Learning from the past in Today’s Architectural Design

Case Study: Architecture in hot and arid zone of Yazd in central Iran

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“Non Lasciare che il Rumore delle Opinioni degli Altri Offuschi la Vostra Voce Interno”

Steve Jobs
ABSTRACT

This thesis, researches traditional housing in city of Yazd, Iran. There are two objectives on this research work. Firstly, vernacular elements used in traditional houses in central Iran and, in particular, courtyard houses in Yazd will be investigated and analyzed in relation to contemporary Iranian design. Secondly, the broader social context of housing in Iran will be explored with a view toward sustainable development and improvement of local architecture. Additionally, this study will explore the social and environmental bases of the traditional Yazd house. In order to develop a cohesive understanding of contemporary issues in Iranian design, a variety of resource materials will be drawn on, including journal articles, reports and books.

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INTRODUCTION

Statement of the Problem
Nowadays some of the important issues of the world scientific communities are the discussion on the sustainable development, saving the non-renewable energy and the sustainable architecture. Undoubtedly the irregular use of non-renewable sources such as the fossil fuels, will jeopardize the world’s environmental situation in the near future. More than one third of total consumed energy has been used in the buildings section, so with this high demand of energy consumption, there is no hope for preserving energy sources for the future. Lack of energy resources emphasize the importance of reaching the sustainable architecture.

The main part of the non-renewable sources have been consumed. It is predicted that the price of fossil fuels continues to rise in the next years, therefore, the idea of the zero energy building has been formed in order to meet the energy needs of the current century and is used for removing the energy related concerns in the current era. Indeed, human hope to accomplish the creative ideas such as zero energy building, neutral energy building or independent building for many years. By using modern technology the biggest human dream, preserving energy resources, can be achieved.

Iranian traditional architecture as one of the best sample of the sustainable architecture, represents the effective usage of non-renewable energies based on the climate region in the past. The ancient Iranian architecture indicates the experience of the Iranian in using the non-terrestrial (non underground) natural energies such as the energy of the sun, wind, water and etc. The different geographical and climatic situations have been integrated with the penchant and intelligence of the past people for using the natural energies in order to form the unique patterns of the Iranian traditional architecture. Today, it is possible to utilize the past experiences and restoration of those traditional patterns which have been forgotten in the current era, in order to meet the climatic needs of each region and decrease the consumption of the fossil fuels.

In this thesis, the country of Iran and its vernac-
ular houses have been investigated as the most notable samples of "adjusted architecture" per climatic conditions. In this thesis, the hot and arid climatic region of Yazd has been investigated. According to the investigations, the usage of the correct materials, accurate identification of the climatic specifications of each region and its related facilities can lead to creation of the appropriate spaces in order to meet the air conditioning and minimize the consumption of non-renewable energies.

In this thesis, the renewable energies in the passive houses and zero energy buildings have been investigated. Meanwhile, it has been attempted to use the new materials and technologies and traditional experiences in the new building complexes as part of the solutions in decreasing consumable energy and expenses in the houses.

Methodology
This thesis relies heavily on textual research. Additionally, the data collected during a research trip to Yazd on May 2016. The data includes field observations recorded by the author, research of various materials in local libraries, and conversations and interviews with local academics.

Central Iran's distinct and relatively constant climatic conditions are rarely factored into the designing of modern day structures. As a result, large-scale commercial and residential construction practices tend to produce buildings that are inefficient and out of sync with local climatic needs. Yazd is among Iran's oldest cities with a rich architectural history. The city's local architecture, along with concepts, ideas, and values rooted in Iran's architectural traditions served as a major impetus for this work. The methods of traditional Iranian architecture can be used to meet contemporary needs. While sustainable energy and development is a key priority, the architectural values and town planning of old Yazd cannot be sacrificed. Sustainability and development will be integrated in such a manner so as to retain the city's essential character. Sustainable development, therefore, can be attained by integrating traditional architectural concepts and values with current technology.

To be clear, this thesis does not argue against development, which would be futile. Instead, it seeks to temper it by promoting and understanding of development that is guided by a consideration of the local environment and social context. A more sustainable and context-based approach to development can still include high-rise apartment buildings and high-density, lower incoming housing complexes. When these development types are in the design phase, consideration must be given to the local environment, wind and solar issues, and privacy concerns. Such an approach to development would be a marked departure from normative standards as it would attempt to maintain a connection to the Iranian and environmental context.

Purposes
1. Identification and interpretation of the traditional architecture in Iranian hot and arid climate and identification of the traditional and modern sustainable architecture (case study is the city of "Yazd" in Qajar period 1795-1925).
2. Investigation of the zero "energy buildings" and "passive buildings" and also investigation and identification of the type of usage in the reproducible energies such as water, wind and sun in the buildings.
3. Comparison between the Iranian traditional architecture and sustainable contemporary architecture of Iran and the world.
4. Method of utilization and the specifications of the Iranian traditional architecture in designing the current architecture, specially in the hot and arid regions of Iran for better living and saving of consumption in the non-renewable energies and decreasing the pollution.
Research Question
The main issue and questions of this research are as follows:
1. Can the renewable energies be used in the modern building instead of fossil fuels?
2. Is it possible to design and implement of the building which followed the sustainability principles according to the Iranian traditional architecture?
3. Is the usage of renewable energies in the current buildings affordable and economical?
4. Are the zero energy buildings and passive buildings useful for the humanity and future generations?

Research Hypotheses
1- Regarding to the specifications of the Iranian traditional architecture, the sustainable principles can use in new buildings.
2- Utilization of the renewable energies in the current buildings is effective economically.
3- Utilization of the modern technology and appropriate materials can lead to appropriate social, cultural and peripheral environment.

Keywords

Thesis Organization
In this thesis, the architecture of the past, present and future time have been investigated.
In the first chapter, the warm and dry climate and the case sample of the city of Yazd have been investigated.
In this chapter, the traditional houses of this city in Qajar period (1795-1925) have been studied regarding the materials, technology, design, form, building direction, height and other components of the central yard buildings in order to demonstrate the effect of simple and accessible techniques of the Iranian architecture in making the sustainable spaces in the Iranian traditional houses.
Meanwhile, the Case Studies of the investigated houses were Gerami house, Golshan house and Lari house.
In the second chapter, at the beginning, the renewable energies and the reason of their usage at the present period, and at the rest, the sustainable houses, zero houses and passive houses in the contemporary architecture of the Iran and the world and the advantages of their construction have been investigated in order to identify some solutions including the utilization of the traditionalal technologies in their modern form for using the renewable energies such as the wind, water and solar energies in the buildings.
In the third chapter, firstly the Iranian contemporary architecture and the entrance of the traditional architecture in contemporary architecture have been investigated by describing some case studies of the Iranian architects’ works such as Mirmiran Seyed Hadi and Diba Kamran. Secondly, the world contemporary architecture and the emergence of the tradition in contemporary architecture have been studied regarding to the architecture of Louis Kahn and his student Venturi Robert.
In the forth chapter, the usage method of the renewable energies such as the solar energy, wind energy and etc. through the application of the modern technologies and new materials and architecture in the modern buildings and specially in the highest ones have been investigated.
Moreover, some high towers such as the high-rise buildings and their samples such as Agbar Tower in Spain have been studied.
At the first part of the fifth chapter, the Discussion then, followed by the findings of this research have been explained. Afterword a general conclusion of its studies have been presented. Meanwhile, at the end of this chapter, some solutions and suggestions have been presented for improvement of living situation of the present and future people in the desert town of Yazd.
CHAPTER ONE

Traditional Architecture, Yazd, Iran

“When the full power of human imagination is backed by the weight of a living tradition, the resulting work is far greater than any that an artist can achieve when he has no tradition to work in or when he will fully abandons its tradition”

(Fathy Hassan, 1973, p.25)
TRADITIONAL ARCHITECTURE, YAZD, IRAN

Identity and organizing are the manifest specifications of the Iranian architecture which are deeply rooted from the cultural and social foundations and principles and are accepted as a principle in Iranian Architecture. Some of the Iranian traditional architecture analysts believe that the formation of this type of architecture was only due to the special climatic and geographical situations of the area. But if we want to consider this subject precisely and scrupulously, we can understand that regarding to the inner, intrinsic and introverted issues, there are the specific lifestyle, traditions, customs and world view which have been formed based on the culture and they have achieved to their evolutionary form along with the environmental and geographical issues.

Anyway, valuing the personal life and respecting to that led to the build of Iranian past houses in the introverted form and made the central yard as the indicator element in the architecture of the Iranian houses. Therefore, introversion has the stable meaning and content in the Iranian architecture through these elements. Perhaps, it can be stated that the most obvious human architecture appearance is house and house construction. In the past, the common word of “house” was used in order to refer to the room and the word “Sara” was used instead of that word for referring to the house. In the community which relies on family strictly, the concept of “house” is more extensive than an absolute private place. The architecture of Yazd in comparison with its surrounding cities is such as the magnitude of the capital of a country compared to the other cities. Although, there are some similarities in using some of the Yazd architecture elements in surrounding cities but in Yazd the conversant architects have worked on these elements during the time and totally each elements have reached to the high degree of the development and extension.

From the historical perspective, each of this element has a long history. In the history book of the Yazd, the different elements of the house have been mentioned such as roofed pavilions, spring house, Paiab, wind catcher, Tonbi, alcove and wooded gardens in beautiful shapes. Meanwhile, in the book “Jame-e-Jafari, there are the names of elements such as Tehrani, pergola, Sabat, Fakhr-e-Madian, Talar-e-Ayneh and Hashti.
Iran

The country of Iran, previously known as Persia, and the name Iran was adopted in 1935. Iran is located in the northern hemisphere a region of Asia known as the Middle East, which is a geographical region of South-west Asia. The official language spoken in the country is Farsi (Persian) and the capital City is Tehran (Oxford Dictionary). The central Iranian city of Yazd is the main focus of this thesis. Countries that share a border with Iran include the Republics of Azerbaijan and Armenia in the northwest, Turkmenistan in the northeast, Turkey and Iraq in the west, and Afghanistan and Pakistan along the east. Large bodies of water along the Iranian coast include the Caspian Sea in the north, and the Persian Gulf and Oman Sea along Iran's southern coast (Norouzi Talab, 2011, p.11-15). The Iranian plateau is located in the country's central and eastern parts. Iran's two major deserts are Kavir-e-Namak and Kavir-e-Lute, and both cover large expanses of land in the country's east (Mares. 1999, p.302).

Iranian Architecture

Architecture in Greater Iran has a continuous history from at least 5000BCE to the present, with characteristic examples distributed over a vast area from Syria to North India and the borders of China, from the Caucasus to Zanzibar. Persian buildings vary from peasant huts to tea houses, and garden pavilions to “some of the most majestic structures the world has ever seen.” Iranian architecture displays great variety, both structural and aesthetic, developing gradually and coherently out of prior traditions and experience. Without sudden innovations, and despite the repeated trauma of invasions and cultural shocks, it has achieved an individuality distinct from that of other Muslim countries. Its paramount virtues are several: a marked feeling for form and scale; structural inventiveness, especially in vault and dome construction; a genius for decoration with a freedom and success not rivaled in any other architecture.

Traditionally, the guiding, formative, motif of Iranian architecture has been its cosmic symbolism by which man is brought into communication and participation with the powers of heaven. This theme, shared by virtually all Asia and persisting even into modern times, not only has given unity and continuity to the architecture of Persia, but has been a primary source of its emotional characters as well. Traditional Iranian architecture has maintained a continuity that, although frequently shunned by western culture or temporarily diverted by political internal conflicts or foreign intrusion, nonetheless has achieved a style that could hardly be mistaken for any other. In this architecture, there are no trivial buildings; even garden pavilions have nobility and dignity, and the humblest caravanserais generally have charm. In expressiveness and communicatively, most Persian buildings are lucid-even eloquent. The combination of intensity and simplicity of form provides immediacy, while ornament and, often, subtle proportions reward sustained observation. Iranian architecture is based on several fundamental characteristics. These are:

- Introversion
- Structure
- Homogeneous proportions
- Anthropomorphism
- Symmetry and anti-symmetry
- Minimalism
History of Yazd

From observation while visiting Yazd it is a city of narrow alleyways and introverted houses. The city is blanketed by a beige color that reinforces its traditional architecture. A visit to Yazd is a unique experience as the city seems almost frozen in a bygone era. Despite its age, the city feels strong and robust and is enveloped by a calming sense of harmony. Long narrow alleyways with arched roofs leading into introverted courtyard houses shield residents from scorching temperatures. The arched roofs create pockets of shade that comfort locals and visitors meandering on foot throughout the city. The design of the old city seems to be in synchrony with nature and climate. As one moves toward Yazd’s more modern quarters, one increasingly feels a sense of displacement. Khademzadeh A, has also praised the city for having preserved its ancient traditions, culture and unique architectural style while expressing concern about the strain of modern development. Khademzadeh’s concerns are shared by those who fear their city’s unique culture and history are at risk.

The architecture of the Yazd city and the process of the house formation

Some part of the most beautiful world deserts are located in the center of the Iranian plateau and the Yazd province encompasses its central part. The Yazd city is known as capital or jewel of the desert. Since the desert and Yazd are not separated from each other, there is a close link between the desert and its architecture. In the Yazd and its surroundings, everything is made of mud and its derivatives. The architect could not think about anything except for this and use another materials, since he knows that nothing else can take its place even if the stone or wood found near him. In this region, the life is combined with the dust and mud.

Basically, the house is considered as the shelter but its design is the mirror of existing thoughts about the space, aesthetics, traditions and the culture of the people. The main place which much of the human life is spent in is the house, therefore, a lot of human needs are met at the house. Hence, the house should be organized such that be responsive to the human essential needs. Therefore, the Iranian house is divided into the internal and external parts.
The relationship between the architecture and climate

Architecture is a consequent and combination of the cultural elements and the related and resulted factors from the beliefs and worldview of the community. Indeed from the beginning, the architecture affects on the human but its effect is gradual and continuous so that the room which the human lives, forms and represents the spirits, beliefs and identity of the human. Architecture is belonged to the culture and can be understood in the background of the history, beliefs, traditions and native traditions. Without recognizing these backgrounds and the natural and climatic effects and native traditions, the background of the history, beliefs, traditions belonged to the culture and can be understood in this concept, the architecture can not be recognized and the architecture is devoid of identity. The link between the architecture and the climate is such as the relationship between the newborn and the arms or the relation-ship between any plant to the dust which is the evolutionary and inspirational dependence rather than environmental. In this concept, the arms, dust and climate are the connectors of the life and vitality and their absence is the symbol of attenuation. The experiences of the native architecture in the world and its experiences in the Iranian architecture, are the injunctive witnesses of the thought of formation in the climatic considerations in the architecture. The native architecture is twin with the people and compatible with the environment. The different amount and various combinations of the climatic factors which are resulted from the difference of the geographical positions of the different regions make the different climatic areas in the world which each of them has its own specifications. The environment, cities and even the buildings of these climatic areas achieved their own specifications in accordance with its climatic conditions. There are some effective climatic elements such as sunlight, moisture and the wind which among them the sunlight which makes the natural light and temperature is considered as the main element.

Hot and Arid climate (Yazd)

Hot and arid climate is the second great climatic group in the country. The geographical area of this climatic zone have expanded mainly in the central parts of the country as a strip at the south-west of the country (South-western slopes of the Zagros Mountains). The diversity of the latitudes and heights of the different points of this climatic zone is very much. In this zone, there are similar weather conditions in the most northern and most southern points of the country, for example in “Dargaz” which has been located at the most northern part of this region (latitude of northern 37°) with the height of 500 m above the sea level and “ Neiriz” which has been located at the most southern part of this region (latitude of northern 29°) with the height of 2100 m above the sea level are the lowest and highest points in this group respectively. The weather conditions of all climatic sub-groups of this group are relative cold in the winter and semi warm and arid in the summer. The thermal conditions of the weather in the winter, make many possibilities for using the solar energy in heating of the building, therefore, in all sub-categories of this climatic zone, the annual percentage of using the solar energy is more than the percentage of the another needs. In this group, because of the low relative humidity of the weather specially in the warm season in all climatic sub-categories, the thermal conditions of the interior spaces in some parts of the warm season can be controlled by using the heavy constructive materials.

Importance of the building form in the hot and arid climate

According to the winter conditions of these areas, the form of building can be expanded through the east-west axis. But the summer conditions lead to building density and necessitate the cube-shaped form of the building. Anyway, with cutting a part of this cube and filling the hole with shadow (shadow of the wall, tree, ivy) and the cooled weather resulted from the evaporation of the water of the grass and the leaves of trees, pool and fountain, it is possible to create a relative pleasant climate inside the building. Around this interior garden, the plan of the building can be free. Therefore, the general plan of building in these areas directs toward the inside. So the building form which is suggested for the hot and arid areas is the well-known and beautiful Iranian traditional buildings which has been repeated from the prehistory duration until now not only in the Iranian interior areas but also in the arid areas of the Middle East. The old courtyard buildings are the best form and possible combinations of the components of the building in order to adjust the climate. The rooms of these houses which are opened just into the yard, are protected against cold of winter, wind and sand storm which are...
usually in the desert areas. In the winter, the south-facing rooms and in the summer, the north-facing rooms of this collection are used and the place of life will be harmonized with the climate. The inside yards which include the tree, pool and green surfaces of the plants are the most effective humidifiers in the arid weather of these areas. In the night, the cold air near the roof moves toward the down and remains within the yards and the bodies of the walls. Therefore, it decreases the maximum temperature of the air inside the yard in day. Hence, in day when the temperature of the outside air and sunlight reach to the maximum level, the inside air of the building will be moderate relatively. The general specifications of the building form in these areas are as follows:
1. All the building are enclosed and toward inside.
2. All the buildings except the bathrooms include the central yard and most of them have the basement, porch and wind capture.
3. Buildings roofs and specially the yard are lower than passages.
4. The height of the rooms are relative high.
5. The roofs are often arched and domed.
6. The walls are relatively thick.

Such as the urban spaces which are restricted and protected against the natural unfavorable conditions, the buildings and the yards have a close fence and controlled climatic environment. This is true about all the buildings of these areas including the commercial, religious, services and residential buildings.

As mentioned before, the oscillation of the temperature of this area is very much and the amount of humidity of the air is less than the human comfort. Meanwhile, the sunlight and its temperature in the summer create a hot environment and the desert dusty winds which flow in most of the days of the year are disruptive. Hence, construction of a central yard at the middle of the building, installation of the pool and creation of the small garden, increase the moisture of the environmental space and the adobe and brick walls which are constructed with the relative high thickness in order to tolerate the heavy load of arched and domed roofs, decrease the oscillation of the air temperature in day and night such as a thermal capacitor.

With installation of all openings toward the relative mild and humid space of the yard and blocking the external walls of the building except the entrance door, the relationship between the inside life space and the external space has been disconnected as far as possible and a small and suitable climate has been created for the comfort of the human within the hot and arid climate.

Vernacular Iranian house/ Four seasoned houses (Chahar fasl)

The conformity of the life styles with the climatic conditions is one of the most important specifications of these areas. An obvious example of this can be seen in the introvert houses of these areas which are called four seasoned houses (vernacular house). For doing this, the northern part of the yard which the oblique sunshine of winter shines on it and has more heat is the winter domicile and is called “Panah” which most of the activities of the household are performed in this part of the house. In the summer, contrary action takes place and the southern rooms of the house which are cooler and have been located in the shadow are the domicile of the household. This part is called “Nesar” which means shadow catcher and cool and most of the time the basement or the cellular locate in this part. In the warm seasons, the temperature of the cellar is less than other parts since it is in the basement. For example, in the house of “Borojerdiha” at the 11:30 AM of the 25 of September, the temperature of the air in the alley, yard and cellar were 36°, 32° and 24° respectively. When the air temperature was very high, the household went to the cellar and used its cooler air. In some houses which the branches
of aqueduct passed under them, there was a way from the cellar into the aqueduct for accessibility to that. Sometimes, the water of the aqueduct entered into the small pool and existed from another part. The place of that room is called “Hozkhaneh” (spring house) which the water pool and entrance channels of the wind capture lead to increase the moisture and coldness of this space.

Usually the height of the summer domicile is high in these buildings in order to rise hot air to the up and the cooler air be replaced instead of that in low level of the room. The wind captures and ventilators are often at the southern part of building in order to better air ventilation. Eight side wind captures of the home “Borojerdiha” have the way into the main room of the house which is the hall of the ground floor and also to the cellar which is under it in the part of summer domicile. The holes on the dome of the hall work as a wind capture from the wind flow and as the ventilator from the opposite side which can be considered as an effective assistance for the comfort of the household in the warm seasons.

The hall of summer domicile part of the traditional houses of the Yazd such as the home of “Lariha” and the home of “Rasoulian” are totally open from the side facing the yard and the door of these houses and the entrance channel of the wind capture are located in the rear of the hall or in the side of its two adjacent faces.

The kitchen and the warehouse are in the corners and in the parts of home which have not the direct relation with the yard and the light and ventilation is low on there. The fuel which was used for cooking was the firewood. For air ventilation of the kitchen, the roof height of this space was very high and there was a circle-shaped vent with the diameter of about half a meter at the top of the dome or the roof of the Kitchen. The required light of the kitchen was prepared from this vent and other roof vents.10

The water pool and plants in the yard, compensate the shortage of the air moisture and in addition to creation of the shadow, increase the air delicacy. All the openings and entrances of the rooms are opened into the yard and the space which leading up to there. The yard is considered as the relational space between all parts of the house. Approximately, none of the window enters to the out of house and the only opening which is related to the out is the entrance door which is related to the yard through the relative long cor-

![Figure 7: Lari House, Yazd, Iran, Source: www.makanbin.com](image1)

![Figure 8: Rasoulian House, Yazd, Iran. Source: www.pichak.net](image2)
idor and “Hahsti”.

In most of the house, there was a big wooden bed in the yard. In summer, the family watered the small gardens in the evening and sunset and sprayed the water into the yard and different activities such as sitting together, eating, sewing and other works were performed on this bed. In this time, the family spent their time in the yard and its cool and moderate space. Also, in the night, they slept on this bed but sometimes the family slept on the roof during the night and specially dawn which were cooler than another parts of the house.

