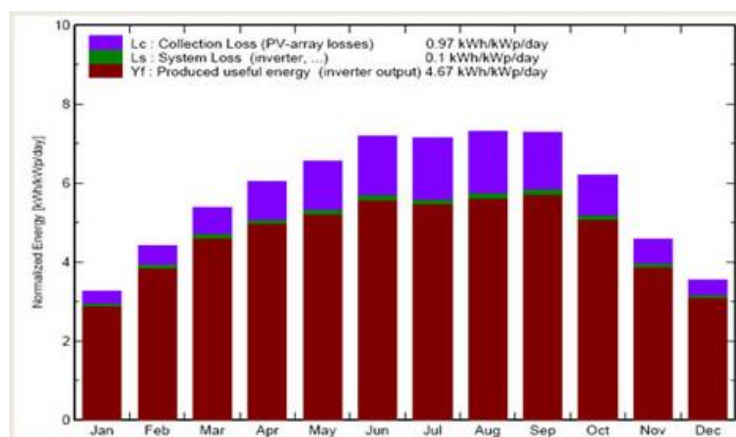


Fig .91 : Calculations results in PV system (<http://zero-energy.ir>)

3.5.3.1.3. Mechanical

Implementation of proper architectural strategy, the thermal energy demand of the building has dropped by almost 85% compared to a similar conventional building and reached 67kW, which is generated by renewable energy. Therefore, with feasibility studies in the region, based on climate information and taking into account the economic constraints of the project, the supply of thermal energy and hot water consumed by solar energy is considered. For this purpose, with the solar system modeling in the TSOL software and performing calculations, solar collectors have been installed on the roof of

the building to obtain solar energy. Acquired thermal energy storage is carried reservoirs. Also, a reservoir used to supply hot water. Using the model provided in IES software, the simulation of collector position on the roof is designed to have the least amount of shading on each other.

Fresh air is supplied through heat recovery through the use of heat accumulated in the atrium. In order to prevent quality loss of comfort, 2 duct fans are installed on the atrium air exhaust, which, in the event of a cloud, is supplied through the BMS system inside the circuit and provides a suitable temperature for fresh air. The thermal terminals of the building are considered as panel radiators. The reason for this choice is the type of building used intermittently. Therefore, the plant system should have a low inertia and, in addition, it should be fitted with a solar system. (<http://zero-energy.ir>).

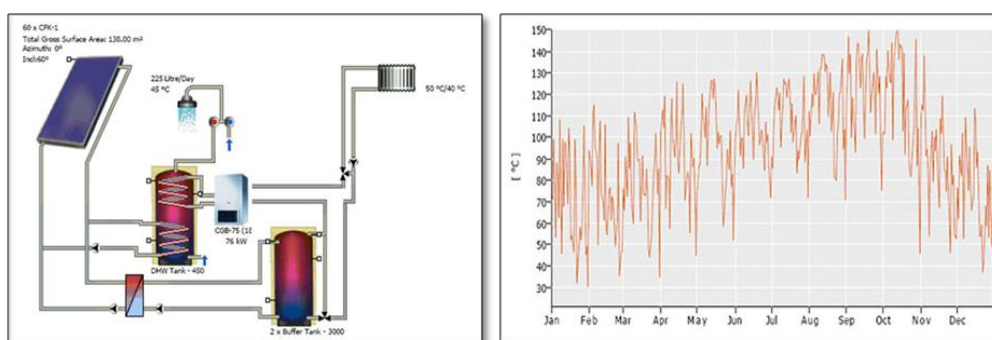


Fig .92 : Layout of system components and maximum collector surface temperature based on tsol calculations (<http://zero-energy.ir>)

		Description
Architectural	Stretching and orienting the building	<ul style="list-style-type: none"> -astern-western stretching -more usable spaces is located on the south side -lacing low spaces on the northern front of the building -he placement of service spaces in the east and west and in the basement

	<p>Spaces Location</p>	<p>-design spaces with high thermal requirements on the south side</p> <p>-Design spaces with low heat requirement on the northern side.</p> <p>-Design highly traffic spaces on the ground floor and close to the entrance.</p> <p>-the placement of spaces with low traffic in the areas far from the entrance or the first floor</p>
	<p>Insulation</p>	<p>The energy demand of building reduced 40%</p>
	<p>Canopy</p>	<p>Use a horizontal canopy with a depth of 40 cm</p>
	<p>Atrium</p>	<p>-the amount of energy required to supply fresh air is reduced to 49% and equals 8.11kqh / year</p> <p>-Decreasing 30% of the total heating needs of this building over a year.</p>
	<p>Wind catchers (Badgir)</p>	<p>- to ventilate the corridors of the building in the middle seasons</p> <p>-two wind catchers in this building, one as input and the other as an air exhaust</p>
<p>Electrical</p>	<p>- low demand Electrical equipment which is adoptable with solar system</p> <p>-Decrease artificial light and increase natural light in the building</p> <p>-Use photovoltaic system in buildings to reduce energy consumption</p>	
<p>Mechanical</p>	<p>-Use of solar flat collectors to supply of thermal energy and hot water consumed</p> <p>-In order to prevent the loss of quality of the comfort conditions in the cloudy weather conditions, two duct fans are installed on the outlet of the atrium, which provides a suitable temperature for fresh air.</p>	