The level of these houses are lower than the natural surface of the ground and alley such as the similar houses. Lower level of the yard than the level of alley has 4 advantages:

- The water of Qanat or the creek which flows in the streams at the same level as the streams of the alley, naturally enters to the garden, small garden inside the yard and if the reservoir be in the basement, the water enters to the water reservoir.
- If the quality of the excavated soil be relatively good, it is used for making the bricks and constructing the building.
- By locating a part of building inside the ground, the temperature exchange between the inside and outside is decreased and the oscillation of the temperature degree will be reduced.
- Building foundations and the total building are more resistance against the earthquake force.

The depth of some yards were more than normal level in order to access to the aqueduct which passed under the yard for watering the garden and small garden. These yards were called the “hole of garden” or the “hole of small garden”. It should be noted that the extent of the house and number of its yards depended on the financial ability and social position of the man of house. The home of poor people barely had some rooms and probably more than one yard but the house of relative rich persons included two yards, the outer yard for men, strangers and performing some of the business affair of the man of house and the inner yard for women and intimate persons. The house of emirs and rich persons had more than two yards which finally reached to the 6 yards and each of them had its own specific application. Another 4 yards included the yards of stalls, servants, eunuchs and orangery.

The yard of stalls was usually near the entrance door of house in order that people can enter to another parts of the house after transmitting the live stocks to the stalls. The yard of the servants as its name represents, was belonged to the living of the servants. The yard of eunuchs was constructed near the inner part of the house and it was the living place of the harem eunuchs and finally the yard of orangery was a relative small and decorative yard which the citrus fruits such as sour orange and orange were planted in its small garden. In some cities such as Yazd which the weather is cold and the average of the annual number of the frost days is 56 and 69 respectively, in the winter, in the night and in the case of frost, they covered the yard of orangery, therefore, they always enjoyed from the freshness, beauty and observation of its evergreen leaves.

Figure 9: Golshan House, Yazd, Iran. Source: www.pichak.net

Figure 10: Adaptation of principles of Sustainable architecture and Traditional architecture of Iran. Source: Hadi Shahamat
Architecture, Technology, Material of Traditional Houses
Yazd and the architecture of its traditional houses

The houses of the Yazd in despite of the intense heat of the summer, scorching desert winds and the winter penetrating cold, have such specifications in both seasons which can present the comfort and pleasant air to their inhabitants since from many years ago, the Yazd architects regarding to their conscious recognition from the climatic conditions and weather of their land, selected the materials for constructing the houses and other architecture spaces which are used for living with specific precision.

In most of the houses and in front of the entrance which locates at the corner of the yard or beside one of the small side of space, the main five door hall locates which sometimes there is a sash in front of that and sometimes this space is open and it seems such a porch-like hall with a sash in front of that and sometimes this space is five door hall locates which sometimes there is beside one of the small side of space, the main entrance which locates at the corner of the yard or considering the materials for constructing the houses, they have prepared the cool and pleasure space for household in the intense heat of the afternoons of the Yazd by constructing the extensive basements and high wind captures. For more ornament of the building, there are the decorative frames with the arched with paintings which all their ridges specified by the plaster and totally create the spectacular boards which not only their repeating does not bother the eyes but also the look of human passes whole of the building slowly with enthusiasm and gets pleasure from that. Inside some of the rooms especially those which have the more spaces, there are decorative fillet, mirror decoration and painting on the wood.

The traditional architects despite of the accessibility to the different kinds of stones and beautiful marbles and skill in making the brick, have not used them for body and the façade of the building and have used just the adobe, since with the assistance of this cheap material, they became more succeed in constructing the protected spaces against the influence of the intense heat and cold of the summer and winter. They have blocked the penetration way of the heat and cold analysis which all their ridges specified by the plaster and totally create the spectacular boards which not only their repeating does not bother the eyes but also the look of human passes whole of the building slowly with enthusiasm and gets pleasure from that. Inside some of the rooms especially those which have the more spaces, there are decorative fillet, mirror decoration and painting on the wood.

The traditional architects despite of the accessibility to the different kinds of stones and beautiful marbles and skill in making the brick, have not used them for body and the façade of the building and have used just the adobe, since with the assistance of this cheap material, they became more succeed in constructing the protected spaces against the influence of the intense heat and cold of the summer and winter. They have blocked the penetration way of the heat and cold into the building easily by constructing the pillars and thick adobe walls. In addition, they have closed the penetration way of the heat from the roof by constructing the false ceiling (Khancheh-pooosh) in the rooms and they have prepared the cool and pleasure space for household in the intense heat of the afternoons of the Yazd by constructing the extensive basements and high wind captures. Discussion in structural and artistic specifications of the Yazd houses and description of their different types of the maps and facade construction are easy and impossible. It should be noted that although the people of Yazd have observed the maximum simplicity in the outer facade of the home and have not emulated with the neighbors but have garnish and decorated the inside of the house so pleasant and soulful as far as possible since this is the place for spending day hours for women, children and adolescents of the family. Therefore, the inhabitants of the home spend their work, activity and rest times in the space which is full of pleasant and striking beauty. The relative extensive pools and their surrounding small gardens remove the recollection of the desert arid and low-water areas from the minds of inhabitants and create the feeling of living in the fresh environment for them.

Designing recommendations in the Iranian hot and arid climate

The form of buildings in various climatic regions are different and it is impossible to use one fixed form in all climatic regions. The modern architecture does not believe in this matter and asserts that it is possible to access to the machine-like buildings through the development of the technology. The buildings had the same design for all climates (all around window, pilot window and etc.). It means that the building was considered as a driving car. Therefore, if one car manufacturer produces a new driving car, this car can be used in all around the world. The building had also the same position. In this part the designing recommendations for the Iranian hot and arid climate will be explained completely:

If we consider the architecture and urbanization of the located cities in this climatic region precisely, we can understand that the weather had an effective role in formation of the cities and buildings of these regions. From many years ago, the people of these regions were encountered with the hard climatic conditions such as burning sunshine, overheating, difference between the temperature of the day and night due to the lack of humidity, cold winters, dry weather, sand and lack of humidity, cold winters, dry weather, sand and
storms with plenty of dust and etc. During these years, people found interesting solutions which have removed some of the annoying aspects of this climate surprisingly and have prepared the life conditions for human being.

- Utilization of the dense and compact texture in cities and villages, covered passages and narrow alleys with tall walls in order to protect the inside of the passage from the radiation of the sun beams and cooling the alleys.
- Selection of the appropriate physical shapes for reducing the external surfaces overlooking the east and west (extension of the building plan in the east—west axis is recommended).
- Covered passages (Sabat) which are used in both arid and hot climate and cold and mountainous climate prevent the influence of the heat and cold respectively. In addition, in those cities which the amount of humidity is high (ex. Dezfool), the “Sabat” are used since it is impossible to use the tree for creating shadow due to the high humidity.
- Utilization of the thick walls which made of mud and adobe in order to delay the entrance of heat to the inside of the building.
- Utilization of the deep lands for constructing the residential complexes due to their coolness.
- Utilization of the cubic-shaped volumes for the buildings with the height of approximate 2 floors and square—shaped plans for minimizing the side area.
- Direction of the houses of this climate should be in such a way that the hot sunshine of the summer does not shine on that. If the body of building locates in one direction, the direction of eastern 25’ is the most appropriate and can be changed to the southeastern 35’.
- Utilization of the light color materials in the external walls of the buildings.
- Utilization of the wooden door and windows due to the low temperature transmission capacity.
- Utilization of the more applicable elements such as porch (semi-open space) in this climate can be very effective since the porch are used very much in the summer.
- Utilization of the domed roofs in order to use the low shadow which is created in one part of this ceiling. The interesting point is that since that part of dome which locates in the shadow is cooler than the other parts, therefore, this causes the air current around the roof. But another roofs do not have this feature. In addition to this feature for the domed ceilings, since these ceiling are gibbous and bulging , therefore, they are always exposed to the air current and guide the heat of inside of the building to the outside.

In this region, the talented architects have optimized the domed ceiling in another way and have made them in the form of two shells. Hence, the air which is between these two shells works as an insulator and minimizes the thermal exchanges. This method have been used for the vaults, too.

- The summer domicile of the four seasoned houses is located at southern part of the building and its openings are toward the north. This part includes hall, spring house, wind capture and pergola. Pergola is a dome which is made at the center of the summer domicile spaces which has the little windows for natural air ventilation.

The winter domicile part of the four seasoned houses receives the energizer sun lights from the early morning. This part has the big room usually which its windows open to the southwest. Another important element which is used in this climate is the “garden pit” which the architects considered the more depth for the yard floor. In some of the buildings of this region, the depth of garden pit is 3-4 m. Indeed, the “garden pit” is considered as the moisture trap. Therefore, the amount of moisture in the central yard and its surrounding parts increases through implanting the different plants and various trees. Another advantages of the “garden pit” include the increasing the height of the yard wall and then increasing the height of shadow in the central yard, easier watering the small gardens and plant surfaces since the existence of the “garden pit” makes the possibility for easy access to the aqueduct.

- Utilization of the mortar and light color Simgel (special mortar) for facade of the buildings.
- Non-utilization of the window in the outer facade of the building (usually most of the openings directions are toward the central yard).
- Meanwhile, the brick grid shields are built in anterior of the windows.
- Utilization of the entirety awnings and consoles for cooling the external walls of the buildings.
- Utilization of different brickwork patterns especially the gibbosity of the “Rokhbam” for creating more shadows on the facade of the building.
- Installation of the window at the end part of the wall for creating more shadows in this part.
- Utilization of the small and colored glasses for preventing the entrance of the beams of sun into the inside of the building.
- More utilization of the vertical windows instead of the horizontal windows.
- Generally the windows are installed in the upper part of the building walls (if there be the necessity for installing the window in the external part). There are some reasons for this. For example, if the windows be installed in the height, the reflected beams from the ground surface do not enter to the inside space and also it prevents the entrance of the dust into the building.
- It is better that the passages and ways have the east and west directions in order to minimize the emitted rates to the surfaces.
- Utilization of the water pool in the middle of the central yard for compensating the shortage of the moisture in the yard.
- Utilization of the decorative false ceilings in order to make doubled ceilings which is an appropriate solution. As explained before, a similar solution was used in the past and the rooms had the double walls.
- Utilization of the “Hashti” as the pre-space and delay space in architecture. But “Hashti” has another important role. The surface of the “Hashti” is as the same as the surface of the yard or with the different height of a few stairs with that. The relation of the “Hashti” with the surface of the passage or alley is in such a way that the yard surface locates lower than alley surface. Therefore, “Hashti” prevents the direct influence and movement of the air current to the central yard.
- Utilization of the thatched cover in the roof of building as a moisture insulator which usually is changed or restored every few years in order to increase its strength since the rain water can wash that slightly.
- Utilization of the central form (central yard) in Iran is not a new phenomena since this pattern has been recognized as an appropriate pattern from the pre-history era and has been used up to now.
- The manner of using the wind capture in the arid and hot region (four seasoned houses) is that, the room which is under the wind capture with the water pool and fountain is made as an octagonal space and each of the building space is located in one side of this octagonal space. Then, if there be a necessity in order to cool one space, the door between that and “Hashti” which is under the wind capture will be opened.
- Non-utilization of the flat and non-fractured façade.
- Implementation of the foliage plants especially near the rooms since these plants can absorb the radiated heat and prevent the reflection of the solar beams to the inside of the spaces.
- Utilization of the tall and high ceilings.
- Increasing the height of turret in the roof of building. This has some advantages. Firstly, if the inhabitants want to sleep on the roof, it prevents the blast of overnight winds. Secondly, this turret can create the shadow in the alley and passages during the day.
- In the hot and arid regions, the appropriate mortar for covering the internal brick walls is the mortar of plaster and soil.
- It is possible to create more shadows in the backyard through plants and scaffold and prepare the natural evaporative cooling instead of coolers in summer.
- The manner of opening and closing of the doors and windows should be developed and be easier practically.
- Opening the external valves of the building should be easier and possible from the inside of the house.
- With constructing the building in the east and west positions of the house, the insulation capability of these two walls can be increased.
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Investigation of the effect of the Iranian traditional houses’ specifications in forming the sustainable architecture

The sustainable architecture is the responsibly and creative management of the health of human-made environment which is based on the ecological principals and proficiency of the sources. The purpose of the stable buildings is designing with the least negative effects on the environment through the proficiency of the sources and energy and includes the following principals:

1- Decreasing the consumption of the non-renewable sources.
2- Maintaining and promoting the natural environment.
3- Reducing the consumption of the poisons.

Sustainable buildings are those which have the least negative effects on the natural environment and effect on logical usage of the natural sources, appropriate management of the building in saving the sources, reduction of the energy consumption and improvement of the environmental quality. Meanwhile, in all stages of the building life, the environmental quality, operational quality and the future values should be considered. In this phase, the four main purposes of the stability are efficiency of the sources, efficiency of the energy, prevention of contamination and coordination with surrounding environment.

Climatic conditions of the Iranian arid and hot cities

The plains of the plateau which form the major part of the area of our country are located mostly in the central and eastern regions of the country. The arid and hot region in Iran allocates more than two third of its area to itself. Two regions of the "Kavir desert" and "Loot desert" which are located in the center of Iran are totally barren and have very little rainfall.

The general specifications of the climatic conditions of the plains of plateau are as follows:

1- Arid and hot weather in summer and dry and cold weather in winter.
2- Very low rainfall.
3- Very low air humidity.
4- Very low vegetation.
5- Great difference between the temperature of the day and night.
6- Dusty winds in the desert regions and their borders.

Regarding to the low humidity and distance from the sea, the difference between the temperature of the day and night is very high. The shortage of water for daily usage of the household and agriculture and also the intense desert winds which distributed the desert sand and dust strictly in the residential areas, do not provide the pleasant environment for human life. But despite of the above mentioned climatic problems, our traditional architecture has found logical solutions for pleasant life in these areas based on its thousand year experiences.

Urban texture

The formation of the urban texture and the conformity of the life conditions with the natural elements and also the usage of these elements in extreme unfavorable climatic conditions in these regions are considerable. It would definitely be said that one of the most important advantage of our traditional architecture is this conformity and provision of the appropriate environment for living in these arid regions. According to the previous researches on the building formation and environmental proficiency in different urban patterns in the arid and hot regions (Carlo Ratti, Delna Raidan, 2003), among the three following forms with equal occupancy level, the formation of the central yard is the best response to the environmental variables regarding to the absorbed thermal energy, created shadow, light distribution in the day and even in the sky perspective. Generally, the researchers assert that these formations of the building are the optimal exploitation of the land and prepare the possibility for using more energy regarding to the specific climatic conditions of the arid and hot regions.

The specifications of the urban texture of the arid and hot regions are as follows:

1- Very dense urban and rural textures.
2- Complete limited urban space.
3- Narrow and erratic alleys.
4- Connected buildings.
5- Installation of the residential places based on the direction of the sunshine and the wind.
Designing and executing strategies

Generally, all the living spaces of these regions including urban spaces, passages, yards, and buildings have been protected against the climatic factors especially unfavorable winds and the necessary measures have been taken for optimal usage of the favorable wind and sunshine. One of the designing performance in the arid and hot cities in order to decrease the temperature of the outside space is the tall walls which encompass the buildings. During the day, the external walls of the buildings create shadow in the narrow passages and the yards of the houses. In addition, these thick and heavy walls provide the cooler space in the summer and warmer space in the winter and decrease the consumption of the required energy for creating the comfort conditions.

The urban texture in these regions are dense and the buildings are connected to each others. The alleys are narrow and have the relative tall walls which extend along the route of broken line. Mainly, there is not any non-restricted urban spaces in these regions since protection of the non-restricted spaces against the unfavorable climatic conditions is impossible. The tall walls beside the passages are very effective elements in creating the shadow against the sunshine and also protection of the passages against the desert winds. It should be noted that the winding alleys are considered as an advantage in the arid and hot regions regarding the bioclimatic situation since the desert winds can blow in the wide and direct routes rapidly and disturb the daily life of the people. The dense texture of these buildings prevents the high temperature of these regions due to the reduction of the body of the buildings which are exposed to sunshine. In the hot and arid regions, the plan of the central yard has the priority and also the dense buildings are the best choices regarding to the reduction of surfaces which are exposed to the sunshine since this lead to reduction in energy consumption.

Building formation

The general specifications of the buildings in the hot and arid regions are as follows:

1. All the building are enclosed and toward inside.
2. All the buildings include the central yard and most of them have the basement, porch and wind capture.
3. Buildings roofs and specially the yard are lower than passages and the number of openings are low.
4. The height of the rooms are relative high and the roofs are often arched and domed.
5. The walls are relatively thick.

Such as the urban spaces which are restricted and protected against the natural unfavorable conditions, the buildings and the yards have a close fence and controlled climatic environment. This is true about all the buildings of these areas especially the residential buildings.

According to one of the related research (Ahmad Aklil, 2010), the formation types of the urban blocks which are more appropriate for efficiency of the energy have been identified. According to the researches, the forms of central yards have the more appropriate operations than linear forms both in summer and winter. Regarding to the different required designing methods based on the conditions of the winter and summer and considering the more needs to the solar energy in winter and vice versa in the summer, the forms of the central yards are more practical for all seasons regarding to the required energy.

According to the previous research under the title of “the effect of proportions of the central yard on the absorption of the solar energy” (Ahmad Haisen & Mohammad Gadi, 2006), the forms of low height central yards absorb more solar energy and create low shadow. In addition, the percentage of increasing the required energy are more in the form of lower height yards. The total annual required energy increases with increasing the ratio of the length on the width in the central yard. Meanwhile, when the proportion of the central yard be close to the square the effect of area of the shadow place on increasing the required energy decreases slightly.

Stability and proficiency of the energy are affected by the external bodies and shells of the buildings. The amount of the wall surface, selection of the materials and thermal insulation techniques
are the key elements in the home energy consumption. The cubic forms have the fewer surface than linear forms against the beam of sunshine. Therefore, architects have been tried to decrease the external surfaces of the building based on the required living space in order to provide the optimal living conditions.

Usage of the local materials decreases the energy consumption such as the first phase which the energy consumption was decreased in transporting the materials. The materials of all the traditional houses in hot and arid cities were the adobe and its derivatives. Regarding to the high temperature, the building materials absorb the heat of sun beams and make it accessible gradually especially in the night which the weather is cold. In the other words, energy remains in the wall for 8 hours and the heat is transferred to the inside of the building gradually. This quality is useful for both warm and cold seasons and help in reduction of the energy consumption. Selection of the local materials with the high thickness creates the stable thermal position in the residential space of inside of the house due to the high thermal mass.

In traditional houses, the ratio of the transparent surfaces to the opaque surfaces (walls) are very low and decreases the direct beam of the sunshine. The number of the windows are less and the height of them is more in order to prevent the influence of the radiated beam. Meanwhile, the color of the building facade is light in order to decrease the absorption of the radiated sunlight.

As mentioned before, the oscillation of the temperature of this area is very much and the amount of humidity of the air is less than the human comfort. Meanwhile, the sunlight and its temperature in the summer create a hot environment and the desert dusty winds which flow in most of the days of the year are disruptive. Hence, construction of a central yard at the middle of the building, installation of the pool and creation of the small garden, increase the moisture of the environmental space and the adobe and brick walls which are constructed with the relative high thickness in order to tolerate the heavy load of arched and domed roofs, decrease the oscillation of the air temperature in day and night such as a thermal capacitor. With installation of all openings toward the relative mild and humid space of the yard and blocking the external walls of the building except the entrance door, the relationship between the inside life space and the external space has been disconnected as far as possible and a small and suitable climate has been created for the comfort of the human within the hot and arid climate. The buildings are usually located below the natural surface of the earth which is cooler than other parts. Lower level of the yard than the level of alley has 4 advantages:

1- The water of the aqueduct or the creek which flows in the streams at the same level as the streams of the alley, naturally enters to the garden, small garden inside the yard and if the reservoir be in the basement, the water enters to the water reservoir.

2- If the quality of the excavated soil be relatively good, it is used for making the bricks and constructing the building.

3- By locating a part of building inside the ground, the temperature exchange between the inside and outside is decreased and the oscillation of the temperature degree will be reduced.

4- Bases of the building are located on more resistant soil than top soil.
SOME TECHNOLOGY OF TRADITIONAL HOUSES IN THE PAST

Special Organization of Environmental Sustainable Architecture of Yazd

In Yazd City, traditional builders have considered a sequence of logically different solutions for human comfort many years ago even though it is in a hot and dry climatic zone. While energy use is not taken into consideration in today’s world, Yazd example architecture principles and characteristics have demonstrated number of passive design processes by taking into consideration the climatic factors and the characteristics of the weather conditions in the area. Yazd architecture is heavily dependent on the subject of sustainability environment and its compatibility of the building with its surrounding environment and the community (Movahed, 2009). The following table below is created in order to visualize the analyzed issues in relation to environmental sustainability of Yazd city. In this table, Yazd city is analyzed in terms of the following environmental sustainability factors: climate, renewable energy usage, water consumption, open space and greeneries, reducing waste and sustainable building materials. For this purpose, the environmental sustainability components in relation to each mentioned environmental sustainability factors are considered.

Afterwards, among them, the utilized factors in relation to environmental sustainability of the case study (Yazd city) are selected and put in to this table. In order to explain the reason behind the selection of these particular environmental sustainability factors of Yazd city amongst other factors, each specific factor has been explained and visualized to open up the research issue in detail. Moreover, the spatial organization environmental of Yazd is considered according to the environmental sustainability factors and components itself. It is demonstrated in every space that is related to environmental sustainability. Finally, it is categorized according to special organization and vernacular components of architecture to the case of Yazd city and one by one are being explained for being utilized in the present time. Therefore, the following items are selected as the main spatial organization of environmental sustainability architecture of Yazd city (Movahed, 2009, Maeiya, 2009, Balkema, 1998, Salingaros, 2000, Madanipour, 1996, Jonkers, 2008).