Tab. 12: Sustainability in zero energy building(by the writer)

CHAPTER 4: CONCLUSION

Conclusion

Vernacular and traditional architecture style in hot and dry region of Iran is one of the richest examples of sustainable architecture. It has been designed and implemented based on the local characteristics of the area and has taken into account all social, climatic, cultural, geographic and environmental factors. It has been very successful in sustaining and respecting nature and maintaining energy resources. Different kind of climatic architecture solutions which was previously had implemented in this climate, prove the idea of sustainability in social, economic, and environmental aspects. The climate condition in hot and dry region of Iran is intolerable according to huge variable temperature up to 60 degree between day and night temperatures in some areas. For example city of Yazd had experience maximum 50c in summer and minimum -13 in the winter. Therefore, compatible architecture design with the climate is of vital importance for reducing energy consumption. Not pay attention to this fact, the building needs a lot of energy for cooling during days and consume a lot of energy for heating at night, which will result in high energy consumption during the year. According to the existing conditions of traditional and vernacular buildings and existing evidence, buildings are designed and built as part of a nature-friendly environment with the least energy requirements. This type of architecture is still using in many cases. Although still feeling lack of proper documentation. poverty of detailed studies and expert reviews is a major weakness about these achievements. But in many case it is proved as a sustainable and eco-friendly architecture style according to undeniable adaptability to environment and human comfort.

In terms of environmental aspect, ancestors always use local material like clay, straw, brick and wood for the building which are almost reusable and are completely environmental friendly and recyclable. Accordingly they had prepared pleasant living space by benefiting from advantage of passive form of design and energies with implementation of valuable vernacular patterns that was not considerably dependent to other source of energy like fossil fuel, gas or electricity for heating, cooling and ventilation purpose. Dependency on active energies is one of the main reasons against sustainability idea due to its effect on global warming, air pollution, water contamination by over extracting of natural resources.

Economical aspect in traditional architecture investigated in two directions. First they prepared comfortable living space by applying creative and smart architectural permanent solution which had very low operation cost or had no operation cost in the time which fossil fuel or any kind of energy was not been easily accessible in all regions . Second with help of local architecture, they was independent from out sources materials and it caused low life cycle cost for building and had been reduced many unnecessary costs.

Industrial Revolution and fast growth of urbanization, contemporary architectural imitation from modern and west architecture style regardless of climate and environment considerations are the reasons which vernacular sustainable architectural patterns and concepts to be forgotten. Consequently Building typology and materials used for construction changed to modern style and passive architecture design is replaced by active design which need huge energy consumption by mechanical equipment for heating, cooling, ventilation and lighting to provide a comfort living space. As a result not only it is generating higher cost for using active energies but also causing environmental contamination, global warming, huge water and electricity consumption and dependency to foreign materials and technologies. By change of construction styles buildings became considerably dependent on fossil fuels and change to a major energy consumer sector in country. Unfortunately, in Iran contemporary architecture style, new buildings currently consume about 3 to 5 times higher energy than industrial countries for electricity in hot regions and fuel consumption in cold regions which cause irreparable environmental and economic losses (tabesh, Economic energy saving assessment through thermal insulation of buildings). Comparison of the annual energy consumption between a traditional building and a new building with a common style in hot and dry climate showed that the energy consumption of the newbuilding, taking into account all climate and building considerations in simulation, was 3.5 times higher than traditionally style building. Low energy demand in traditional building achieved according using valuable traditional and vernacular techniques. According to the studies, it can be concluded that contemporary architecture and most common present architecture style unlike traditional architecture use huge amount of energy sources according due to the cheapness of different types of energy, wrong culture of energy consumption, no enough attention to appropriate climatic design, implementation of inappropriate material, lack of precise supervision and execution of non-standard construction details and imitation from foreign architecture styles. Therefore contemporary architecture of Iran is far from sustainability concept which is a very tangible point.

Although our traditional architecture is a valuable and rich architecture, in the contemporary era, just imitation of traditional architecture is not feasible, and only meaningful concepts can be used and considered in design. study show just by appropriate design consideration and proper use of material and appropriate implementation of vernacular architecture ideas and techniques in a modern way not only energy consumption of building will decrease enormously but also it can help to present and prove sustainability idea. Considering above mention items In addition to utilization of solar energy generation in building, the idea of zero energy building easily is achievable in hot and dry region according to high potential of sun radiation.

This research first explores and presents the concepts, patterns, and techniques used in traditional architecture as a model of sustainable architecture. Then, the attempt has been made to introduce these concepts and solutions for implementation in contemporary architecture in order to achieve sustainability as much as possible.

Therefore paying attention to main principles of passive energy design in hot and dry regions during building life cycle from design, construction, renovation and demolition is significantly essential. These principles stated below as it was explained in detailed in pervious chapters

- Selecting best Building's orientation and stretching for optimum energy performance.*
- Using energy efficient multi-layer glazed and selecting windows frame with low thermal conductivity to minimize energy lost.*
- Optimum design of windows to wall ration in each building direction to attract maximum light entering to the building to decrease heating demand in winter and optimum design on canopies to prevent sun radiation coming inside during hot summers to decrease cooling energy demand.*
- Paying attention to sealing and insulating of windows frame.*
- Use of appropriate type of thermal insulation layer for building envelop to minimizing energy lost (roof, floors and walls)*
- Using light color and reflective material with low thermal conductivity to minimize heating absorption of building mass due to strong sun attraction in summers*
- Use of porous building materials in the walls to minimize heat transfer to the building.*
- Implementation of local material with low heat transfer coefficient and insulation layer instead of high depth walls to reduce the heat transfer of the external environment inside building as well as increasing the latency of the transferred heat. For example new type of bricks with low thermal conductivity.*

- *Selecting Interior space lay out according to importance of usage*
- *Passive thermal Design will help reduce energy demand of building and air conditioning system like atrium*
- *Utilization of efficient Heating and cooling system*
- *Utilizing the potential of solar energy to generate energy according to ideal solar radiation conditions in hot and dry areas of the country.*
- *Paying attention to design green space to increases the relative humidity and shading in the environment and consequently decrease cooling demand in hot summers*
- *Special attention to court yard design for better air circulation and provide pleasant place fin hot summers*
- *Design wind catcher as complementary of air conditioning system by natural air circulation*

Results of utilization of some of the above mentioned issues in contemporary architecture:

- *total energy consumption of contemporary building can be reduce up to 20%, only by the optimum design of the windows and canopies of a building in each direction*
- *the heating demand of the building according software simulation could be reduced around 17% by using double glazes windows and decrease up to 39% by utilization of triple glazes windows instead of single-glazed windows.*
- *Energy consumption in the north, south, east and west fronts of building fell down by 13, 14, 11 and 12.6 percent only by replacing metal frames with UPVC type in all fronts.*
- *Other studied shows by insulation of exterior walls, building energy consumption reduced by 11.7 and by implementation of smart electrochromic glazes building energy consumption reduced by 27.3 percent as well. In addition by simultaneous insulating walls and using electrochromic glasses, the energy consumption of the building can be reduced up to 46.3%.*
- *In a real case (zero energy building) only by Implementation of some architectural strategy, the thermal energy demand of the building has dropped by almost 85% compared to a similar conventional building. The total energy demand of building supplied with photovoltaic panel which had designed in roof. Items had been considered in design are as follow:*

- *Stretching and orienting the building*
- *Spaces layout in the building*
- *Insulation in a zero energy building*
- *Implementation of canopy on the south side of the building*
- *Use of the atrium to provide fresh air during the heating of the building*
- *Use the wind catcher in the building*
- *Electrical and mechanical Installations*

The research shows by consideration of climatic design and paying attention to valuable traditional concepts and ideas for utilization in contemporary architectures, utilization of certified local material, minimizing energy consumption of buildings easily is achievable. Also, due to the geographic location of hot and dry region of Iran and availability of solar energy in more than 80 percent of the days of the year, providing the energy required of the building easily is achievable by solar inactive systems. Consideration of above items in building life cycle could help to retrieve the concept of sustainable development in contemporary architecture.

Building Sustainability aspect can be achieved are mentioned as follows:

1- Economical aspect:

- *Reduction of energy consumption will decrease cost of building operation due to decrease building energy demand.*
- *Building energy demand will reduced and consequently lower demand for extracting fossil fuel will be required which will help government to reduce many costs.*
- *Energy-saving revenues can be used to sustainable development of the country and infrastructures.*
- *High potential of electricity generation from solar panel systems can help families in economic aspects.*
- *By maximum utilization of energy efficient local material instead of imported material in building lifecycle significant economic saving will be achieved.*
- *By encouraging material producer to improving quality of energy efficient local material, the production cycle and the domestic economy will be strengthened.*
- *Passive houses or low energy building will have minimum dependency on HVAC systems and consequently require minimum operation costs.*

2- Environmental aspects:

- *Low energy buildings will decrease speed of global warming by lower energy consumption and production of lower co2 emission*
- *Low energy buildings will require low energy demand. Consequently less fossil fuel demands needed for extraction and air, water, ground and environmental contamination will reduce during extraction and transportation.*
- *Buildings made of local and natural materials has the least environmental damage to the nature*
- *Buildings made of local and natural materials at the end of life cycle can be recycle and reused without malicious environmental effect*
- *The view of city will be more compatible with environment*

3-Social aspects:

- *Less dependency on non-local and imported resources*
- *Maintain and promote the style and tradition of the vernacular sustainable architecture*

Hope that architects and construction industry professionals can take advantage of the sustainable architectural ideas which had used in traditional architecture with climate considerations in the building life cycle, in order to preserve the tradition of vernacular architecture and enhance the quality of contemporary architecture.

Declaration of Authorship

I hereby declare that the attached Master's thesis was completed independently and without the prohibited assistance of third parties, and that no sources or assistance were used other than those listed. All passages whose content or wording originates from another publication have been marked as such. Neither this thesis nor any variant of it has previously been submitted to an examining authority or published.

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