- Type of Plan
- Air Circulation
- Wind Catcher
- Roof
- Pool (Hoz)
- Spring house (Hozkhaneh)
- Garden pit (Godal Baghcheh)
- Basement (Sardab)
- Thickness of Wall
- Sabat
- Qanat

Type of Plan

In this plan the vernacular house of Yazd region is being shown. The environmental state has an effect on the design of the vernacular houses of Yazd region. However, the extent and complexities are different according to owner’s financial state, environmental influences according climate, renewable energy, and water utilization, Greeneries, decreasing waste and building materials verify the sustainability of the house (Khorshand Mashhadi, 2012). Furthermore, The Houses are shaped around courtyards. In central courtyard plan, winter part is positioned in the north direction, summer part in the southern direction and the seasonal part in west and east direction. However, the plan type is categorized according to the courtyard and has thick walls and a minimum of openings. They are built close to one another, shielding environmental factors such as solar radiation and sandstorms. The walls are structurally independent; nonetheless collectively offer thermal shelter from the severe desert sun (Memarian, 2005).
Air Circulation

The air circulation of vernacular houses in Yazd city which is related to environmental sustainability to explain Circulation of air is the function of natural cooling and ventilation elements in a vernacular house in Yazd. The hot and dry air is caught by the high adobe wind catchers and is led into the house. On its way through the long adobe chimney and with the help of the evaporation principle, the air becomes moist and cool. Through the adobe wind canals inside the house, a part of the air is led into the basement and the other part into the summer residence and the courtyard. The first part passes through the basement’s adobe wind canals under the courtyard and absorbs moisture from the canal walls. Accordingly, it blows out through the small openings on the surface of the courtyard. The evaporation and the air circulation process cause a more comfortable climate inside the building in the courtyard (Karizi AA, 2011).

The trees in the yard are also an element of the natural cooling system. They provide a better air quality and more shadow in the courtyard. Furthermore, their roots keep the basement’s wind canals moist. This fact increases the evaporation process on the air flow in the basement (Karizi AA, 2011).

Wind-Catcher (Badgir)

The wind catcher of vernacular element in Yazd city which is connected to environmental sustainability to clarify the orientation of the wind tower generally means that the position of the wind tower flank is based on the four main geographical directions. It is determined by its purpose, use of wind power and the desired direction in which the wind blows. There are one-directional wind towers in Yazd which are facing the desired wind direction and in some cases, one directional wind towers draw air and the air flow is reverted back towards the wind to create a negative air pressure to ensure that warm air in interior is blown out of the house. The desired wind direction in Yazd is from the northwest. The long sides of wind towers are therefore oriented towards the northwest for maximum usage of the wind to provide cooling for buildings (Maleki, 2011).

Moreover, Wind-catchers are environmentally and sustainable energy systems which traditionally have been used in the Yazd city for air circulation and cooling purposes. They are only relying on natural air force to supply comfort and fresh air (Azami, 2005).

Wind-catchers have been used for four major motives (Roaf, 2005, Azami, 2005):

1-Air circulation and fresh air for indoor area.
2-Convective cooling in the buildings where the temperature of indoor area is Between: 25-35°C.
3-Evaporative cooling in hot-dry region where the indoor temperatures are upper than 35°C.
4-Providing night time cooling.

On the other hand, as the wind-catcher originally was considered in hot area, applying contemporary wind-catchers in supplementary type of climatic situation creates some problems such as heat lost, cold draught in winter and disorganization of the system in hotter times and during time when the wind speed is not enough to run the system (Elmualim, 2003).

Consequently, in designers and engineers are not confident enough to apply wind-catcher in the buildings. The significance of applying wind-catchers on the one hand and its limitations in different climatic condition on the other hand reveals the requirement of further studies in this field. It is attempted in this study to introduce a wind-catcher which can be transmitting today's architecture (Ibid, 2003).
Kinds of Wind Catchers

Badgir (Wind catcher) is a sustainable element of Iranian traditional buildings in hot & arid regions of Iran considered as a passive ventilation method in architecture for cooling houses built in these areas. In addition to their height (as wind catchers built very tall) the wind catchers are also considered as a symbol of towns centered in the desert. In those houses, the wind catcher is usually constructed in southern side of the courtyard.

Wind-catchers have several different external shapes and are divided into several categories. Single faced wind-catchers are the simplest kind. They are small and are built over an opening on the roof. It faces the pleasant breeze and cold winds with all other sides being closed off (Bahadori Nejad, 2007).

These kinds of catchers are mainly built to protect the building from heavy storms and it is mostly seen in System and in some parts of Yazd. The second type is the two faced wind-catchers. The openings, in this type are in two opposite directions and built with long and narrow windows (Hekmatpanah, 2010).

Figure 15: Wind Tower scheme . Source: Grosso,M

Figure 16: One Faced Wind-Catcher Plan (Nasri, 2010)

Figure 17: Two Faced Wind-Catcher Plan (Hekmatpanah, 2010)
The third type, trihedral, is very rarely used. The design of this kind is more complete than those designs of the others. The inside channels are made of small rows of bricks or plaster divided into several parts. In some cases, at the bottom of the catchers, there is a big pool that decreases the overall temperature and absorbs dust, which provides a graceful condition for the occupants. These types of catchers are mainly built in Yazd (Bahadori Nejad, 2007).

Consequently, Mechanical cooling systems in buildings are the major manufacturers of carbon dioxide productions, which have negative forces on environment and increase universal warming, mainly in hot-dry environment. Due to the lack of energy supply, wind catchers can be used as an environmental sustainable challenge for cooling and air circulation reasons.

Wind Catcher with Two Level, Yazd, Iran

The Wind Catcher show in the picture is located in the city of Abarkooh, a province of Yazd. This Wind Tower is the only tower with two level in Iran. This tower is a part of an ancient house which belonged to a wealthy family in Abarkooh and was built on the Qajar period. 18 meters height and has 18 square meter surface wind opening and 19 meters air control valves that are connected to the second Wind Tower and have the ability to adjust the wind even without air.

The top part of wind tower (second level) designed with a layered arrangement which better control the lighting.

Figure 18: Tetragonal Wind-Catcher Plan (Hekmatpanah, 2010)

Figure 19: Wind Catcher with Two Level, Abarkooh, Aghazadeh House, Yazd, Iran. Source: www.makanbin.com
Cistern / Ab Anbar
Mode of Construction

Ab Anbars built inside private dwellings are usually square or rectangular; public ab Aanbars in towns or along the caravan routes are generally round. While the former have a flat roof and are often built into the foundation of the house, the latter have a distinctive hemispherical or almost conical roofing.

Water remains quite cool inside the ab Aanbar, since it is generally built beneath ground level and is insulated by very thick walls. In the south of Iran, most particularly in Yazd province, one or more ventilation towers (badgir) is built along the edge of the ab Anbar’s roof, directly on the tank wall and connected by a duct to the upper part of the ab Anbar chamber under the domed roof. Fresh air entering through these ducts keeps the air inside the ab Anbar chamber circulating and the water cooled. In the case of ab Anbars with domed or conical roofs, the center of the roof is sometimes pierced, and a short ventilation chamber made of brick is built directly over the ab Anbar chamber. A duct inside the ventilation chamber leads from the openings or slats (that catch the breeze on top) directly inside the roof, again circulating air inside the ab Anbar chamber. The height of these ventilation chambers is generally about one meter, though some can occasionally be seen that reach a height of two or even three meters.

The Cistern shown in the picture is located in the city of Yazd. It is constructed during Qajar, about 180 years ago. This Cistern has six wind towers and which three of them were built first and three more added in a later time. This can explain the reason of small differences between the wind towers. The tower are about to 10 meters high and have octagonal shape. The tank is 12 meters deep and can hold up to two thousand cubic meters. It has two entrances, one on the north and the other on the south. The entrances have fifty five stairs which designed with bricks.

Shelters and walls are constructed that have grid-type openings to minimize obstructions and maximize privacy. The roof of semi open areas acts as a vast insulation and they don’t permit warm air to come inside effortlessly in Yazd vernacular houses. (Ghobadian, 2006). Roof is covered with flat clay shaped like an arch. This is achieved by laying wooden beams on either side of the wall approximately thirty cm from each other then they are covered with mats. After the lengthy process, they are all coated with clay plaster. The wooden beam must be smooth as possible and should be treated against bugs, termites and other pests that are attracted to wood. There is a major problem with such structures, which is the fact that they are not earthquake resistant which can be a safety concern (Shohouhian and Soflaee, 2005).
For water reservoirs, bazaars and mosques, dome shaped roofing is used. It is effective in dispersing heat due to its convex shape. The shape alone naturally causes there to be an unbalanced surface on the roof, which is a perfect way to create a constant shade on a part of the roof throughout the day. That is the reason why a dome-shaped roof is a very effective type of roofing to use for bazaars, mosques and reservoirs. As mentioned above, when flat roofs are constructed, they are usually square brick paved to alleviate the sun’s radiation intensity and the angle (B. Ahmadkhani, 2005).

The existence of the pool at the center of the yard points to the centrality and importance of the water. The pool represents all the universe specially with the reflection of the blue color of the sky within itself. In addition to its decorative aspect and usage, pool is considered as the center which the symmetry and polarity of the side raceways, the overlooking gardens and even the surrounding spaces of the small garden are determined based on this center. There are different shapes of the pools in the yards of the Iranian houses such as the 6-sided and 12-sided shapes, rectangular shape with longitudinal proportion and circular shape.

Considering the pool of the yard as the place of ablution, washing and saving the water for watering the small garden and its effect on subtilizing the air, the water of the pool which is in the heart of the yard is a symbol of life, paradise, purity, beauty and prosperity in nominal culture and aside from its consumption aspect, has been used more due to the traditional aspects. The water pool and the plants which are in the yard compensate the shortage of the air moisture and more than creating the shadow, increase the air elegance.
The pool which locates at the center of the yard and basements and usage of water in some spaces such as the “spring house” for subtilizing the air and creating the appropriate visual sight and sometimes creating the water sound by fountains and instill a sense of tranquility are the small samples of using the water in the residential houses. For example, in the arid and hot climates, the evaporation of the water can decrease the air temperature. The amount of evaporation in a limited space such as the internal yard depends on the area of the water surface, the amount of relative air humidity and the temperature of the water.

Spring house (Hozkhaneh)
In Iranian houses, the installation of the pool under the dome of the home creates some specifications such as coolness, humidity and reflection of the various images. This space is called the spring house (Haeri Mazandarani, 9833: 980). Spring house was in the underground and there was a pool for residence and coolness of the summer. In fact, the spring house was a summer home which had a pool with fountain. Usually the protraction of the wind captures reach to this space and the passage of the wind over the water of the pool creates the elegant air in this space.

Garden pit (Godal Baghcheh)
The garden pit was made in the center of the central yard and one floor was gone inside the earth. Some samples of the garden pit are in Kashan, Yazd and Naein. The garden pit not only provided the required soil for used adobes in the building but also made the possibility to access the water of aqueduct. Therefore, there was usually the running water in the garden pit which filled the middle pool and its overflow went to the other houses. Beside this yard, there were some semi-open rooms which were used for implanting some trees such as pomegranate, pistachios and fig. Regarding to the small size of these yards and their lower surfaces and usage of humidity and coolness of the earth, in addition to the humidity and coolness of the plants, there was a space which was more climatic than the yard.

Basement (Sardab)
Basement is the underground which has been made under the summer living part of the house and it is a semi-open space such as the porch. Its ceiling is 70-100 cm higher than the central yard and mostly it has one pool. The windows between the surface of the yard and the ceiling of the basement transfer the air of central yard to the inside of the basement. Meanwhile, the underground rivulet or the aqueduct which pass through this space, cool and moisten this space (Esmaeilzadeh and Torabi Langari, 1998).

Material Building in Yazd Architecture
In hot and arid and Mediterranean climates, buildings usually constructed in light surface colors and massive construction, such as adobe, brick, or stone (Lechner, 1991). These massive materials not only retarded and delayed the progress of heat through the walls and roof but also acted as a heat sink during the hot summer days. The mass cooled at night and then acted as a heat sink the next day. Although wood did not use as a basic material in construction but it was utilized for doors, windows, decorated screens and furniture. In Iran, Windows usually were decorated with color glasses which not only used as statistic aspect but also minimized solar penetration and heat gain through the windows. Usually, retractable bamboo shades which could be adjusted to either exclude or admit solar radiation hanged outside Earth sheltered building was another technique which was an effective barrier to the extreme temperatures. The deep earth
is usually near the mean annual temperature of a region, which in many cases is cool enough to act as a heat sink during summer days (House & House, 2004).

**Thickness of Wall**

In the hot and arid region, thickness of the wall plays a significant role in the comfort factor of a building. In the city of Yazd, walls are constructed from adobe and brick, which is about 1 meter thick. This thickness can create a comfortable living space for the inhabitants. The reason is that adobe and brick materials can dissipate heat very quickly and during the night, this is exactly what happens. Consequently, the materials temperature remains persistent throughout the day, as it does not absorb much heat during the day. Additionally, the city walls are required to be thick in order to support the heavy dead loads of these vaults and domes. The thick masonry walls work as a very good thermal mass and minimizes the day and night temperature variations between the outer and inner parts of the buildings (Memarian, 2006 and Pourvahidi, 2010).

**Sabat**

In the design of traditional houses in the hot and arid area in Iran, there are several precautions taking against the hot climate. Houses are isolated from the street and surrounded by high walls. During the day, external walls of houses provide generally shady areas in narrow streets and especially in courtyards. By means of heavy and thick walls, warm environment in winter and cool environment in summer could be provided easily. One noticeable and conspicuous of urban planning in old location in cities with hot and arid climates is the roofed lane and porches passage. It is called sabat. A sabat is designed in order keep safe human living in desert from direct radiation of sunlight in shade for some moments. In fact, Iranian architects, in the same 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 sabats. A sabat can modulate a transient temperature. It is such a way that any pedestrian on his way to his destination is positioned in shade in a suitable succession. In many sabats, there are several integrated entrances of houses that are of highest importance in view of improved sense of neighboring and local correlation. Debate is more usually laid up from blind alleys. A string gate is also more usually fixed at its entrance. Such space is commonly called “darband” that is in sum, wholly suitable to provide added security for the occupants across the lane.
Structure of Sabat

There had been numerous creative climatic planning in order to use energy efficiently. Studying of these and combining them with new climatic systems can be a proper way to make the building more sustainable. Regarding the four climate regions Iran, there are different adopted architectural approaches on the basis of the best ways of efficiency and sustainability by using the best combination of vernacular materials. The important point in using such materials is their environment friendliness.12

In arid and hot climate some other precautions against the solar radiation are:

- Minimization of the number and the area of windows.
- Construction of a window at a high level to obstruct the floor radiation.
- Reduction of the absorbance of the facades by light colors.
- Providing natural ventilation particularly at night.
- Constructing a part of the building into ground which is to be always cooler than the outer ambient temperature in summer.

Materials of Sabat

In hot and humid regions some materials have been used (are used) that each has a lower thermal mass and has the capability to store and keep as reserved the volume of heat neither. For this reason, wood, as an example, is considered to serve as a good material. However, since in these regions, there is little grass covering, wood was merely used for roof framing and windows or doors woodworking. And in making other parts of building uses are made of native and local materials existing in any region there such adobe, bake brick, brick and alluvial rocks, marine coral stone and reed. As these kinds of stones (rocks) are porous and they can be used as good thermal and acoustic insulators.13

Qanat

A Qanat is a gently sloping underground channel with a series of vertical access shafts, used to transport water from aquifers in highlands to the surface at lower levels by gravity. Qanats create a reliable supply of water for human settlements and irrigation in hot, arid, and semi arid climates.
Structure of Qanat

Some parts of the qanat are described as follows:

**Gallery:** The qanat gallery or tunnel which is an almost horizontal tunnel dug to get access to groundwater reserves, and to transfer this water to the earth’s surface. The dimensions of the tunnel are such that the workers can easily go. Through and work in it: between 90 and 150 centimeters high, and its width is less than half the height.

**Exit point of the qanat:** Where the tunnel and the ground surface eventually intersect is the exit point of the qanat which is called the “mazhar” meaning where water appears. Exit point of the qanat: Where the tunnel and the ground surface eventually intersect is the exit point of the qanat which is called the “mazhar” meaning where water appears.

**Shaft wells:** There are some vertical shafts sunk along the tunnel to connect the surface to the horizontal gallery. The main application of these wells is to haul the debris and excavated materials from the tunnel on to the surface. They also provide access and help ventilate the tunnel and provide more oxygen for the workers. These wells play an important role in repairing the qanat, by making it possible to send down the needed facilities and tools and remove the debris. A shaft well is between 80 and 100 centimeters in diameter, and the distance between the wells vary from 20 to 200 meters. In fact, the deeper the shaft wells, the further they are from each other. The distance between the shallow wells (up to 40 meters) is two times as their depth, but in terms of deeper wells the distance is equal to their depth. Shafts wells: there are some vertical shafts sunk along the tunnel to connect the surface to the horizontal gallery. The main application of these wells is to haul the debris and excavated materials from the tunnel on to the surface. They also provide access and help ventilate the tunnel and provide more oxygen for the workers. These wells play an important role in repairing the qanat, by making it possible to send down the needed facilities and tools and remove the debris. A shaft well is between 80 and 100 centimeters in diameter, and the distance between the wells vary from 20 to 200 meters. In fact, the deeper the shaft wells, the further they are from each other. The distance between the shallow wells (up to 40 meters) is two times as their depth, but in terms of deeper wells the distance is equal to their depth.

**Mother well:** The furthest shaft well from the exit point, sunk upstream is called the “mother well”. The mother well is usually the deepest well, in which a large inflow of water shows the qanat is in a satisfactory state. If the water table goes down so much that it is located below the bottom of mother well, no water can seep into the gallery, and if this situation persists, the qanat will inevitably dry up. If a qanat is extended so far that another well is needed, the new well would now be the mother well and the former one would be a normal shaft well. In a nutshell, the last well is always called the mother well. The depth of the mother well varies from qanat to qanat, and the deepest one in Iran has been recorded in the qanat of Gonabad at 300 meters. The mother well is usually the deepest well, in which a large inflow of water shows the qanat is in a satisfactory state. If the water table goes down so much that it is located below the bottom of mother well, no water can seep into the gallery, and if this situation persists, the qanat will inevitably dry up. If a qanat is extended so far that another well is needed, the new well would now be the mother well and the former one would be a normal shaft well. In a nutshell, the last well is always called the mother well. The depth of the mother well varies from qanat to qanat, and the deepest one in Iran has been recorded in the qanat of Gonabad at 300 meters.

**Farm:** The farm is a cultivated area which is less elevated than the exit point of the qanat, irrigated by the water coming out of the qanat. The extent of the cultivated area depends on several factors such as the qanat discharge, soil quality, soil permeability, local climatic conditions, etc. The water flowing from the qanat is insufficient, the water is stored in a pool to increase the volume and head of water so that it can delivered to the land at a higher flow rate and thus irrigate the farms. The irrigation cycle differs from area to area but is usually between 12 and 15 days. It should be noted that an irrigation cycle is a water management order according to which the shareholders take turns irrigating their farms. For example, if the irrigation cycle is 12 days, every farmer has the right to take his share just once every 12 days. It should be noted that an irrigation cycle is a water management order according to which the shareholders take turns irrigating their farms. For example, if the irrigation cycle is 12 days, every farmer has the right to take his share just once every 12 days.
The Qanat in the Past, Yazd
Technology / Material

Yazd’s qanats have evolved over centuries with the overarching goal of transferring water from source to destination while minimizing evaporation and retaining potability. This is a significant challenge in Yazd’s hot, arid climate, where its distance from the Oman Sea and Persian Gulf results in minimal rain and high evaporation. Diurnal temperatures actuate from 50 to 20 Celsius within 24 hours, and seasons vary from a long hot summer (mid-March to mid-September) to a cold winter (October to February). However, the Zagros Mountains crossing the province gather snow in the winters and trap water in their crevices forming a subterranean aquifer. This is where the qanat transect takes its birth.

The traditional process of qanat making began in the mountains. Experts surveyed the mountain vegetation and soil deposits mapping potential water sources. Digging typically began prior to the cold and wet season before a fresh annual installment of mountain water had been generated. Qanat builders typically worked in two pairs: one pair did the excavation, the other using wooden windlass and leather buckets, removed the soil and piled it around the opening. The diameter of a typical opening was no larger than 3 feet, but depths varied from 50 - 300 feet depending on the location of the existing aquifer.

The next step was the construction of the horizontal subterranean channel to guide the flow of water. With the depth of the source well determined by a rope, vertical shafts of successively increasing depths were dug at 150 feet intervals and oriented towards the desired flow direction. Their first 20 feet or so would be reinforced with baked clay hoops and bricks to avoid landslides. These shafts were then horizontally connected by subterranean tunnels some 3 feet wide and 6 feet high, typically sloped at around 1:1000 feet to ease flow. The length of a qanat thus resulted from both the quantity of water within the aquifer, and the relative destination and topography of the concerned terrain. It could range anywhere from 1 to 10 miles. Its first destination was the agricultural fields surrounding the historic city, where the water was collected within open to sky ponds and distributed into the various agrarian lots on a carefully monitored basis. The remainder was directed towards the city.

Historically, the first contact of qanat and city happened at ab anbars, subterranean cylindrical reservoirs designed to stabilize a low water temperature, withstand water pressure and resist earthquakes. Typically, a linear stairway descended from the entry to the platform at the foot of the faucet used to retrieve the water. The specific faucet depth determined the water temperature, with some ab anbars accommodating multiple faucets at various intervals along the stairway. A semi-circular brick-lined dome with central escape vents helped cool the water through convection while protecting it from dust and pollution. And badgirs (wind catchers) helped maintain fresh air circulation and prevent water deterioration. No one was given direct access to the water; it was always drawn beneath the ground level using the pasheer, thereby minimizing water contamination.

These Ab anbars played a pivotal role in the ur-

Figure 32: Morphology of Yazd. Source: hydrocityblog.blogspot.com
Distant qanats split into a distribution network of smaller canals called kariz bringing water to a hierarchy of city-center and neighborhood specific ab anbars. Their specific locations within this hierarchy determined both their size and character: smaller neighborhood reservoirs were usually endowed with fewer badgirs; larger city-center reservoirs often served by six or more. Each ab anbar provided water to a limited number of streets and houses, defining a distinct community shed around it.\(^{(3)}\)

While there are no verifying records, it is apparent that the formal complexity of Yazd’s historic communities was in fact ordered around existing qanats and ab anbars. Each dwelling was located within easy reach of their only water source, the community incrementally evolving around this infrastructural armature. As evident from the extant examples within the historic core ab anbars thus configured the formal structure Yazd’s historic neighborhoods in as much as its numerous mosques and school.

As the qanat’s eventual destinations, Yazd’s traditional dwellings each had their own domestic ab anbars located within enclosed courtyards. They held around 50 cubic meters of water. They would be filled once every two weeks, and cleaned of sediments once a year. When a domestic ab anbar needed filling, the local water manager would record the formalities and open up the specific qanat from the reservoir leading to the dwelling.\(^{(4)}\)

The spatial organization of the dwelling was a climatic diagram of summer and winter spaces centered on this domestic water source. In the hot, arid summers, inhabitants spent the day in the cooler basements connected to the badgirs, or in the vaulted summer rooms around the courtyard oriented north to keep the sun away. At night they would sleep on the roof under warm quilts while the cool night winds would circulate through the open doors and wind catchers, drawing the heat from within the house. In winter, the wind catchers were closed off to prevent heat loss. The activity shifted to the south facing winter rooms around the courts. Their glass doors captured the low winter sun storing heat within their thick walls helping to maintain a warmer temperature during the cold nights.\(^{(5)}\)

Yazd’s infrastructure network thus had larger formal and social dimensions. The qanats that brought water depended on and thereby nurtured the guilds that made, monitored and maintained them. The ab anbars as visually conspicuous urban artifacts were the centers and local monuments of various communities. And the badgirs and domes, beyond their climatic dimensions, marked the desert town’s distinct roof-scape. As an infrastructural system unifying the regional and dwelling scales, Yazd’s qanats represented a complex intersection of urbanism, formalism and capitalism and all in one.

Qanats were in wide use throughout the dry lands of the Old World until recently for several reasons. First, qanats are made of local materials. Second, they tap aquifers using no source of power other than gravity. Third, water is transported for substantial distances in these subterranean conduits with minimal loss of water through evaporation and with little risk of pollution. Water loss through percolation is reduced by lining the tunnels with clay hoops when they pass through loose sand, and by infusing their beds with layers of impermeable clay.

The Qanat Today

By 1500 CE, the historic core of Yazd had expanded to more than twice its size, avoiding the northern desert and dissipating into the outer agrarian villages. Further growth continued due south-west until circa 1925, and by 1979 (towards the end of the White Revolution in Iran) it had enclosed the historic core to the east and west. Over the last three decades, rapid urbanization has transformed Yazd into a sprawling modern city some thirty times its original size.

But amidst this urban explosion, no new qanats have been built using traditional methods since 1963.\(^{(6)}\) This is also apparent in the shrinking numbers of ab anbars relative to the spread of urbanized land. According to Dr. Reza Abouei, of the 3,300 qanats within the Yazd Province, around 3,000 though active are increasingly polluted from industrial discharge. Meanwhile less than 500 badgirs don the city’s historic rooftopscape.\(^{(7)}\) Evidently, it is not just the qanat’s infrastructural dimension, but its holistic urban paradigm that has been gradually eroded.

This erosion is as much a cultural as a political phenomenon. With the advent of the White
Revolution and its Land Reform Program against feudalism in 1963, the government had begun purchasing agricultural land from feudal owners and selling it back to the peasants at a much lower price. Yazd’s water distribution and ownership traditionally controlled by a select few now came under a much larger purview. Subsequent government intervention had to be geared towards giving this larger demographic their fair share. With increased agricultural production necessitating the drilling of source aquifers, many qanats began to dry out or became seasonal, even as the drilling industry attracted more people into the city.

Today, despite continuing preservation efforts, active historic qanats remain undesirable due to their unpredictable water supply and high maintenance and repair costs, eventually leading to their neglect and abandonment. Today, houses in Yazd are no longer organized around a courtyard, but a central covered hall with a separate entrance from the front garden to ensure privacy for women. This hall often has a higher ceiling to buffer the dwelling from the sun, with operable clerestory windows to expel hot rising air. The traditional north facing Aivan, the raised veranda for enjoying morning and evening breezes, though present is often air-conditioned, making it in effect, a year round living room for the family. Meanwhile ab anbars both within and beyond the historic core lie abandoned, with emerging development increasingly oblivious to their presence.

But despite their increasing replacement by modern wells, surviving qanats and ab anbars, however few, continue to serve Yazd’s agricultural lands, bazaars, schools and mosques, embodying the resilience of this ancient tradition. Their presence remains a dominant magnet for continuing tourism, encouraging ongoing preservation and restoration efforts. And they continue to garner attention as pointers to alternative sustainable urban practices.

The Qanat in the Future

If qanats and ab anbars were more than utilitarian infrastructure, can these larger ideas suggest alternative models of development today? The following reflections on this question are incipient and represent only part of a larger dialogue on Yazd’s future encompassing other social-economic dimensions that are beyond the scope of this study. But they do attempt to outline plausible transformations of the growing city (or at least parts of it) through parallel development processes and scenarios unified by the qanat.

Where People Live

Qanat technology was known in Iran by the sixth century BC, when Indo-Iranians began to settle as agriculturists, to worship one god (Ahura Mazda), and to conquer the Old World. Three centuries later, when the Parthians invaded Iran, qanats were in widespread use on the Iranian plateau (Polybius X: 28; Vitruvius VIII: 6.3). By this time, qanats had opened alluvial fans to settlement, enabled basin cities to expand, and established the foundations of modern plateau settlement patterns. Qanats became an important factor in where people lived. The largest towns were still located at low elevations on the floors of intermountain basins and in broad river valleys. Most of these early settlements were defended by a fortress whose water was drawn from hand-dug wells that reached down to shallow water tables. Qanats enabled these settlements to grow by tapping water rich aquifers located deep beneath neighboring alluvial fans. Qanats carried water from the fans below ground for many kilometers to such settlements providing supplementary water to irrigate more extensive fields and sustain larger urban populations. Even more dramatically, qanats made it possible to establish permanent settlements on the alluvial fans themselves. Earlier settlers had bypassed the alluvial fans because water tables there were too deep for hand-dug wells, and the ravines on these slopes were too deeply incised in the fans for simple diversion channels. In these locations, qanats tapped somewhat more limited “water hinterlands” with underground water drawn from upslope alluvial deposits in mountain valleys. For the first time, small towns and villages were built at these higher elevations. And further up river valleys in the mountains, small qanat watered hamlets appeared.

In many areas, these water hinterlands formed a series of progressively smaller arcs with the qanats of each higher settlement starting where those of the next lower settlement ended. Although configurations varied on the plateau, frequently the regional settlement pattern exhibited a correlation in age, size, water rights, and elevation. The largest place was the oldest and the lowest, and usually had prior rights to the largest water catchment basin. In any case, over much of the Iranian plateau these new upland settlements increased
the cultivated area, supplied additional food to urban centers, provided living space and work for a growing population of farmers, as well as upland bases for herders and fuel collectors. The Iranian plateau was the first core area of intensive qanat use. Even today, as much as one third to one half of the irrigated fields and orchards on the plateau—an estimated 15 million acres—are still watered by qanats. Cities like Tehran, Qom, Qazvin, Hamedan, Yazd, and Kerman received virtually all of their water from tunnel wells until deep wells were introduced after World War II. In the 1960s, an estimated 21,000 qanats were still functioning in plateau settlements with an additional 17,500 used but in need of repair (Ghahraman 1958). Their aggregate length has been placed at more than 160,000 kilometers, and their total discharge at 20,000 cubic meters per second (Goblot 1962). Although these figures are not precise, they convey a sense of the scale of qanat use on the Iranian plateau, the role of qanats in defining the location of settlements, and their importance in the daily lives of Iranian villagers. In more immediate ways, qanats defined the built environments of towns and villagers, the architecture of daily lives.

**Figure 33: Cities & Qanat Scheme. Source: Author**

Qanat: Water as a renewable resource

The rate of flow of water in a qanat is controlled by the level of the underground water table. Thus a qanat cannot drain an aquifer, because its flow varies directly with the subsurface water supply. When properly maintained, a qanat is a sustainable system that provides water to settlements indefinitely. Qanats exploit ground water as a renewable resource.

The self-limiting features of qanats that make them a sustainable technology can, however, be their biggest drawback, particularly when they are compared with the range of technologies available today. First, the flow of water in qanats varies from year to year depending on the recharge rate of the aquifer. In the Middle East, where drought hits on average once every four years, this uncertainty often results in conservative cropping strategies geared to the cultivation of low-risk, low water-consuming, low value crops like wheat and barley.

Designing for the Desert

Policies encouraging passive climate control through the timeless lessons of Yazd’s traditional building types and architectural elements can help create a contemporary fabric that is climatically responsive yet diverse. Traditional badgirs for instance were the formal resultants of a climate sensitive design seeking to balance the heat gain and loss between earth and wind. Yazd’s ubiquitous domed roof form was likewise a response towards minimizing solar gain with half its surface consistently in shade save the noon hours when the sun is directly above its apex.

Such ideas however obvious can only be effective through their consistent use in mainstream development. Incentivized planning codes can encourage such approaches through public-private partnerships, density bonuses and government subsidies. In turn prospective buyers and residents could pay rents or mortgages through the amount of energy saved. In essence, the success of transforming Euclidian use based zoning into sustainable form based and performance based codes as seen in other cities around the world, can chart new directions in balancing sustainable design and cohesive urban form.
Qanat Builders as Urbanists

Ongoing efforts such as the 2007 UNESCO organized “International Training Course on Qanats” are helping to increase awareness on their cultural and technical aspects. The good news is that qanat building skills are receiving renewed attention.

The bad news is that there continues to be no administrative mechanism to incentivize these skills within mainstream development. The idea of qanat builders as intrinsic participants in city making is in fact an echo of their ancient tradition. They could be involved in the early planning phases as experts on the location and viability of old or new qanats and ab anbars. Such trends could generate a significant employment base within Yazd’s real estate market allowing the amalgamation of traditional building techniques with modern methods.

The challenge, of course, is that such ideas will need significant political and administrative incentives to get them off the ground. Effective branding among other things will constitute a key part of this effort, with new developments involving qanats and qanat builders needing to find ways to inspire citizens to want to live in them. But no planning effort can anticipate the vagaries of public sentiment. If qanats and their builders can remain marginalized on the one hand, they can also become the force behind a renewed public environmental consciousness. People can come to realize that infrastructure should and can be more than purpose driven.

CASE STUDIES
Lari House, Yazd, Iran

Lariha house and its vent are from Qajar era. This building is around 150 years old and built by Hadji Mohammad Ebrahim Lari in the style of aristocracy in its time. From the north of the house was used as wintry, and from the south was used as.

The doors, windows, sashes, rooms and paints are the beauty exemplar of plush house in 19 century. In aristocracy house there is a space often for fun that this space is decorated with mirrors or mold-

Figure 34: The Qanat Transect. Source: Vinayak Bharne & Blayna Bogosian

Figure 35: Lari House, Central courtyard. Source: forum.kalout.ir
Golshan House, Yazd, Iran

Golshan house, is the famous historic house in heart of the old town of Yazd. Built 123 years ago, around 1893 square meters. This house has three courtyard and two entrances, two East and West courtyard which have a rectangular shape and are almost in the North-East. 42 rooms. The house has three part, outer part and inner and Narenjestan.

Gerami House, Yazd, Iran

This building was commissioned in the late «Qajar» period by «Mr. Seyyed Asadollah Mazar», the son of «Aqa Seyyed Mehdi» -the patriarch of the Gerami family of Yazd-. The «Mazar»'s descendants later adopted the name of «Gerami». According to relatives of the present owner of the house, a dated marble inscription existed above its portal which indicated that its construction dates back to 110 to 1 This building is a large house comprising two different parts, each of which possesses a central courtyard. These two courtyards are aligned and laid out along a north-east - southwest axis. The southern courtyard is slightly larger than the northern one and the spaces surrounding it are more substantial and more elaborate. The larger courtyard is encircled on all four sides by built areas, whereas the built areas of the smaller one occupy only its eastern and western sides. Although a room also exists on the southern side of this courtyard, this room is unrelated to it and belongs to the larger one. The closed walls of the northern and southern sides of this courtyard are covered with arcades. These arcades and their frames have transformed the facades of these two sides into elaborately carved surfaces, endowing the smaller courtyard with the atmosphere of central courtyard. 20 years ago.
What can be learned from the traditional Iranian architecture

According to the previous researches, the Iranian architects use the natural sources and energies in appropriate manner through using the simple and accessible techniques in designing (central yard and its proportions) and constructing the residential spaces (materials) and along with the appropriate exploitation of them, create minimum environmental pollutions. Since with the minimum amount of energy consumption, the comfort conditions are created in the houses. Hence, regarding to the concept of stability, these houses which have the high compatibility with the nature, can be considered as the symbol of stable architecture.

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Notes

(1) For more on qanat construction, see A.A. Semsar Yazdi, Qanat from Practitioners’ Point of View, Mohandesin Moshavber Setir, Tehran 2005. Also see by same author, Proceedings of International Symposium on Qanat, Volume Two, Sherkat Sahami Ab Mantage, Yazd, 2001.

(2) Builders are known to have first constructed the storage space and fill it up with hay and straw up to where they could start constructing the dome. After the dome’s completion, the straw would be set on fire clearing the interior.

(3) As is often with secular, public use structures, one cannot trace the precise origin or patron of most ab anbar reservoirs in Yazd. Though the earliest urban water supply constructions in Yazd are believed to date from the Sassanid period and many others have been continually repaired and used, most extant ab anbars can be today traced to the late Safavid and Qajar periods. The Shesh Badgiri anbar or ‘Six wind catcher’ reservoir was constructed in the Qajar period, while the Khan Bazaar anbar can be more accurately dated to Qajar ruler Nasr al-Din’s reign. There are approximately 75-90 surviving anbars in Yazd today, and some of the important ones are the Seyed Va Sahra, Masoudi, Hadij Ali Akbari, Kajeh, Golshan, Rostam Gerei, Kohan Doozha, Malekotijar and Mirza Shaft reservoirs.

(4) For more see Javad Saf-Nejad, Qanat: Selected Scientific Articles, Sherkat Sahami Ab Mantage, Yazd, 2001.
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CHAPTER TWO

Low energy, passive and zero-energy houses

“The Renewable Sources: Sun, Wind, Water are considered as building material in all respects, and their action as being able to influence the settlement character of the city”

Le Corbusier
The use of renewable sources will meet satisfaction of the required energy needs

Extensive need of human to the energy sources is always one of the essential issues in the human life and effort in order to access to the permanent source of energy is one of the oldest human's dreams. Meanwhile, human always looks for the permanent source of power in his imaginations which can be accessible in every time and place. With the advancement of the human civilization, the plants especially the trees, wood and after them the coal, oil and gas entered to the energy market but because of various reasons such as increasing need to the energy, limited fossil sources, environmental pollutions which are resulted from the burning and evaporation of the toxic gases which cause the breathing problems, increasing of the hot water springs. With increasing of the air temperature and extensive changes of the climate, the scientists and experts decided to use the clean energies such as solar energy, wind energy, geothermal energy, hydrogenous energy and etc instead of limited fossil energies in order to prevent the resulted challenges and dangers. Therefore, the developed countries have focused strictly on using other energies of the nature especially the renewable ones.

Increase of the standard of living in countries, advancement in different fields and increase of the population has led to proliferation of the energy consumption. The current population of the world is about 6 billion and its annual growth rate is 2-3% approximately which is doubled every 20-30 years. In addition, per capita consumption of the energy in the global scale is 0.8 KW. According to the economical indicators, the amount of national per capita gross profit increases 2-5% in one year progressively. Hence, if the efficiency of changing energy to the national capital be considered as a constant amount, the world consumption of the energy will grow 4-8% annually. According to these numbers, the energy consumption of the world in the next century will be high. Consequently, there is an important question, “Do the fossil sources of energy in the next century meet the required energy of the world in order to survive, develop and improve?”

From long ago, human tries to prepare the new opportunities for himself through the usage of the abundant and accessible energy of the nature in order to make the work easier, perform his activities with less cost and more speed and take additional steps to his comfort.

The first used energy by the human was the energy of the sun. Human took many advantages from the light and heat of the sunlight so that this energy became an inseparable part of process of some industries and even at the present has maintained its position. The people who accessed to the open currents of the water or lived in the windy lands, used this moving energy and with converting and restraining that, increased their powers for performing the more difficult and great works. Another used energy which the human was familiar with that in the past was the thermal energy of the earth. The people who live in the volcanic areas used this energy consciously or unconsciously for exploiting the thermal-therapeutic specifications of the hot water springs. With increasing the population and its extension and dispersion and also synchronous to the increasing need to the new and more practical and effective energies, the human discovered the fossil fuels gradually and found it as an inexhaustible source which was the promise of a brighter future.

Dependence of the human to the fossil fuels increased more and more and with the development of the science and technology, production of the various machineries and tools and especially with the occurrence of the Industrial Revolution, utilization of the fossil fuels reached to the peak point. However, along with these developments, the human found that in addition to the limitation of the fossil energy, its utilization will not be with-out cost. Soon afterwards, the consequences of the burning of the fossil fuels changed to the new challenge of the communities. For example, the annual current consumption of the oil is about 10 billion tons which will be increased. Although the coal is one of the most primary fossil fuels but today 40% of the world electrical energy and 56% of the electricity of the U.S.A are provided from the coal and annually several billion tons of gasses NO2, SO2 and CO which resulted from the burning of the coal are released in the earth atmosphere. There are two methods for using the renewable energies. The first method is the combinational method which all of these energies are transferred to the electricity. In the second method by applying the specific devices, these energies are used directly in heating, cooling and mechanical rotor axes (method of supplementary collections). The second method is premier and more efficient than the first method due to the removal of the unnecessary transformations but because of the inclusiveness of the technology, there is more tendency toward the combinational method.
Non-Renewable Energies

Fossil fuels such as coal and oil are made from the residual of the plants and animals which have been buried under the seas in the old times and naturally are found in solid, liquid or gas form or combination of them in the mines. These fuels are divided into two types.

Live hydrocarbon sources
Live hydrocarbon sources include the residuals of the plants, trees, bushes and other herbs which are used as the fuel in different cases.

Dead hydrocarbon sources
Coal
Coal is one of the sources of producing the fossil energies which often found in the underground mines. The utilization of the coal in the current conditions can be possible through spending high cost and hard work. Coal has more applications in thermal ovens, freighter ships and steel factories due to the high heat production.

Oil
The oil is a black and tense liquid which is extract-
ed from the underground through drilling the deep wells and be considered more than other fuels since its extraction, reservation and purification is easier than the others.

Gas
Gas is one of the hydrocarbon sources which can be achieved through special techniques.

Natural gas
It is a combination of the gasses methane, ethane and propane. This gas is achieved from two sources of independent gas and the gas together with the oil.

Liquid gas
This gas is the most practical consumable gas because of its easy transformation from the gas form into the liquid form and it is used in the household capsules. These gasses are the combination of the propane butane, propylene and butylene or indeed a combination of the refined parts of petroleum.

The reasons of the need to find a replacement
There are two main reasons for replacing the new energy sources instead of fossil fuels.
• Limitation of the sources of fossil fuels

Regarding to the population growth and increase of the annual energy consumption, the average consumption of the fuel is about 10 billion tons so that in the current time, this amount will increase to 15 billion tons. This increase leads to the reduction of the fossil fuel sources. According to the studies, the average life of underground sources of energy such as the oil, coal and natural gas will not be more than 100 years and this growth demonstrates the need for alternative sources.
• Environmental dangers

Global warming and Greenhouse effect
• Consumption of the fossil fuels releases the carbon dioxide and other gasses. Excessive accumulation and increase of these gasses in the earth atmosphere create a thick layer of gas which such as the plastic coverage of the greenhouses, prevent the return of extra heat which resulted from the radiation of the sun light to the earth surface to the space and keep the heat in proximity of the earth surface and warm the air of the earth such as the greenhouse. According to the estimation of the scientists, the temperature of the earth during the present century will be increased between 0.8°C and 3.5°C because of this environmental phenomena. In one hand, this effect makes the extensive climatic changes in different regions of the earth and some events such as the drought or the flood and intense storms conversely. In the other hand, this effect causes the rising of the water of the seas and oceans and the submergence of the many coastal and land regions which are prone to be changed into the land due to the increase of melting rate of the polar ices.

Air pollution and acidic rain
Acidic rains are one of the forms of air pollution. The gasses sulfur dioxide and nitrogen oxide which resulted from the consumption of the fossil fuels are combined with the steam of the air and make the sulfuric acid and nitric acid which move with the clouds over the extensive area of
the earth and when the clouds change to the rain, these acids return to the earth surface and de-
structure the woods, vegetation and even the human
made buildings and contamination of the surface
and underground water sources.

Renewable Energies
The renewable energy is any type of energy which
is used without exhausting its sources.
- Light (Solar Energy)
- Wind
- Water (Hydropower)
- Rock (Geothermal)
- Ocean Thermal
- Rock (Geothermal)
- Plants & Animals (Biomass)
- Woody Biomass

Solar Energy
Sun is the great and infinite source of energy
which the survival of the earth is dependent to
that and other kinds of energies have derived
somehow from the sun. If we gather all the fossil
fuels and burn them, the resulted energy is equal
to the energy of 4 days radiation of the sunlight to
the earth. The light and heat which reach to the
earth per second is million times more than the
power of the nuclear bomb which exploded in
the Hiroshima and Nagasaki. At the present, the
energy of more than 160000 villages in the world
is supplied based on the solar energy and this is
the beginning of the route. In Indonesia which
consists of several thousand big and small is-
lands, utilization of the power plant and electrici-
ty transmission lines is impossible approximately.
Therefore, the solar energy is the only hope of the
20 million population of the Indonesian villages.
At the present, there are several extensive and
uninterrupted researches in this field and in the
near future, the production and utilization of the
great solar power plants will be comprehensive.
Today, there are 6 methods for producing the
electricity from the sunlight: Parabolic mirror,
central receiver mirror, parabola mirror, sterling
mirror, solar chimney, solar pool and photovolta-
ic optical cells. However, today the solar energy
is restrained through the usage of solar cells or
implementation of the thermal power plants. The
inclusiveness of the other methods is under inves-
tigation. The Nevada desert which was the place
of nuclear tests in the past, at the present has
been changed to the world great solar laboratory
and the World Bank is under the pressure from
long ago to undertake the expenses of the ex-
plotion plan of solar energy and other compat-
ible plans with the environment. The solar power
plants with very low cost and without producing
the destructive gasses and without occupation of
the useful places will be replaced instead of fossil
fuels power plants completely.

Our country, Iran, locates on the sun belt of the
earth and one fourth of its area has been covered
by the desserts with the radiation intensity of
more than 5 kwh/m², therefore if 1% of this area
be used for constructing the solar power plant
with the efficiency of 10%, the power of the pro-
duced electricity is 9 million MWh more than the
seven times amount of gross electricity produc-
tion of all the power plants of the country during
the year 1987. There are some performed activi-
ties in this field in Iran including solar air heaters
and the solar reservation and dryness collections,
solar water heaters, solar bath, thermal tubes,
solar desalination devices, solar concentrators,
solar followers, solar passive collections and so-
lar cooling systems. Annually, the 1034 x 2.7 J of
the solar radiation energy reaches to the surface
of the earth. In Iran, the average radiation of the
sun is 5 KWh/m² (horizontal plane) which this
amount of received radiation reaches to the av-
erage of 1600 KWh/m² annually. Regarding to the
mentioned radiation intensity which is more than
the average of radiation intensity in many European countries such as England, the utilization of the solar energy in Iran is practical technically and economically.

Wind Energy

Wind is a kind of energy which originally is created from the radiation of the sun to the earth and the different temperature between two regions and sometimes it can be so powerful which the strongest structures can not resist against that. In some regions, the permanent or seasonal wind flow has the certain repeated period and this feature can be used for estimation of the accessible wind energy.

The present form of the wind power plants were established on 1980s and produced just 50kW energy in that time. But today, this amount reaches to the several MW. The present power plants change their direction based on the wind direction and transform the kinetic energy of the wind to the mechanical energy and then to the electrical energy by the horizontal and vertical axes. The wind power plants with very low cost, high power, no environmental pollution and need to extensive space can be useful in many areas. In our country due to the specific geographical position, there are many seasonal and no seasonal winds in different seasons of the year. Hence, there are many windward lands which the installation of the windy power plant in them is possible. In addition, due to the extensive beaches, the coastal winds are always operational. Today the internal industrialists have produced different forms of wind generators inside the country. Moreover, some power plants have been installed in some windward regions such as Roodbar and Manjil and the construction of the power plants in other cities is under investigation. For example, the province Sistan va Balochestan can be an appropriate choice for this purpose due to the 10 day powerful seasonal winds.

In the country, regarding to the windward regions, there is a suitable ground for expanding the utilization of the wind turbines. The wind electricity generators can be an appropriate alternative for the gas and steam power plants. According to the studies and investigations in estimating the potential of wind in the country, there are 45 appropriate sites in 26 regions of the country. Regarding to the 33% general efficiency, the nominal capacity of these sites is about 6500 MW and this is on conditions that at the present the total capacity of the power plants of the country is 34000 MW.

Nuclear Energy

The nuclear energy is one of the most controversial renewable energy which despite of the problems and concerns, many countries consider the nuclear energy as the healthiest and cheapest energy source for their future and have placed its utilization in their long term program. The price of each KWh of the nuclear electricity is equal to the half of the cost of produced electricity from the fossil fuels. The biggest problem of this energy is the radioactive sewage which needs some solutions in order to excretion on the extensive scale. This energy can be used for producing electricity and heat but there are some concerns about the limited Uranium of the world. However, the development of the technology has provided the possibility for using other radioactive elements instead of Uranium. Regarding to the sources of the Uranium and other similar elements in Iran and its indigenous nuclear technology, Iran is one of the country which can accelerate its energy development through investment in this part. In order to produce the nuclear electricity, Uranium should be enriched up to 3%. There is a possibility for this enrichment in Iran and its two under construction power plants will increase the electricity production power of the country more than 2000 MW in the near future.
Geothermic Energy

The earth is a live planet which is always changing from inside and outside. The center of the earth consists of the molten and under pressure fluid and there are some valves on its surface for controlling this pressure and preventing the splint of its shell. These valves are the volcanoes which transfer the thermal energy of the depth of the earth to the surface and in their surrounding always there are many wells, boiling water and geyser fountains. The geothermic energy is provided from the decomposition heat of the radioactive materials, chemical reactions of the earth center, molten core of the earth, orogeny phenomena and the pressure of the thick layers in sedimentary basins. This heat can be directly transferred to the mechanical machineries or can be used for producing the electricity. Meanwhile, this heat can be used in industry indirectly. Today, this energy is used for some processes such as dehumidification, distillation and heating and cooling of the industrial environments and those regions which have not the possibility for constructing the geothermic power plant, are transferred usually to the tourist attractions and playground. At the present, despite of the lack of economic justification for using this energy, more than 35 countries use this energy directly and about 20 countries use that indirectly. Since Iran locates on the world volcanic and seismic belt, it has many geothermic sources which the most important and richest of them have located in Sabalan, Damavand, Makoo and Sahand. Totally these sources have the thermal reserve which is Joule equivalent.

The phases of the first project of the electricity production from the geothermic energy in Iran, has been performed with the electrical capacity of 50Mw on 1995 in the hillside of the Sabalan mountains. Meanwhile, in Oct. 1996, the potentiometric project of the geothermic energy of Iran was started by the New Energy Organization and 10 areas have been potentiometric.

Oceanic Energy

The oceans are the great sources of the moving energy which can be seen in different forms such as waves, tide and surface or underwater constant currents which are resulted from the temperature difference between the different points. Investigation of the usage of the wave energy has not the long history and there are only a few decades which the researches have been started in this field but utilization of the energy which resulted from the temperature difference in oceans backs to the year 1929.

Today, the construction of the ocean temperature energy conversion power plants (OTEC power plants) is increasing but transferring the resulted energy from the temperature difference to the electrical energy, is a new step in electricity production. However, there are some limitations in this direction which should be removed. For example, the power transmission lines should be expanded to the beaches and the production and transmission electricity buildings should be strengthened against the sea storms and coastal weather. These kind of power plant equipments
are still expensive and massive. Construction of these power plants lead to supply of the electricity for some regions which there is no possibility for connecting to the nationwide electricity network due to the inaccessibility or being trapped in the water. Meanwhile, it is possible to provide the sweet water of all these power plants. Iran with some regions with the coastal lines of more than 1800 km in the south and different islands is one of the countries which can use this energy very much.

**Iranian hydroelectric power plants**

The hydroelectric power plants are eco-friendly power plants which can be used for multi-purposes due to the easy utilization, appropriate expenses of controlling the flood, supplement of the water, production of the electrical energy, contribution to the stability of the network and etc. One of the most important advantage of the water management in Iran is the control of water sources through constructing the storage dams. Iran not only has reached to the self-supporting in study, designing and implementation of these structures but also at the present is considered a the 3rd world country in constructing the dam and control of the water sources due to the under constructing 85 big storage dams.

**Biomass Energy**

Biomass fuels which are resulted from the wastes of the woods and the agricultural crops of the world are considered as the biggest solar energy source which can provide the equal energy of 70 billion tons petroleum for human annually. This amount is 10 times more than the world annual energy consumption. The important point in using this source is that the CO2 which resulted from the biomass fuels, will be absorbed and consumed by the fresh plants again and has no effect on the greenhouse phenomenon and warming of the earth. These fuels are used more in heat production and although their efficiency is not high in comparison with the fossil fuels, but they lead to considerable economical saving. The usage of this energy is encountered with some limitations such as lack of appropriate place for constructing the installations of biomass fuels projects and the possibility of applying the defense policies of the forestation. Iran has the extensive forest resources and is one of the countries which can use the biomass fuel for providing the required energy in the forest areas. In addition, with further investigations and identification of the economical justification, all the facilities for using this energy are available in Iran.

Regarding to the investigations and all the possibilities, changing the biomass to the energy can have the considerable effect in providing the energy of Iran. For example, the total useful energy of the urban garbage is equal to the 89.745 peta joule. Meanwhile, according to the current technology, there are another examples such as the energy of the methane and alcohol which produced from the agricultural, forest and animal wastes, potential of the producible electricity from the urban garbage of the country and the biogas which resulted from the anaerobic purification of the urban sewage. 
Advantages of Using the Renewable Energies

1. Lack of producing the environmental pollutions
2. Free and unlimited energy source
3. Very long useful life
4. Easy accessibility
5. Renewable resources

Low energy, passive and zero-energy houses

Global warming, thinning of the ozone layer due to the usage of the various pollutants, increasing the environmental pollution, decline of the biologic species, irrevocability of the fossil fuels and their carbon emission have jeopardized the health and survival of the earth and have made the energy crisis. The crisis which along with the increasing of the environmental pollution was considered as the warning to the people worldwide in the middle of 1960s and led to formation of the advocates’ groups of environment in different parts of the world. Architects such as another involved persons have tried in order to find the new ways for preparing a pleasant life for humans. Since all the activities of the humans are performed in the made spaces by the architects and all of the strong points and weak points of these spaces affect directly on the health of human and environment, therefore, the architects have a critical role. Designing in the part of building as the most consumer of the energy among another parts with the zero energy application, definably can be considered as an important step in achieving the reciprocate purposes against the existing energy crisis.

As we know, with the industrial revolution and technical and technological developments in architecture, the local architecture of different parts of the world which was formed based on the nature and its surrounding environment was forgotten as the climate. The decade of 70 can be considered as the decade of familiarization with the environmental crisis which created some reactions which led to stable formation which not only paid attention to the nature, but also focused on human, humanitarian and humanistic dimensions.

Environmental purposes: Creation of the better environmental quality, reapplication, removal of the garbage and survivor, consumption of little changed materials, recycle of materials and recycle of water from the wastewater and removal of the pollutant emission.

Economical purposes: creation of the better values, reduction of the current expenditures, reduction of the energy consumption, presentation of the flawless solutions and ease of production methods and prospective solutions.

Social purposes: security, conformability, quality utilization, removal of the energy shortage, creation of the sound insulation, flexible programs, health life, home cares, permanent instruction (Jalalian, 2008, p.2)

In the year of 2001 in Iran, more than 33% of the energy has been consumed in the buildings. One of the method for reducing the energy consumption in buildings is their appropriate design in preventing the heat exchange of the building with the surrounding environment or in other words, their compatible and stable designing with the environment.

The standards of the compatibility with the natural environment as the innovation of the 21 century and then the idea of zero energy building and sometimes the buildings with additional energy which their practical samples are in U.S.A., England and Ireland have decreased the energy consumption to the 85%, 77% and 75% respectively. Utilization of the wind and sun as the climatic features and the tradition of the building construction in Iran and all parts of dry and hot regions have an important role in constructing these buildings and decreasing the environmental pollutions and the energy consumption. Utilization of the traditional ventilation systems and modern systems lead to 50-60% reduction in consumption of the fossil fuels. This issue is valuable in possessing the clean environment.

History of thriftiness in energy consumption

The first movements of the concept of pure energy are attributed to the Poldolinsky at the early of 19 century which was used for connecting the thermodynamic principals to the economical production in the agriculture field. The subject of recovery of the energy and fossil fuels entered into the industry field and approximately in 1960s, the concept of pure energy was reviewed in order to fast reduction of the consumption due to the tangible energy shortages. The process of investi-
gating the production of the pure energy in 1970s led to its analyses by renewable technologies until this process changed to the production of the new technologies practically in 1980s. Then, in 1990s the concept of energy and its necessary technologies was developed and in the next decade, different organizations were established for producing the tools and supporting the various workshops to the extent that in the past decade, some mandatory and persuasive solutions were presented strictly by the government organizations in order to present and utilization of these technologies (www.zerocarbonhub.org).

Definitions and expressions of the Zero energy building

There are various methods for defining the zero energy buildings.

What is the definition of the zero energy building in order to be produced? What are the scope and extent of the zero energy buildings? What is the purpose of its construction? What are the resulted values of this building for the future user and even the employers of these projects? Are the home users worried about the high expenditures of the energy?

It can be noted that some organizations such as DOE15 pay attention to the national energy sources and attempt in order to use the primary energies and energy sources. The designer engineers attempt to achieve the stable and compatible designing with the climate and reduction of the fossil fuels consumption in the building. Therefore, those who are worried about the environment, attempt to reduce the emission of the pollutions resulted from the consumption of the fossil fuels and loss of energy as far as possible. Also, regarding to the novelty of these concepts in Iran, the following items should be considered:

- Utilization of the principles of Iranian traditional architecture as the compatible architecture with the climate in order to maximum utility of the current energies in the nature and combine that with the modern energies.
- Suggestion of the new ideas in combining the modern and traditional architectures.

Generally, the zero energy buildings are the new generation of the green buildings which produce the most part of their required energy from the obtained energy of the climatic elements and without the electrical energy and fossil fuels. The reason is that all the required energy of the building is produced within the building through the ventilated systems which produce the green energy.16 Since the fossil energy does not use in these buildings, these are free of co2 and have the comprehensive systems for increasing the energy efficiency, reducing of water consumption and minimizing the waste products.16 In these buildings the architect has an important role. Some of the important items in this building are direct and indirect usage of the light and heat of the sun, usage of the air natural current, utilization of the modern energies and suitable direction.

Figure 43: Net Zero home. Source: www.greenengineering.ir
Advantages of the zero energy buildings

1. Compatibility with the nature.
2. Balance of the energy consumption with the energy demand.
3. Maximum usage of the passive energy.
4. Reduction of the energy demand.
5. Reduction of the electricity consumption.
6. Removal of the energy consumer waste systems.
7. Just sufficient design.
8. Considerable reduction of the environmental destruction.
10. 100% usage of the renewable energies.
12. Heating through passive systems.
13. 50% reduction of drinking water consumption.
14. Utilization of the ventilation system without mechanical device.
15. Optimal usage of the wooden wastes and production of the bio fuel.

Designing principles (zero energy buildings)

General principle in designing the zero energy buildings is based on the more reduction in energy consumption.

The Canadian Zero Energy Buildings Association presents two general solutions for designing these houses:

1. Appropriate designing regarding to the structure and physic of the buildings which leads to 70-80% reduction in energy consumption due to the observance of its principles (this solution will be explained in the next parts).

2. Utilization of the renewable energy sources such as solar energy, wind and bio fuel. This can be applied in these houses by using the renewable technologies.

Physic of the building (zero energy buildings)

The important principles for reducing the energy consumption are as follows:

1. The general formation of the building be in square or rectangular shape as far as possible in such a way that the building has the minimum angles and peripheral walls.
2. Installation the more windows in southern part and the less windows in northern part.
3. Minimum number of external openings.

Disadvantages of the zero energy buildings

- High primary expenditures and need to their usage instructions.
- Shortage of the technical knowledge, abilities and required experiences in designing and constructing the zero energy consumption buildings.
- The technology of the photovoltaic cells has reduced the prices near to 17%. This leads to reduction of the investments on energy producing systems which are based on the solar energy.
- Reduction of the possibility for selling these buildings due to the primary expenditures and need to hard competition in sale.
- The absorbed solar energy by the shell of these buildings has the more efficiency just in the southern part and in the other parts its efficiency decreases more due to the presence of the shadow.

U.S.A.

Recently the Department of the Energy of the U.S.A. (DOE) have executed the procedure of manufacturing the energy producing tools from 1995 which consisted of 3 processes:

- The process of definition and presentation of the new produced tools which their production is based on the suggestion of the people, users and workshops and experiences in developing the current tools.
- The process of preparing an inventory of supported current tools by DOE.
- The process of supporting the workshops in order to access to the suggestions of the users and transmission of their opinions regarding to their needs in the energy production process.

In U.S.A., the program of the government organizations has been focused on researches, devel-
opment and promotion toward the zero energy buildings. According to the statement of the state of California, all the residential buildings and commercial buildings will reach to zero energy consumption until 2020 and 2030 respectively. Meanwhile, according to the program of the Massachusetts, the buildings will reach to zero energy consumption until 2030 (Johnson controls, inc.2008 :5).

Europe

After transmission of the low energy buildings to the zero energy buildings, there will be some energy plus buildings which produce energy more than their consumption during the year. Among the countries, France hopes that all the buildings have the extra energy until 2020. Another countries believe that just the energy consumption in the buildings should be considered. The purpose of the stable building is the effective usage of the sources which reduce the negative effects of the buildings on the nature such as reduction of the waste products through using the recycled constructive materials. It should be noted that the zero energy building can be stable or not based on observance or non-observance of the principles of the stability respectively.

The world integrated life is an idea which has developed by the World Wildlike Fund (WWF) in England. This idea consisted of stability laws and principles of the building which includes the principles of the zero carbon building.

According to the analyses, the consumption of the natural energies in Europe is 3 times more than the capacity of the earth. Therefore, alteration in their life style is highly recommended.

Low energy and passive houses

High energy prices and global climate changes are forcing us to change our energy consumption habits. Since buildings use 40% of the total energy in the US and European Union, energy efficient houses are becoming more and more interesting. Number of ongoing governmental and local society projects are focusing on human continence and ways to change consumer’s behavior. For example:

- use public transport (buses, subways, trolleys, trains)
- buy smaller and environment friendly cars
- turn off electronic devices that you are not using (TV, computer)
- when shopping for new electronics, favor products with low energy use (labeled with A++, A+, A, B) (www.our-energy.com)

Energy Efficient Houses

Energy efficient house is any type of house that uses less energy than a regular one. Optimization of energy consumption and best possible use of available energy is not new idea. Similar to modern time, in the ancient time people dealt with a problem of constructing buildings with appropriate thermal comfort, and the main question was how to make a house warm during winter and cool during summer. This concept was first studied by Socrates, a classical Greek philosopher, almost 2500 years ago. In early literature this concept is known as “Socratic House”. “Socratic House” is a hypothetical description of energy efficient house.

The essence of Socrates’ studies was influence of the Sun movement to the shape, form and construction of a building. “Socratic House” base plan is trapezoid with base oriented to south and roof falling toward north to avoid wind blasts. North wall is massive because in that time there was no thermal isolation. South oriented porch was projected to block high summer sunshine, but also to allow low winter sunlight to get deep into rooms. House on northern hemisphere should face to south and in southern hemisphere to north to get most of the solar energy. On other side, back wall should be isolated very well to avoid energy losses.

Today, there are five main categories of energy efficient houses:

- low energy house
- passive house (ultra-low energy house)
- zero-energy house (or net zero energy house)
- autonomous building (house with no bills)
- energy-plus-house

Low Energy House

There is no global definition for low-energy house. Because national standards vary considerably, ‘low energy’ developments in one country may not meet ‘normal practice’ in another. In Germany a “Low Energy House” has an energy consumption limit of 50 kWh/m² per year for space heating. In Switzerland the term is used in connection with the MINERGIE standard – no more than 42 kWh/ m² per year should be used for space heating.
Right now, it is generally considered that low-energy house uses around half of energy mentioned in those standards for space heating, typically in the range from 30 kWh/m² per year to 20 kWh/m² per year.

Low-energy buildings typically use high levels of insulation, energy efficient windows, low levels of air infiltration and heat recovery ventilation to lower heating and cooling energy. They may also use passive solar building design techniques or active solar technologies. These homes may use hot water heat recycling technologies to recover heat from showers and dishwashers.

(our-energy.com)

Autonomous Building

An autonomous building is a building designed to be operated independently from infrastructural support services such as the electric power grid, municipal water systems, sewage treatment systems, storm drains, communication services, and in some cases public roads.

Autonomous building is much more than energy efficient house – energy is only one of resources to gain from the nature.

Energy Plus House

Energy-plus-house is house that on average over the year produces more energy from renewable energy sources than it imports from external sources. This is achieved using combination of small power generators and low-energy building techniques such as passive solar building design, insulation and careful site selection and placement. Many energy-plus houses are almost indistinguishable from a traditional home, since they simply use the most energy-efficient solutions (appliances, fixtures, etc) throughout the house. In some developed countries power distribution companies have to buy surplus electricity from energy-plus homes, and with that approach house can even earn money for owner. (www.our-energy.com)

Passive House

(Ultra Low Energy House)

Definition of passive house is: “A Passive House is a building, for which thermal comfort can be achieved solely by post heating or post cooling of the fresh air mass, which is required to fulfill sufficient indoor air quality conditions – without a need for recirculate air”. Some countries have their own standards that define passive house in more strict way. In Germany the term passive house refers to the rigorous, voluntary, Passivhaus standard for energy efficiency in buildings. In Switzerland is in use similar standard – MINERGIE-P. It is estimated that the number of passive houses around the world range from 15,000 to 20,000 and the vast majority have been built in German-speaking countries or Scandinavia. The Passivhaus standard was developed in Germany in the early 1990s by Professors Bo Adamson of Sweden and Wolfgang Feist of Germany and the first dwellings to be completed to the Passivhaus Standard were constructed in Darmstadt in 1991.

The Passivhaus standard can be applied not only to residential dwellings but also to commercial, industrial and public buildings.

The Passivhaus standard can be applied to any climate in the world and works equally as well in warm climates as it does in more moderate climates. To date Passivhaus buildings have been designed and built in every European country, Australia, China, Japan, Canada the USA and South America... a research station has even been constructed to the Passivhaus standard in Antarctic (our-energy.com)

The Passivhaus standard

- The building must not use more than 15 kWh/m² per year in heating and cooling energy.
- Total energy consumption (energy for heating, hot water and electricity) must not be more than 42 kWh/m² per year
- Total primary energy (source energy for electricity and etc.) consumption (primary energy for heating, hot water and electricity) must not be more than 120 kWh/m² per year

To get some perspective on those requirements, we can compare house built to meet Passivhaus standard with houses build to meet local regulations in some countries:

- In the United States, a house built to the Passive House standard uses between 75 and 95% less energy for space heating and cooling than current new buildings that meet today’s US energy efficiency codes. The Passivhaus in the German-language camp of Waldsee, Minnesota uses 85% less energy than a house built to Minnesota...
building codes.

- In the United Kingdom, an average new house built to the Passive House standard would use 77% less energy for space heating, compared to the Building Regulations.
- In Ireland, it is calculated that a typical house built to the Passive House standard instead of the 2002 Building Regulations would consume 85% less energy for space heating and cut space-heating related carbon emissions by 94%.

Building costs for passive house were in past much higher than building costs of regular house, but with technology development and higher demands for specifically designed Passivhaus building products costs are now much lower. For example, in Germany it is now possible to construct Passivhaus buildings for the same cost as those built to normal German building standards because of increasing competition in the supply of the specifically designed Passivhaus building products. (our-energy.com)

Can a Passive House can also be Net Zero... And can a Net Zero house also be passive? Yes! But the two things are NOT the same

The fundamental differences between the Passive House standard and a Net Zero building are:

Passive House is focused on achieving an absolute minimum amount of energy use required to heat and/or cool a house (up to 90% less than a standard house of similar size) as measured on a BTUs per square foot basis...

A Net Zero building is designed to generate as much energy as it uses in a year. (green buildings, poplar-network.com)

Why Passive House?

Building to the Passive House Standard reduces our buildings’ operational energy demand to an optimized extent through passive measures and components such as insulation, airtightness, heat recovery, solar heat gains, solar shading and incidental internal heat gains. Passive House reliably delivers up to approximately a 90% reduction in heating and cooling demand and up to a 75% reduction in overall primary energy demand when compared to our existing building stock. A Passive House may be any building type such as home, school, office, store or factory. Passive House buildings affordably and predictably provide the most resilient, comfortable and healthy interior environments.

When considering a building standard there are eleven complimentary reasons to choose the Passive House Standard.

1. It fundamentally addresses the climate crisis imperative. To mitigate the worst effects of climate change we are required to decarbonize our economies while meeting the demands of global development. Passive House does this by providing the same low energy budget to both the rich and the poor. With Passive House we can slash energy demand and maintain services in the developed world, and also build modern services in a low-energy manner in the developing world. The large scale leader in this effort is the Brussels Capital Region of Belgium where all buildings, new and retrofitted, public and private, residential, commercial and institutional, will be required to meet the Passive House Standard starting in 2015.

2. It is a global building energy performance standard. While the energy standard is uniform for all, the paths to achieve it are widely varied and necessarily incorporate local climate and building tradition specific optimization. Whether the local building tradition is wood or masonry, or the climate is heating dominated or cooling dominated, hot and humid or a mixed climate, Passive Houses can and are being realized.

Figure 44: Net Zero house, Source: www.google.com
3. Its development is a global collaboration. With roots in the study of low energy buildings from China to Canada, it is the active exchange of information and experiences by scientists, engineers, designers, builders and occupants, across the earth’s regions and climate zones, that is driving forward the successful evolution and implementation of Passive House worldwide.

4. It produces a predictable product. Passive House utilizes a clear methodology that focuses on optimizing passive building components with the globally validated energy model called the Passive House Planning Package (PHPP). The PHPP energy model is the key tool used to integrate all building components and systems, and serves as the basis of verification for the Passive House Standard. The PHPP’s high level of accuracy sets it apart from other design tools, allowing, for example, heating and cooling systems for Passive House projects to be confidently sized approximately 75% smaller than typical for a given building. To further insure success, the methodology may also include the use of scientifically validated and certified components, design and construction by certified architects, engineers and tradespersons, and the building may be certified by one of the currently 26 accredited certifying entities around the world.

5. It is affordable in both construction and operation. The methodology results in only an added overall construction cost premium of approximately 5% to 10% because the construction costs for high performance elements are substantially offset by a reduction in heating and cooling systems sizing. Typically the first Passive House projects by architects, builders and consultants may have a higher cost premium due to the learning curve and lack of optimization, but with subsequent projects and better optimization, the cost premium can progressively shrink to 5% or less and even go negative. Because the reduced energy use translates into substantially lower energy bills the cost premium should have a simple payback of under 10 years. And because the cost of borrowing the additionally required money should be less than the monthly cost savings in energy bills, the return on investment really starts in the first month of occupancy. Lower energy bills and protection from future price shocks make Passive House occupancy affordable for the long term.

6. It produces the most comfortable and healthy indoor environments. With airtightness, continuous insulation, high quality windows and other measures, Passive Houses often have the most comfortable, quiet and draft free environments. With continuous low-volume ventilation providing filtered fresh air to living and working spaces, the indoor air is free of dangerous concentrations of typical contaminants. And unlike buildings that rely on manual ventilation, people in a Passive House can open and close windows whenever they wish.

7. It’s a catalyst for local manufacture of high-performance products. Industry has developed to serve the implementation of the Passive House Standard, first in central Europe and now globally. Typically small and medium-sized companies have developed specific products and services to cater to its growing needs. Around the world more companies are recognizing the potential of this sector and are either improving their existing products or developing new ones to cater to their local as well as regional and global markets.

8. It enables storm resilience. In the coldest weather, without power, a Passive House can maintain safe indoor temperatures for an extended period without power. In the hottest weather, if overnight passive cooling is available, it is also possible to maintain safe indoor temperatures for an extended period without power. By substantially reducing peak power demand and enabling local renewable power sources, utility system redundancies and a more robust power distribution system are possible.
11. It locks in energy savings for future generations. Unlike renewable energy production or energy saving machinery that requires active maintenance and replacement, Passive House emphasizes things like insulation, airtightness and external shading that will save energy today, tomorrow and everyday into the future without significant maintenance or replacement costs. Consequently, any lost opportunity to optimize performance with an investment in passive measures will become a much bigger future liability in our efforts to decarbonize.34

Passive House is uniquely raising our expectations of what sustainable high-performance building can be and should be. Choose Passive House. The project was developed by the building services company Air optima, which now has its headquarters in the world’s first Passive House Premium. With a total area of about 900 square meters, the building, officially known as the “House of Energy”, also has space for the operations manager’s flat, a training center, and a permanent exhibition on the topic of “Construction and Refurbishment”. The three-story solid construction was certified by the company Herz & Lang (nypassivehouse.org)

The first Project of zero energy building in Iran

Project of design and implementation of the First Iranian zero energy building was defined by the Materials and Energy Research Institute in 2012 and its planning and implementation in the form of EPC was assigned to the Improvement and Modernization of Energy Consultants Company (MABNA). The zero energy buildings are those which their annual net energy consumption is zero. The zero energy building of the Improvement and Modernization of Energy Consultants Company in the Karaj province was designed and implemented as the first Iranian zero energy building with the purpose of decreasing the primary energy consumption and compensation of the consumed energy through the energy production from the reproducible and clean resources and its construction phases are performing right now. The mentioned building with an area of 2000 m2 has been designed in two floors and has the research-training usage. Based on the architecture of this building and other elements such as wind capture and greenhouse, the required energy of the building has been decreased as far as possible and some parts of this required energy are prepared by using the solar energy.

Utilization of the elements such as solar passive design, direction of the building, locating of the spaces, insulation in designing the building architecture and application of the modern standards of designing decrease the energy consumption of this building up to 90% (87 KWh/m2) in comparison with the normal building and this amount of energy is compensated by the solar devices. In addition to the energy application in designing the building architecture, several elements such as wind capture and greenhouse are used in the building which in addition to representation the ideas of the traditional architecture, its combination with the modern aspects of the building is considerable.

Figure 45: The world’s first Passive House Premium building, located in Kaufbeuren in Bavaria. Source: www.globalconstructionreview.com.

Figure 46: The first Zero Energy house, Iran. Source: www.memarnews.ir.
Meanwhile, usage of the wind capture in the building has been caused the reduction of energy consumption of the building in the middle seasons. Utilization of the controlling modern systems and BMS in building leads to appropriate control on energy consumption of the building. Finally, the usage of the photovoltaic and solar warm water systems for producing the energy from the renewable and clean sources have transferred the above mentioned building to the zero energy building.

Geometry of the wind capture

Figure 47 represents the wind capture of the zero energy building. The height of the wind capture is 14 m from the surface of the earth. For beautification of the corridors in the building, the air inlet and outlet valves between the wind capture and corridor have been constructed in a grid form. This is a two-way wind capture with 8 air inlet valves which 5 valves are in the western side and 3 valves are in the southern side. Valves have a rectangular shape. According to the measurements in the environment, the direction of the wind is from the southwest. Therefore, the wind enters the wind capture from the both sides. According to the observations and measurements, wind blows the building from the southwestern direction with the speed of 4 m/s and the angle of 45°. It should be noted that basically this building is designed and constructed such that has the ability for receiving the maximum wind and the measurements of the wind have been taken before designing the building in the area.

One Example of Sustainable House in Iran

Noori house (Light house)
The Noori (Light) house which made by Patan Company has the sustainable and contemporary design without any damage to the lifestyle of the inhabitants. The idea of designing this house is making the house which visually attracts the attentions and the place which its environmental systems and construction methods do not damage the quality of the lifestyle but at the same time adds some spaces to that which are designed for the modern life and make the stability intuitively. The purpose of designing the light house is to prepare the highest level for the stable houses. The standard that all the houses should be designed and constructed based on that until 2016.

Designing
The structure of the light house has a simple warehouse-like formation with the 40 degree slope of the roof. The photovoltaic panels provide all the required electricity of the house and are located on that. An extensive roof covers the central space. The life space is tall and the plan is open light and exposed to the breeze. The bedrooms, bathroom and services and laundry rooms (rooms of radiator device, washing machine and etc,) are in the ground floor and the living room which is the life space is on the first floor and uses one wooden moving structure. It means that the floors are located between the frames and if necessary they can open. The structural system which is used in this house is the kingspan - tek. This system is an insulated panel with the high thermal operation which provides the amount of $U=0.11 \text{ w/m}^2\text{k}$ and the airtight amount of $1 \text{ m}^3/\text{hr}/\text{m}^2$ in 50 pa. which decreases the heat dissipations potentially to the two third of consumption of a standard house. The foundation of this house is consisted of the wooden tape floors which are on the wooden timber ring which is separated from the ground by screw piles with the least damage to the earth.
Practical materials in the light house
In this house the practical materials are renewable and recyclable including wooden frame, oak cover, screw piles, floating floor instead of concrete floors, wool carpet and natural rubber flooring.

Meanwhile, there are two different levels in this house:

1- BASF PCM: this is a phase change material that made of gypsum board which absorbs the heat of the room through changing from the solid into the liquid and puts the heat in the tiny microscopic capsules which are embedded in the floor.

2- Compact concrete surfaces: In order to access the real zero carbon and zero energy homes, the inhabitants should use knowingly those apparatus and devices which reduce the energy consumption and produce the renewable and alternative forms of energy. The applied technologies in this house are divided into two parts in order to achieve the purposes of the zero energy house:

1- technologies of the reducing the consumption and
2- technologies of producing renewable energies.

Technologies of the reducing the consumption

1- Mechanical ventilation with thermal recovery (MVHR)
2- Electricity: usage of the effective devices with the energy label A+++ and low energy lighting technologies which are provided by the LED lights.

Technologies of producing renewable energies in Noori, light house

• Non-fossil-fueled boiler (biomass): the refueling of these boilers is performed by the wood chips which are used for preparing the hot water and heat of space in the winter.
• Solar thermal panels: these panels produce the whole hot water in the summer and part of hot water in the fall and spring and decrease the use of non-fossil-fueled boilers and the amount of wood and minimize the expenditures as far as possible.
• Photovoltaic panels: these panels absorb the solar energy and prepare the whole required electricity for the home and transmit the additional energy to the network.
• External wall (building shell): the system of the walls is the kingspan tek which prepares a structural method with the maximum effective thermal level without any vents.
• Ventilation: in light house, the wind capture is used for effective and flexible ventilation. This wind capture transmits the received light into the depth of the building and creates the appropriate night ventilation for bedrooms of the ground floors.

Figure 49: Noori house, Source: memarnews.ir

Then, when the room becomes cool, this material returns the heat into the environment.

The wind capture receives the wind from every direction and the outside air which has less temperature than still air of inside the house, has been lowered and ventilation will be possible.

• Reduction of the solar absorption: the external shutter shades are used for reducing the received heat. These shades absorb the direct sunlight in the summer and prevents the increasing of the heat.

• Heating: the cover of the building creates the high level of thermal and non-porous insula-
tion, therefore, the house should be warm just in a few months of the middle of the winter.

• Reduction of the light traversing sidewall: According to the amounts of thermal transmission coefficient which are mentioned in the constitution, the light traversing sidewall of this house is 5-10% less than the traditional houses. Meanwhile, the ratio of the light traversing sidewall to the wall is 18% in comparison to the 25-30% in the common houses. Therefore, the living room is located in the first floor and the amount of sun light will be maximized and the bed rooms are in the ground floor.
• **Airtight amount:** with designing the lobby on the front and back of the house, the amount of airtight in light house has been increased and the central space has changed to the thermal core.

With comparison of the light house of Patan company which is based on the different structural laws with the other houses with the same shapes and designs, we can understand that the amount of energy consumption to what extent has been decreased.

![Figure 50: Noori house, Source: memarnews.ir](image)

• **Water:** in designing the light house, the inhabitants are informed to use which water for different usages. For example, the rain water is used for gardening and laundry machine or the used water of bathroom and shower for WC. With observance of all these items, the average of 50% of water can be reserved in comparison with the normal house.

With comparison of the light house of Patan company which is based on the different structural laws with the other houses with the same shapes and designs, we can understand that the amount of energy consumption to what extent has been decreased.

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29 Now North American companies are coming on board to compete with the global market, creating products that can be globally exported. See http://www.casagrandewoodworks.com/windows.html
30 If overnight temperatures remain hot, then comfortable indoor temperatures can only be extended for a matter of days as there is no countervailing cooling mechanism available.
31 The BRTF Report was produced by the Urban Green Council and presented to Mayor Bloomberg and City Council Leader Christine Quinn in 2013 following widespread power outages and resident dislocations resulting from Super storm Sandy. See report here: http://www.urbangreencouncil.org/BRTF/Report
34 Per McKinsey 2010 report, Energy Efficiency: A Compelling Global Resource, “Big gains await developing countries if they raise their energy productivity....they could
slow the growth of their energy demand by more than half over the next 12 years...which would leave demand some 25 percent lower in 2020 than it would otherwise have been. That is a reduction larger than total energy consumption in China today.” Download report PDF here: https://www.dropbox.com/sh/ymplnlh4tcdmarl/eYOX-0buqsK

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“On the one hand, creating architecture and urban planning to correspond with the values and ideals of Islamic society was an essential element in this period. On the other hand, western-influenced trends like Post-Modernism and Deconstructivism, also played a role in Iranian architecture”

(Diba and Dehbashi, 2004, p.34)
Iranian Contemporary Architecture

Iran's contemporary architecture can be divided into three periods. From the 1960's up to the Islamic Revolution constitutes. In our view, the first period during which some new architecture, rooted in the national heritage and culture, was conceived. Taking distance from modernist international dogma. It clearly demonstrated a longing for the country's traditional and spiritual essence.

Iranian architects, studying the concepts laid out throughout their history, looked for ways to formulate a vocabulary, modern in expression but relevant to the overall concepts of their patrimony. The International Style and the school of Modernism were strongly promoted by architectural schools and firms like Abdolaziz Farmanfarmaian, efforts to achieve a cultural identity in Iranian architecture advanced through the work of architects such as Houshang Seyhoun, Kamran Diba, Hossein Amanat and Nader Ardalan. In 1974, Ardalan presented (with Laleh Bakhtiar), in his referential book "The sense of Unity", an archetype of the worldview analysis of the traditional architecture of Iran.

The second period was instigated by the Islamic Revolution (1978). During the first ten years (1978 to 1988) works tended toward a typological known reference to established traditional architecture, weather Islamic, Safavid or Qajar. While striving to remain in the path of the international post-modernism movement, they attempted to re-capture some images of the past Iranian classical architecture. Islamic concepts and identity were used as a referential model for revivalism, although it lacked enough clarity to define a style of the architecture adequate to the period of the area.

The competition of the Iranian Academies launched, in 1994, the third period striving for a fresh path and line based on essential concepts and metaphors of the local culture. Original ideas emerged in this nationwide competition marking the beginning of other revivalism, historic contextualism, progressivism new and contemporary expressions which emphasized a search for the essence of Iranian heritage and an analysis of cultural space emerging through innovative configurations. From that period these different trends coexist: modern progressivism and even high-tech, scientific DE constructivism avant-garde, without bearing to social and cultural context, abstract pure and modern, and finally the relevant conceptual based on the comprehension of the archetypical meaningful Iranian values, using abstraction in innovative forms with a blurry touch of perennial cultural space principals.

Presence of the past in Iranian contemporary architecture

The philosophy of the interaction between the tradition and modernity and its reflection in the social and cultural arenas and especially in the architecture theoretical topics has always provided the contexts for the presence of the past architecture with different standpoints and approaches in the Iranian contemporary architecture and has introduced various questions in the manner of this presence in the opinions and monuments of the Iranian effective architects but there are various attributes toward the manner of presence or combination with the roots which demonstrate a type of self-consciousness of the intellectual foundations which resulted from the rich and productive past. Regarding to the presence of the past in the Iranian contemporary architecture, Dr. Saremi Ali Akbar, asserts that "when we were separated from the tradition,
we could see it again... This awareness of the past is a modern awareness. It means that the modern human is aware of his past. Before this, there was a little awareness of the separation from the past. Based on the documents, the awareness of our separation from the past architecture comes back to the first Pahlavi era and has continued up to now. This awareness is related to the kind of modern human’s astonishment, the human who wants to achieve everything.

The human in the present time is the result of his past history namely his existence and position in the present time which the human determines his direction toward the future probabilities based on them. Hence, it can be said that the desired or undesired, past and history are running inside us but the problem of our contemporary architecture is the manner of presence of this past and the manner of its application in the architecture. In the other hand, one of our distinctive feature from the past artist is that we look at to the past from outside and we have exited from the continuous and stable movement of the tradition. The conjunction and continuity of the Iranian past architecture have caused that the Iranian contemporary architecture always attempt toward the manner of attitude to the historical past and its development and finally to reach the valuable Iranian contemporary architecture.

According to the investigations and total comments in the presence of the past architecture in the contemporary architecture and its results which have considered the range of imitation of the components and appearances to the use of principles and foundation by the theorist or movement toward the access to the instructions and theoretical frameworks for achieving the monument with the Iranian identity. This relationship can be thought in another phase. With little deliberation in the previous attempts in the theoretical area (opinions and thoughts) and practical area (architectural attempts), it is revealed that the designer had always attempted to answer two issues:

1. Considering the architecture and the development
2. Considering the past and its position

The results of two above issues can be identified in different approaches. In the other words, the method of the designer in order to consider the architecture from one hand and the past architecture from the other hand, has created a kind of architecture which although has been performed artificial and external in some phases and deeper and with more awareness and policy in the other phases, it has formed the Iranian contemporary architecture which continues its way. The investigation of these approaches can be effective and supportive in determination of this route and attempt in order to make the productive relationships with the past historical achievements. The last-oriented approach and its effects on the Iranian contemporary architecture can be investigated as the main point of views in the following attributes and approaches:
THE MOST PROMINENT APPROACHES IN THE PRESENCE OF THE PAST IN THE IRANIAN CONTEMPORARY ARCHITECTURE

Tradition as the adaptation

In this attribute, the same adaptation from the product of the past architecture and copying from the elements and appearances of the past architecture and imitative form of the historical forms of the Iranian architecture have been performed and not only minimize the relationship between the form and some factors such as the structure and its surrounding urban environment but also have considered the form as the shell for the nostalgic view to the past architecture and promotion of the culture and Islamic values. Also, time and local disjunction of the form with its important contemporary buildings should be considered in these attribute and approach.

This thought which is a kind of adaptation from the past architecture, has not been able to find a valid position in the Iranian contemporary architecture due to the change of environment and nature of the era.

Negligence to the effective conditions and factors on the formation of one architecture based on the historical past and changing of the social needs and conditions is one of the short-sighted factors toward this attribute in the contemporary era.

In this regard, Pirnia Mohammad Karim, declares that usage of the traditional architecture does not mean the imitation from the architecture of the Safavid and Al-e-Boyeh since this is the wrong and ugly work and by performing that we have lost the time.

In this attribute, tradition is crystallized as the preservation or restoration of what is available. In this situation, there is just a consumable relationship with the date of architecture and no progress will be made.

This attribute often separates from the creativity which is the main and productive aspect of the architecture. This thought which recalls the past nostalgic architecture contacted with the common audiences in the time intervals of the contemporary architecture which has performed by the rational view and full intuition and not with the bigotry and blind imitation. However, it could not change to the component phenomena after a while under the influence of the circumstances of the contemporary architecture and just changed its direction to the past imitative phenomenon.

In this insight which demonstrates an adaptive approach to the Iranian traditional architecture, there is an attempt to the promotion and gaining the Islamic-Iranian identity which has led to the similarity in the form which is inspired directly from the Islamic-Iranian architecture elements. This restorative approach has considered the insight to the traditional architecture and the Iranian architecture after Islam as the inspiration and adaptation sources in the monuments, opinions and thinking. This attribute by using the technology as the inside tool, attempts to change the future insight of the past-oriented product to the architectural monument and product.

What is remarkable in this attitude is that the adaptive elements is responsible for referring the mind to the past not referring the mind into the past architecture. Therefore, the mission of this attitude is related to the mind and thought of the viewer of the monument. Also, the viewer in contacting and observing of these monuments, will have a kind of mind returning to the previous years and in the other hand, this attribute can be a kind of subsequent view of losing what was in the past. It seems that this nostalgia, in comparison with the past, affects on the feelings and emotions of the audience more than the viewer’s mental area and as far as these emotions are transient, its effect is also transient. In confronting with these monuments and their different aspects, just some images from the traditional architecture images and does not show its space continuum and its purpose is to demonstrate the past images and not the continuum of the past architecture.

Tradition as the transmission

This attribute in summary means the usage of the patterns and historical typologies in new format in such a way that they can find the new role in today’s changed conditions.

In this attribute, each pattern is belonged to the special context and environment and picking up one pattern or form from the environment and putting them in the new environment is considered as the innovation and creativity. From the point of view of this attribute, in the Iranian architecture, we are encounter with the combination and proli-
eration of the shapes and their complexities but it is possible to access to the principles, foundations and patterns which are in the architecture permanently and demonstrate themselves in different and developed forms in each historical period. Some of these past architecture patterns are associated with the shape and functional changes in today's architecture and since their identities are separated from the time, there is more possibility for continuum in their nature.40

Dr. Falamaki M.M, in the book "formation of the architecture in the western and Iranian experiences "asserts that "the old patterns have introduced more in the abstract meanings and contents and less in the shapes. Every time in the Iranian territory and in every point of the Iranian history which one architecture monument is shaped, the patterns are cut based on the color, scale and traditions of that temporal and spatial extent and find the certain physical shapes and these shapes change to another shapes.41

In this attribute, the existence of the past patterns and typologies and the manner of their retransmission (utilization process) to the today's architecture have been always controversial. "Where do the forms come from and what is their origin? Are they eternal? Namely, their memories are in the minds of all human beings in the different lands and times. Are these historical elements? Were they created through the history of the architecture gradually and are repeated now?..."42

By contemplating in this attribute, it can be deduced although the monument in the formation process has been referred to the past architecture and puts the concept and pattern of the attribute to the past architecture in the creativity route, what shaped this pattern is the different route of producing this pattern which is transmitted to the monument in such a way that the pattern has been shaped in the past and it seems that in the formation process and its usage, there is need to cognition more than the external and physical aspects. The past architecture and its patterns should not be used solely based on the functional and operational attributes in responding to the present architecture environment. In this attribute, the sprite and the purpose of using this pattern and its consequent hidden concepts which are the source of tradition and valuable concepts of the past architecture are not considered and just the principles and physical appearances are seen and the reproduced pattern is encountered with the inside basic changes and sometimes the functional changes.

Tradition as the transformation

In this attribute, "the history is the starting point of the process which its purpose is to add the new values to the architecture. This method which is closer to the creativity, changes the consumable relationship with the culture and history to the productive relationship and permits the history in order to perform its main duty which is the historical of the past achievements."43

At a glance, the fundamental concepts of the Iranian architecture (introspection, transparency, continuity, balance and hierarchy) and the themes, myths and literature in other glance are used for intellectual creativity in formation process of the architecture monument.

In this attribute, the architecture monument has the sprite and culture of the land and in physical representation is the messenger of the hidden environmental factors of the community and in the abstract statement, it is the transmitter of the concepts and themes of the architecture and culture of that land in the architecture spatial combinations.

In this insight, referring to the concepts and themes of the past architecture is the deeper look toward the historical architecture, therefore, this presence has the higher position than the previous approach (schematic and physical approach) since the concepts and values of the Iranian architecture have the specification beyond the place and time. Many of these principles (introspection, transparency, continuity, ...) can be recognized in the architecture of the different periods which belong to the different styles and their presence in the architecture of the previous periods and their consistency and continuity represent their values. These are principles which are considered as the prominent features of one architecture.

In investigating this approach, there are two things which should be mentioned:

Firstly, the creator of the monument is aware of the deeper aspect of the past architecture and his look to the architecture and after that the past architecture is resulted from this issue.

Secondly, the principles, concepts and foundations of the architecture in the past architecture are not necessarily specific to this architecture and they can be considered as some principles of the architecture not the past architecture. In other words, these principles are refined in
designing process such a way that by passing through the route of one creative mind, they find special flourish and appearance within the body of the monument. In the presence of creative thinking, these concepts form the motifs and spatial structures which demonstrate the presence of the Iranian architecture in the contemporary architecture. The consistency and continuity of the Iranian architecture can be looked for in the thought, motif and structural ideas of the design which in each phase and period of time, the new values have been added to its previous values for establishing an architecture with the Iranian identity. The creator of the monument by refining these principles and internal themes of the architecture and past culture, puts the contemporary monument in one productive process with the past historical achievements. Therefore, the physical presence and material appearance which are selected by the architect from the past architecture have been underrepresented and usage of the meaning and concept will have more effects. The purpose of this approach is the creation of one architecture monument which produces a productive relationship with the past instead of consumable relationship. In this thinking, the designer looks for the architecture and creation of the monument which its essence and nature represent the hidden concepts and themes inside the monument in the past architecture. "This attribute in the architecture is similar to the literature to some extent. The new and innovative monument maybe created through the rewriting of an older topic", 44

The monument in resulting from the past does not have any special structure and system but tries to demonstrate a totally different form and prepares a familiar space conceptually. In rewriting the monument, the change of the themes is along with the change of the structure. In rewriting, the maintenance of the properties of the first pattern is not necessary and the past concepts and themes form a part of the design idea. Therefore, the design can close to the architecture with the Iranian identity by relying upon the fundamental concepts of the past architecture and without need to the imitation and repeat of the familiar elements and the past appearances of the architecture. The influence of the historical past of Iran is more preferred than its affectedness and has the deeper relationship in this process.

**Tendencies and approaches**
- Tradition as the adaptation: Mosque of Sharif University of Tehran (Hojat Mehdi), Pilgrimage Organization  
- Tradition as the transmission: Sports Complex of Rafsanjan (Mirmiran, Seyed Hadi), Tehran Museum of Contemporary Art (Diba Kamran), Iranian Academies’ collection (Mirmiran Seyed Hadi),  
- Tradition as the transformation: National Library, Water Museum (Mirmiran Seyed Hadi), Sacred Defense Museum (Sheikh zeinaldin), Iranian Embassy in Berlin ( Diba Darab)

**Relationship with the past architecture**

**Presence of the past in formation process of the contemporary architecture monuments**
- Structural ideas of the design  
- Usage of the form and space structural ideas of the past architecture:
  - Hierarchy, geometry, unity, balance and harmony (form-oriented from the past architecture)  
  - Introspection, reflection, continuity, transparency and cohesion (concept-oriented from the past architecture)

**Space structural concepts**
- Metaphor-oriented from the Iranian history and culture.  
- Myths and historical themes (concept-oriented from the past architecture)  
- Past spatial ideas (passage and vacuum)  
- Spatial qualities of the past architecture (concept-oriented from the past architecture)

**Structure making**
- Usage of the forms of the past architecture  
- Structural elements and decorations (form-oriented from the past architecture)  
- Form and structure  
- Usage of the historical patterns in the new structure (form-oriented from the past architecture)  
- Precise usage from the past architecture form (form-oriented from the past architecture)

**Application of the past materials**
- Traditional materials (form-oriented from the past architecture)  
- Traditional materials with the modern materials (form-oriented from the past architecture)
Analysis of the past-oriented approaches

Past-oriented approaches:

**Concept-oriented from the past architecture**
- Reference of mind to the past architecture
- Spirituality (Philosophy of Mysticism) - Cultural Complex of Farshchian
- Eshragh (Philosophy of the light)
- Consistency and continuity of the fundamental concepts and their evolution
- Metashor-oriented and space-oriented - National library, Water Museum (Mirmiran, Seyed Hadi)
- Usage of principles and concepts (introversion and reflection), Iranian Embassy in Berlin (Diba Darab)

**Form-oriented from the past architecture**
- Originality of the form and usage of the historical patterns in the new format, Cultural and sport complex of Rafsanjan (Mirmiran Seyed Hadi)
- Precise usage from the past product
- In connection with the usage of building - Mosque of Sharif University of Tehran (Hojat Mehdi)
- No connection with the usage of building - Pilgrimage Organization

SOME SOLUTIONS IMPLEMENTED IN THE IRANIAN CONTEMPORARY ARCHITECTURE

**Case Studies:**

**Rafsanjan Sport Complex**
Seyed Hadi Mirmiran, 2001

The design of this sports complex draws on the typology of the traditional icehouses (Cistern) of southern Iran. In a similar manner to the icehouses, it combines an opaque volume (the cone-shaped dome) with transparent elements (the wall and the diagonal glazed roof that divides indoor and outdoor pools). All internal walls are of brick and exposed concrete, which helps preserve the spatial integrity of the interior despite the diversity of the program (gymnasia, pools, saunas, restaurant, etc.). The structure is reinforced concrete: external walls are double-layered and insulated.
Consulate Office Of Iran
Seyed Hadi Mirirmiran, 2001-2004

The building for General Consulate of Iran in Frankfurt, Germany is perceived across a high glazed wall. This represents the dramatic spirit of Iranian architecture and the culture of the country. The site is a rectangle of 48*94 meters that a street lies along one of its longer sides while its two other sides border a park. The situation of the land, the street and the park implied the notion of envisaging the street and the park as two urban public spaces that could be connected via the consulate site. We have named the resulting space “Gallery of Iran” in which people can move about freely and get in contact with different aspects of Iranian culture via posters, books, art works and etc.

This space divides the consulate building into two main parts, one part is allocated to daily activities (such as the visa section) and the other section is allocated to formal diplomatic activities of the consulate office. The space of daily activities establishes strong visual-spatial relationship with the "Gallery" and in fact these two can be considered as one. The main consulate spaces are separated from the "Gallery" by an opaque glazed surface. The required spaces of these two sectors are organized within a stone volume. These two sectors are linked together over the gallery. This has brought about the formal unity of the volume. The Diplomatic Sector (organized within the so called volume) hides behind the high glazed wall. This wall constitutes the street facade of the building. The other two sectors stand bare. The stone volume is designed in a way that provides an open space on the ground floor of the main sector. This space will be used for special ceremonies.

A transparent glazed roof connects the surface of the park to the upper part of the glazed wall and smoothly unifies the space of the consulate area with that of the park. This glazed roof covers the main sector. In southern side of the building a broad shallow band of water is devised to pass through both the interior and exterior spaces of the complex. This element makes the space of the consulate fine and pure, brings about a dramatic spatial quality by reflecting the image of the elements of the building and also connects the consulate building with another part of the park.

The consulate building is a transparent volume that represents lgerity. It is made up of floating freestanding volumes and glazed surfaces that have engendered a dramatic ambiance and have unified the complex with the surrounding natural environment. At the same time highest technologies have been deployed in its construction. In general, the combination of technology and spatial drama has resulted in the proper expression for the consulate building of Iran in Frankfurt.

Figure 53: Consulate Office Of Iran. Source: www.memar.ir
**Tehran Museum of Contemporary Art**
*Kamran Diba, 1969 – 1977*

**Components**
This museum in one of the most active cultural and artistic centers in Tehran that manifests appealingly in the urban area that is well impressed by traditional Iranian architecture patterns.

**Materials**
The building is constructed from stone and concrete in the area of 8500 square meters. Overall surface of the walls is over 2500 square meters.

**Construction system**
Tehran museum of contemporary art is a post-modern building using ancient Iranian architectural elements that poses minimalistic. Traditional rustic arches and skylights are designed from desert ventilators. Internal spiral design of the building follows modern patterns.

**Illumination**
Wind catchers (Badgir) clearly glare in the building, which they previously had the role in air flow and air conditioning.

**Galleries and the site**
The museum includes 9 fully-equipped large and small galleries to display artworks. At the center of the vestibule the fine artwork of Japanese artist “Noriuki Haraguchi” is placed that is made of oil and steel. In another corridor the memorable artwork of Henry Moore is placed and spatial artworks of artists like Parviz Tanavoli, Henry Moore and Alberto Jakumeti are located on the surrounding green yard that is called “Bagh-e- Tandis” (statue garden). Tehran museum of contemporary art also contains several lateral parts that cinematic, achieve, professional library, bookstore, artwork treasure and café besides 8 main galleries can be mentioned.

Tehran museum of contemporary art, Iran, is one of the successful projects that succeeded to present some of the patterns and the elements of Iranian traditional architecture with updating sustainable elements of Iranian traditional architecture in the building of the museum in the best way as follows:

A) Reassignment of the Wind catchers function while maintaining its originality of natural ventilation to Skylight with controlled diffuse lighting (indirect) to the required museum and gallery spaces

B) Converting vestibule from only being as a space distribution to lobby and access to the other parts of the museum

C) Passageway with the old function of passing in the traditional Iranian architecture but in a wider context with the museum conditions

D) Chaharsou, with benchmarking the intersection role from traditional Iranian architecture in museum and plays the role of communication way in different parts of it

Finally, the museum can be a successful model for the design of spaces and art collections of all time.

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Figure 54: Tehran Museum of Contemporary Art.
Source: www.memar.ir

Figure 55: Tehran Museum of Contemporary Art.
Source: www.memar.ir
The aim of founding the Iran Centre for Management Studies (ICMS) was to create a small size but independent institution “devoted solely to management studies at the graduate level”. The idea which gave rise to the original program initiated from an institutional lack which existed at that time within the Iranian higher education system. Some members of the Ministry of Higher Education and the management education milieu became interested in creating a new model, and thus formulated general objectives for a new program in 1971.

Compared to its innovated educational approach, the functional organization of the ICMS was rather traditionally rooted in its reference to the old madrasa structure. This organization, which was translated into the spatial program of the architect's brief, consisted of:
- Student's units, constituting 16 clusters
- The Lecture room a common space where 60 to 80 students were to meet;
- The Library conceived as the focal element of the program;
- The Refectory or the “Dining Atrium”, another social space of the program;
- The Administration section;
- A sports area, technical services and a layout of gardens/orchards.

The master plan of the campus consists of a rectangular garden space surrounded by the student housing units on all sides, by the administration building to the east, the dining room to the north and the classrooms to the west. The library is placed at the center of the garden. Four gateways places at the end of each axis give access to the contained open space of the garden. This cluster scheme is located on the highest point, the hilltop of the site. The architecture is looks inward and there is a hierarchical continuity. The form of enclosed gardens, courts, porches, and covered spaces is more important than any individual volumes.

Conclusion

After investigating the analyses and with the purpose of categorizing the results in the defined groups and mention their evidences, it can be possible to recognize the considerable cooperation in the past oriented approach of the Iranian contemporary architecture in despite of structural differences. Although, there is not any tangible unity and solidarity in the opinions of the thinkers and experts of the Iranian contemporary architecture especially after the Islamic revolution, but there are some consensus in some fields. In the process of forming the contemporary architecture monument in the past– oriented tendencies, along with the structural ideas of the design, spatial structures, body and material, there are two prominent and distinguishable approaches as follows:
1- Concept-oriented from the past architecture

2- Form-oriented from the past architecture

Each of these approaches has its own parameters and items which can be divided into the smaller categories through their further expansion. These parameters and items can be identified in the design process and formation thinking of the past-oriented architecture and will be investigated in the following part:

In other hand, attention to the conditions and effective factors on forming one architecture regarding to the historical past and changes of the needs and social conditions are considered as the important factors in looking at the past in the contemporary era. Our understanding from the manner of contact with the past and the presence of the past in the contemporary monument refer to the time principle (Panagiotis Michalatos 1977) and the identification and perception of the monument in the present time. The accurate application of the history and comprehensive understanding of that which is always on the verge of evolution can be the effective factors in creation of the architecture monument.

Regarding to the approaches, it can be said by contemplating and analyzing the language and describing the past architecture, we should think about the effective and deeper relationship with the background and past history which is basically an evolutionary process and reach to the new statement in the contemporary architecture. Meanwhile, we can use the movement and sublimation in order to use the tradition as the ladder with the purpose of bringing the artist to the maximum level of the Iranian art. The art which is neither the past product nor the imitator of the west image but it is retrieved from the opinions and thoughts of this time and its expression of that in the current architecture space in Iran.

**Western contemporary architecture**

There are different factors such as the rationalism, development of the sciences, development of the philosophy and especially the development of the technology caused the promotion of the modernism. Utilization of the manifestations of the technology such as the usage of the metal which began at the first in bridge construction and after that in building construction was effective in formation of the modern architecture. The first international exhibition which held in Hyde Park of London in 1851 and known as the Crystal Palace consisted of metal structure and the glass and directed the attention to the new materials and new language for the architecture. Meanwhile, the need of using metal structure and glass in buildings of the Chicago, development of the Chicago school in 1871, the exhibition of Paris in 1889 and the construction of the Eiffel Tower made the appropriate background for utilization of the new materials.

The new art movement since 1890 in the arts and from 1890 until 1910 in architecture led to the formation of the new principles in the art and architecture including the non rock-orienting, criticism from the imitative schools, attention to the new forms, approach to the art and zeitgeist and attention to the production of the modern works. Some of the movements which inspired from the industry and technology such as Futurism paid attention to the speed, mobility and use of technology. After the world war, the need to construction of many buildings and application of the new architecture principles for constructing many buildings caused the development of the new architecture.

Gropius, mies van der rohe and Le Corbusier are some of the famous architects of the eminent modern time. Le Corbusier considered the five principles namely constructing the taller buildings to the earth through the pillar, flat roof and roof garden, open plan, usage of horizontal and extended window and open view and usage of roof console as the principles of the modern architecture.

Gradually, attention to the nature in the works of Organic Right and attention to the statues orientation in the works of Le Corbusier’s and Right, caused the diversity of the simple volumes. Brutalism and utilization of the naked materials affected in formation of many works. At the middle of 20th century, there were some doubts about the principles of the modern architecture. Some
people criticized the simplicity and uniformity of many of modern works and others criticized its lack of attention to the culture and history. Criticism against the modernism was increased in the 1960s and after that the post modernism was evolved and some people considered that as the continuation of the modernism.

Structuralism which formed in the early of 20th century and was at the center of the attention of some of the artists and architects was criticized and Deconstruction was evolved. In the 1980s, Eisman Steve by designing the Wexner artistic center, applied the thought of deconstruction in the architecture field.

The development of the technology led to the formation of another school namely High Tech and after that the application of the technology with environmental considerations caused the formation of the another school under the name of Eco Tech. The fractal geometry and fold geometry are another tendencies of the western architecture.

In addition, if the profession and knowledge of the architecture are considered as the interdisciplinary profession and knowledge, it will be revealed that the architecture can not be developed and promoted satisfactory without the development of the related sciences and knowledge.

By evolution of the new materials and scientific developments, the contemporary architecture of the world began to flow in more extensive manner and brought with itself the various and different concepts and discussions of the human thought.

The traditional architecture of the adobe, brick and stone which had a kind of inactivity and identified expression in the consequent centuries in the light of its representations through the heavy and somewhat closed architecture, gradually went to the clear, open and explicit architecture and propounded the events of the new world with the prominent layers of reception and perception of the current developments. Meanwhile, the mind and wisdom created the exceptional time duration in the architecture along with the new and developed technological attempts.

If the past specifications put the tradition and heaviness in the first step, the new language of the contemporary architecture manifested its clear roots about the comprehensive democratic and clear social fact. In the era of the failure of dominations and colonial governments, the unilateral political relations changed to the regional information which the architecture could not ignore the fact of the new world through its form and demonstrations.

Probably the whole architecture story of the new movement or somehow the architecture of the new era was the origin of the kind of growth in which many of the historical barriers and limitations changed to the contemplation, discovery and tendency toward the development and knowledge.

The presence of the nature in architecture space has been a unique blessing. The eye looked for the hidden aspect of the successes and the tendency toward the development was equivalent to the tendency of permeation of the light in architecture. In this era the stately palaces of the political and religious governments replaced by the more moderate communities which architecture is the base of their civilization which was outside the control of the people and now as a device represents and manifests the tools of its new thought and culture.

The technological astonishments in the battle of human for extending the borders of the knowledge and gaining the new successes are very important. The explosion of the freedom in the architecture space is a kind of human story which arranged its look toward the future dynamics. Therefore, there is no need to clearness of the other related topics to the single area of the human knowledge.
Entrance of the traditional architecture to the world contemporary architecture

After finishing the world war and urgency to re-construction of the destructions of the war and constructing the many buildings, the tendency toward the modern architecture was increased. Therefore, the usage of the current technology, modern materials, premed structures, performance—orientation and stay away from the splendid historic styles were considered. In this period of time, the modern architecture was introduced in the west as the only important and Avant-Garde style and its influence dimension was extended worldwide as a global style. The modernism resulted from the realism and Chicago School which ends to the rationalism (global style) and Bauhaus and after that to what that we call it modernism which includes the 50 years duration. Some of the main features of the modernism are as follows:

1- Continuation of the eclectic elements which resulted from the historical methods of the 19th century.
2- Attention to the importance of usage of the materials especially brick in relation to the structural quality of the decorative elements.
3- Tendency to design of the accessories such as the designing the ceramic and handles, elevator and the home furniture.
4- Utilization of the landscape mode was considered as the constructive elements which related to the structural methods such as the imaginary designs.

One of the various specifications of the modern architecture related to the consideration of the nature of the structural materials. These materials were used without any change and in their nature modes as far as possible and utilized with no cover in the buildings since the usage of the decorations in the architecture was considered as the obscurantism and affectation. Therefore, the representation of the nature of the materials which can naturally (not fictitiously and artificially) enriches the architecture was considered. The other point involved in making possibility for all artificial elements in order to represent their role in the building. In the past architecture, some parts such as the stairs were mostly within the heavy walls and was hidden in the behind space of the house which was more appropriate for the closet.

The modern architecture not only represented the possibility for exposing the stairs to the eyesight but also showed that it can be used as the factor which increases the architectural richness. The consideration of the honesty and ethics in the modern architecture is among the representation of the constructive factors and emphasizing on them.

Another features of the modern architecture was the possibility for using the engineering facilities. In this situation, utilization of the skeleton which composed of the shafts and pillars that can tolerate the structural load of building just in the certain and centralized points changed the wall into the curtain which is used for restricting and distinguishing the space.

The modern architecture breaks the continuous and uniform facade of the Renaissance and Baroque. In the Renaissance architecture especially in the Baroque castles, all the building had the continuous and uniform facade and if the kitchen, stairs or room were behind that, they were represented as the same in the facade. But in the modern architecture, it is possible to show the character of each part of the building in its body in identified and clear manner through the technology. Therefore, the original modern architecture is the architecture which each part represents its own personality and identity. The Crystal Palace which made on 1851 for the London Exhibition can be considered as the beginning point for the modern architecture and if this point was not historically correct but it is very important. Since it was here that one of the prominent representation of one of the factors in creating the modern architecture which had the main role in its extension and development was manifested unprecedentedly. The big crystalline building made by Joseph Paxton for the modern exhibition composed of the iron and glass which the components were produced in the factory as premed structures and then installed in that place.

Figure 5B: Bauhaus School. Source: www.arch.net
Louis Kahn and beginning the attention to the traditional architecture in the modernism

The time of the Kahn’s first buildings refers to the 1925 but until the mid of 1950s, he could attract the attention of the American and the world by implementing some works. In the works of Kahn, the experiences of the modern architecture, classical Greek inspirations, medieval architecture, Islamic architecture and even the academism of the 19th century of the Europe can be seen. Totally, we can say that he was under the influence of the Bozar school (Centre of fine Arts) and for this reason there is a kind of attitude toward the history in all of his works , therefore we can feel his closeness to the history-oriented post modernism. Some of his works have been remained as the projects.

These projects have been designed at the highest level and complexity but in the implementation time, the forms are simplifies through the selection of the appropriate , natural and traditional materials. Kahn in despite of his previous architects does not look for the explanation or approval of the writings and his speech is unclear. In the works of Louis Kahn, the precise application of the materials and the expression of the rules of using them and diversity of this utilization are obvious.

Louis Kahn is the first Russian-born American architect which was raised after the World War II and also he is the first person who became separated from the world school of the “form follows function”.

Some projects such as the Sydney Opera House which made by the Utzon Jorn and John F. Kennedy International Airport in the New York City which made by the Eero Saarinen approve that the form does not follow the function.

The architecture of the Kahn is not placed in both the organic architecture of the Frank Lloyd Wright and the new architecture movements such as the modern architecture school of Le Corbusier and Mies van der rohe. Kahn usually spoke about the form, lighting and those spaces which have the certain functions.

He in his writings about the light and lighting assets that “light and lighting cause the existence of everything. The substances are derivative from the light. In other word, when the light is consumed, the substance is achieved. The substances are those which their presence lead to creation of the shadow which is belonged to the light. The light moves to the substance and the substance to the light and these movements create the constructive climate and environment. Form says to itself, “I should make something.” In the works of Kahn, it is usually the same emotion of the old and new. The severe research for the all things which were beautiful and rational to the human development. This thought which the past has the root in the present and also the “research for founding the fact” are implied in a brief and poetic sentence of the Kahn: “The future is today”. He in his travel to the Italy (Rome) from 1950 until 1951, investigated the architecture of the Rome. He started his teaching in the university of the Pennsylvania (1957-1961) and from that time, he paid more attention to the history. Meanwhile, from the historical perspective, he made a development in the modern architectures’ traditional movement.

He made a coordination between the structure and function of the building. Louis Kahn believed that the architect is belonged to the university and for this reason he developed his beliefs in the university. He considered the instruction as the permanent recognition of himself. According to his statement, the modern architecture which was the best and most appropriate choice among the other styles, was involved in disturbed orientation and taste addressing. According to the Kahn, its main reason is the weakness of giving morale and respecting to the human life in the material forms of architecture. He pointed to the life order of the nature and the living world for organizing this situation.

Louis Kahn’s architectural work through the five principles:

1- The combined passions in the entire building
2. The use of building materials, according to their nature
3. Feel the atmosphere of architecture as the main objective
4. Light significance as part of the project
5. Proportions and its architectural

Date of the death of the modern architecture

The Charles Jencks is the historian and architecture critic which considered as one of the important theorists of the architecture of the post-modernism. He wrote a book in 1977 under the name of “the architecture language of post modernism” but despite of this book, the Jencks named and extended the new process of the Venturi in architecture.

Jencks notified the exact date of the death of the modern architecture on 15th July, 1972 at 23:33 PM when the Pruitt-Igoe residential apartment complex was destroyed in the St. Louis, Missouri of the U.S.A. by dynamite. He stated this apartment complex was the symbol of the modern cubic architecture which is without any decoration. Meanwhile, most of its designing principles were in accordance with the mentioned principles in the CIAM congress but since the abstract language which used in designing of this modern complex was different with the thing that called as a house by the black and relatively poor people of this complex, therefore, destruction of that complex was the only solution for finishing the suffering of the inhabitants of the building and the building itself.

Among the adverse effects of this complex for the city, it was its change to the gathering place for corruption and this matter was considered as one of the destruction factors and removal of the building.

According to Jencks, the architect should not design the building lonely (such as what was common in modern architecture) but he should be the co-worker and consultant of the users. The pattern of the form of building should not be just in the mind of architect but it should be what that the future inhabitants have familiarity and can communicate with it.

In this book Jencks such as his predecessor, Venturi Robert, made the main criticism against the Mies van der Rohe and specially his cubic designs for the Illinois Institute of Technology (America) which was a complex of similar beautiful boxes which did not have identity and function.

Robert Charles Venturi and post-modernism architecture

The entrance of the past architecture in the contemporary architecture

From the 1960s, the topic of the post – modernism was introduced in the architecture as an important style and there were some infrastructural criticisms against the logical and tech-oriented thought of the modern architecture. The beginning of this movement was Robert Venturi who was one of the student of the Louis Kahn.

He wrote a book in 1996 with the name of “complexity and contrast in architecture”. According to his previous teacher, Vincent Joseph Scully, this book is the most important book since 1923 which have been written after the book of Le Corbusier with the name of “Toward the new architecture”.

In this book, Venturi criticized the philosophical principles and the world view of the modern architecture. He rejected the technology-oriented insight and instead of that he demanded the attention to the human specifications and the human-oriented architecture. In this book, the main criticism of the Venturi is against the Mies van
der roh since he was the symbol of the modern architecture in his life time and never obviate his opinions in the 1920s and 1930s. He in his book and in response to the slogan of the Mies, less is the more, stated that the less is bore. Based on the opinion of the Venturi, the architecture is not only the technique and technology but there are more complex and conflicting issues in the building which can not be ignored or removed. Charles Moore is another architect of the postmodernism who answered to the slogan of Mies and says “Moore is more”. He believed that instead of deduction orientation and removing the question, the pluralism should be considered in order to find an appropriate solution for the complex of issues. However, there are a beautiful irony and meaningful dichotomy in this slogan since he used his surname in the beginning of this slogan. It means that another mystery of this slogan is that “I am the more”. Based on the Venturi, the buildings cannot have the same form and philosophy. The building is not such a machine which only consists of technological and mechanical issues. If for Le Corbusier the Parthenon Temple of Athen with a collection of pre-made volumes and surfaces and the mathematical rules and proportion is a symbol, for the Robert Venturi, no pre-determined formulas but the towns which located in the foothills of the Italy and constructed based on the climatic conditions are considered as the criterion. Venturi rejected the international style totally and instead of that he believes in contextualism. It means that each building should be designed and constructed based on the cultural, social, historical and physical background and the special conditions of that site. This style can be called as the “local style” or “native style”. Modernists considered the architecture as a technological issue. Technology has the common feature and follows the same principles and regulations worldwide. But the post-modernists have a cultural attitude toward the architecture and the culture of each region is different with the culture of other places. Now there is a question about what issues should determine the form and meaning and this form should response to what issues? In terms of post-modern architecture, these issues can be summarized in the following items: 1- Cultural, social, historical and economical features of the people who use that building. 2- The specifications of the city, street, square, alley and store. 3- Climatic conditions, moisture, coldness, heat, jungle and desert. 4- Everyday lifestyle of the building’s inhabitants, their need and habits, manner of usage and their mental backgrounds in relation to the environmental forms. Robert Venturi was the first modern architect who used bravely the decorative frames and traditional symbols. He has used the decorative frames exaggeratedly at the top of the windows of the administrative center of nurses and dentists (1960). He attempts to make the relationship between the architecture and buildings with the human identity. According to his opinion, the conditions determine the shapes and symbols. Therefore, in different conditions, the shapes and symbols should be different. Venturi dose not reject the decorations but he considers them as a part of historical and cultural specifications of each region which can be used in new building. Robert Venturi wrote another book in 1972 in Las Vegas with the name of “learning”. In this book, he attempts to attract the attentions of the architects to the culture of the people and their daily life’s specifications. He stated in his book that the symbols are not those which we dictated them to the community as the intelligentsia but they have been introduced by the people and are comprehensible for them. He believes that the boards of the above part of stores and the popular architectural volumes which are in accordance with the public understanding change the Las Vegas to an attractive place which should be considered by the architects. According to the most works of the post-modern architects, they attempt to use the signs and symbols which represent the function of each building in the region. One of these houses is the house of Venturi’s mother house which its design is based on the symbols of one house and whatever is considered as the house in the west. If the Le Corbusier in his book (Toward the modern architecture) attracted the look of architects to the automobile, ship and in summary to the technology, the Venturi and other post-modern architects want to attract the look of the architects to the culture, history, traditions and everything which forms the human’s identity and his surrounding physical environment.
Venturi’s mother’s house (1962-1964)

The Venturi’s mother’s house is the first house which made based on the post-modern style and it is the symbol of this architecture. Robert Venturi made this house for his mother in 1962 in near of the Philadelphia in the State of Pennsylvania in U.S.A. He has used some symbols such as the sloping roof, window, arch entrance and other signs of the house in his design. At the first glance everyone in the west identifies this building as the residential house.

In addition, the private spaces such as the bedrooms and bathroom locate in the left side. This asymmetry and dichotomy in arrangement of the plan have been changed to the solidarity and unity in the facade through the sloping roof, the wall under the chimney and decorative arch above the entrance of the building. Therefore, the solidarity and unity have not been achieved by elimination of different elements of the building but all the contrasts of the building’s complexities are in this design and the unity in diversity has been considered in the building by all the parts which were used in constructing the building.

Portland building

Portland building has been made by the Michael Graves, architect and industrial designer, and is considered as the first great work of post-modern architecture. This design which demonstrates the many symbolic elements on its great and heavy shell, has the functional-oriented approach in deliberate contrast with the modern architecture which at that time was completely dominated. As the Graves explains about his architecture, “this symbolic expression is an attempt to reestablishment of the language and values of the architecture in order to be separated from the uniformity of the modernism”.

In 1979, Portland administered the contest for designing the building of public services in block with the area of 40,000 cubic feet at the center of Portland. This project was designed in order to include the municipalities of the Portland. According to the plan, the building locates in a unique way at the beside of the Town hall, Department of Justice and the park of Chapman Square. The young Michael Graves presented his ambitious design and in despite of lack of experience could contribute in this contest due to the presence of his friend, Philip Johnson, in the Jury. The colorful and low expenditure of the Graves’s design affected highly on the jury and rejected the expensive concrete and glass designs of his competitors.
Finally, this price was granted to the Graves. The jury knew that his design will indicate the Portland in the map and this was fulfilled. This building attempts to create the relationship between the past and the future. This symmetric block building with the four rectangular shells with the yellowish white color and plaster represents the redefinition of the classic architecture which achieves to its purpose with the utilization of some elements such as the crown stones, pillars of the facade and the entrance porch in a larger form than scale.

This building has been located on the two-level base which is reminiscent of a Greek column which divides that into the three classic parts: base, body and head. In addition, Graves instead of making relationship between the building and its surrounding environment and position, entered a strong symbolism in his design with colors. Green for the earth, blue for the sky and etc. The reactions to this building was a combination of the opinions of the architects and the Portland’s inhabitants. They criticized the belonged elements to the known styles of the architecture such as strips and round frames through the elements which are needed for creation the sense of magnificence in the formal public buildings. The others considered the purpose of this design with the extra symbolisms and imagined them with their references to the past.

Indeed, this building was criticized for the superficial combination of a traditional aesthetics which had formed without giving any meaning to the elements in order to play their functional roles. For example, although he unified the design of passages in order to prepare the intermediate and protective spaces between the pedestrians and city as usual, these passages which formed the shell of three facade of the Portland building in one line only had two entrances at the surface of the street which caused the hard accessibility to them. These problems made some limitations in accessibility of the forth shell of the building facing the park. This part had two small entrances which led the people to the non-opened restaurant and rear lobby. Meanwhile, the users of the building complained of narrow and unpleasant lobby and its dark and daunting office spaces. Worst of all, there were some cracks in the building which represented the need to some repairs in both lobby and dinning room spaces in 1990.

This reconstruction was performed only 8 years after opening the Portland building. However, the Portland building is considered as the index key point in the history of the architecture which brings out the post-modern from the architectural academies and enters them in the public. This building paved the route for the different complete post-modern buildings such as the Walt Disney Collection (1990), Central Library of Denver (1996) and Saint Kalta School (2006). The Portland building apart from its mistakes, represents the absolute deviation from the uniformities of the modernism style. As Graves jokingly explains “I thought that why they are upset? Modernism just gave them the possibility for selecting the vertical, horizontal, white, gray and black. Be realistic!”
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CHAPTER FOUR

Solutions for Today’s Architectural Design
"Materials, Technologies, Architecture"

“Tradition means the chain of revealed truth, wisdom and knowledge, which is transmitted and renewed generation by generation, this linking various successive layers of temporal existence to the primordial reality which originated them”

(Stefano Bianca, 2000, p:23)
SOLUTIONS FOR TODAY’S ARCHITECTURAL DESIGN “MATERIALS, TECHNOLOGIES, ARCHITECTURE”

The use of Renewable sources to satisfy energy needs in buildings

The purpose of utilization of the solar energy in buildings is better utilization of the sun light in order to supply the heat and cold needs and if necessary to supply the electricity of the buildings. In the first phase, with utilization of the solar architecture plan which is similar to Iranian traditional architecture, the cold and heat needs of the buildings are minimized. In this plan, various parameters such as direction of the building, thermal insulation, determination of the appropriate windows level and windows double glazing in some regions and usage of some solar passive systems such as Trombe wall are considered and utilization of them leads to decrease the required energy of these buildings in comparison with the normal building with the same substructure considerably. In addition, the amount of this percent depends on the amount of using these parameters and the climatic conditions of each region.

Since there are different climatic areas in Iran, there-fore, the facilities of the solar energy are the subordinate of these different climatic areas. Hence, for decreasing the required energy of a building, its design should be in accordance with the climate of that region. In all climatic regions, those buildings which have been constructed based on the climatic design principles, minimize the necessity of the mechanical heating and cooling.

Required information

1- Investigating the specifications of the solar radiation.
2- Investigating the temperature.
3- Investigating the specifications of the amounts of precipitation and moisture.
4- Investigating the amount and conditions of the wind blow.
5- Investigating the specifications of the insulation.

There are two main issues in solar design: firstly, manner of designing in order to more utilizations of the solar energy and secondly, the manner of designing in order to minimize the thermal wastes with the purpose of better usage of gained energy. In the case of lack of attention to each of these issues, the intended design will not have the necessary practicality.

The lack of interest of the different groups of people in utilizing the solar energy in houses is the cheapness of energy carriers in Iran whereas regarding to the current situation of the energy, the necessity of implementation of the solar designs is inevitable.

It should be noted that the usage of the solar energy regardless to the climatic design of the building not only is not effective but also will have the additional costs.

Utilization of the solar energy in buildings

- Preparation of the consumable hot water: in active solar systems, the consumable hot water is prepared mainly by the solar water heaters with through the flat collectors.
- Preparation of the required heat: some percentage of the required heat of buildings are prepared usually through one of the following methods or their combination: Trombe wall, greenhouse, solar pools and etc.
- Preparation of the required cold: cooling through the solar energy is performed through different methods such as the absorptive systems. Preparation of the required coldness of buildings in the heat period by the absorptive systems is in such a way that the required heat of absorptive chillers’ generator is prepared by the solar systems such as flat collectors with high efficiency and etc.
- Light preparation: the light of buildings can be supplied by the photovoltaic cells. It means that with calculating the required energy for light of the buildings, the number of the photovoltaic panels (each panel is consisted of series and parallel placement of some cells) and the capacity of the required reserve battery are determined. Therefore, the required light of buildings will be supplied by solar panels, charge of regulator which prevents the overcharge ands over discharge of the battery and the reserve battery.
- Solar heat systems: there are two methods for preparing the required heat of building through the sun: passive and active methods.
  - In passive heating system, the heating of the building is performed naturally and through natural elements such as the sun. This system makes the possibility for building in order to
work with very low energy without any need to the external artificial energy or fossil energy.

There are various methods for using the passive solar energy which the most common of them are:

- Direct reception method
- Greenhouse method
- Trombe wall and water wall
- Ceiling pool or laver and
- Thermal fan (ventilating power)

Solar active and passive heating and cooling in building

a) Solar passive heating in the building

There are two primary measures which should be taken for solar passive heating: usage of glass in the southern side, usage of thermal mass for absorption reservation and heat distribution.

There are 3 general methods for passive systems:

1- Direct absorption
2- Indirect absorption
3- Isolation

The purpose of all solar heating systems is the heat reservation through the constructive materials and releasing this when there is no sun radiation. When the constructive materials reserve the heat for the next utilization, the solar heating provides the pleasant space inside the house.
Direct absorption

The most common solar passive system is called the direct absorption. Direct absorption is related to the sun light which enters to the building through windows and heats the internal space of the home. During the sunny hours, this heat is reserved in thermal mass of the ceilings and internal walls which are made of water, stone, concrete and brick. The reserved heat in the thermal mass is transferred to the inside of the house during the hours which the sun went down. The design of the direct absorption system is calculation of the window area and the required thermal mass for heating the space of the home. Generally, the area of the glass in direct absorption should be at least 0.07 and at most 12% of the ceiling area of the house. In direct absorption, using the double glazed glasses is recommended.

In this system, the space of the house is a solar collector, heat absorbent and distribution system. The glass of the southern side leads the solar energy into the inside of the house where the thermal mass such as walls and floor are exposed to the direct or indirect light radiation. The direct absorption system consumes the 40-75% of the solar energy which radiated to the window.

In direct absorption system, walls and floors are the thermal mass of the operational parts of the house. In addition, it is possible to reserve the heat through the water tanks.

The thermal mass becomes warm during the day due to absorption of the heat and leads the heat to the space of the home during the night. Most of the solar passive systems work regarding to the thermal mass or the materials with the high absorption capacity and heat reservation such as brick, concrete, mosaic and water. In the plan of the building, the thermal mass can be used in the ceiling, interior walls, fireplace and balconies. These surfaces do not need the direct sun light but their colors should be dark. The thermal reservation amount of various materials depends on thermal conductivity, specific heat and their density. Most of the time with increasing the density, heat conductivity will be increased.

General laws of direct absorption system

1- Analysis of the solar heat reservoir for conducting the heat to the houses.
2- Thickness of the materials of the thermal mass should not exceed 15.24 cm.
3- Those floors which are used as the thermal mass should not be covered totally by the all round carpets and they should be without any floor covering as far as possible.
4- Utilization of the dark color for the floors, light color for the low-mass walls and any desirable color for those walls which are used as the thermal mass.
5- For each 0.09 m² of the southern glass, 67.9 kg of the constructive materials or 15.12 liter water are used as the thermal mass.
6- Holes of the concrete blocks which are used as the thermal reservoir should be filled by the concrete.
7- Usage of the thin thermal mass in residential space in comparison with the thicker concentrator surfaces is more advantageous.
8- The area of the unprotected mass surfaces which are exposed to the sunlight should be 9 times more than the area of the glasses.
9- The solar temperature without using the thermal mass is used in direct absorption.

The solar heating is the most basic passive solar technique which includes increasing the number of windows in the southern side and the kind of window which is considered as the thermal mass in most of the houses. In solar house, about the 25% of the windows are toward the south and 3% of them are located on the ceiling of the houses. Energy saving in this method is low but the costs are lower than the others.

Indirect absorption

In the indirect absorption system, the thermal mass is located between the space of the house and the sun and absorbs the beam of the sunlight and transfers it to the space of the house. Indirect absorption system consumes 30-45% of the solar energy which reaches to the glass as the thermal mass.

The types of indirect absorption systems are as follows:

1- Heat accumulator wall system (Trombe walls)
2- Pond system
3- Water wall
**Trombe wall**

In this system, the thermal mass is located approximately behind the glass of southern side. There are several valves at the top and bottom of the Trombe wall which permit the heat to flow from these wall and glass to the interior of the house. At the night, when the valves are closed, the radiation of the heat from the wall, warms the space of the house. Usage of this wall is a technique for taking the heat of the sun and is made by the French engineer Felix Trombe.

A part of southern wall which made of thermal mass materials such as concrete is covered by the glass which has been located in the distance of 0.05 m from the surface. The sun light enters and the heat is trapped by the glass which helps the wall in order to absorb the heat. Then, the heat is radiated to the inside of the house during the night and sunset hours. The Trombe walls do not need ventilation since the purpose is to circulate the warm air and taking the heat through the radiation of the sunlight on the wall.

The heat accumulator wall should be solid and has no open valve or vent to the outside or the space of the house. In summer, the Trombe wall has the better efficiency than the direct absorption method. The Trombe wall are combined with the windows of the direct absorption method on that certain wall. The double glazed glasses are recommended for the heat storage. The glass and the thermal mass should have 2.54-7.62 cm distance from each other.

**Pool or pond on the roof**

The heat absorber mass has been located on the roof. This method is used for heating and cooling. The glass wall ponds on the roof should be exposed to the direct sunlight from 10:00 AM until 14:00 PM. Meanwhile, in summer, these ponds should be exposed to the night free and cool air. The height of the water in the roof is about 15-30 cm. Therefore, the building structure should tolerate the 150-300 kg water in each m².

This system which is used for the heating and cooling has two important features:

1. The intense fluctuations of the temperature in inside is very low.
2. Regarding to the extensive radiation surface (usually all the roof), there is an appropriate thermal quality in inside.

In the winter nights, the water tank should be protected by the thermal insulation in order to prevent the rapid loss of absorbed heat which has been absorbed during the day. In the summer days, this water tank should be totally in the shadow. The ponds can be open in the summer days in order to use the cooling which resulted from the evaporation.

In different areas of the world, providing the comfort conditions in the warm months of the year is possible through the cooling process. In many countries which are in the tropical zones, the cooling load component allocates the high share of consumable electricity to itself during the warm season. In the present, the compression systems are the main method in providing the cooling process and air conditioning. These systems have been recognized as the main factors of the destruction of the ozone layer. In addition, their electricity consumption is very much, too. Hence, the usage of the solar energy for cooling process is considered as the replacement of the compression systems.

**Adjacent greenhouse method**

The double glazed glasses or transparent plastic are suitable in this method. The wall between the greenhouse and living room should have the high thermal capacity (water wall or Trombe wall) but in selecting another materials, there is more freedom of action. With appropriate designing, all the incoming radiations to the greenhouse are changed into the heat. Therefore, the efficiency in winter is 60-70% and the amount of heat which is
transferred into the rooms is 10-30% of the radiant energy which can be increased through adding the mechanical accumulator system.

3) Water wall:
Water is stored in the rigid tanks. Heat storage capacity of the water is 2 times more than thermal mass. Hence, there is need to less volume than thermal mass proportionally. At least, 13.23 liters of the water is poured for per square foot of glass in the tank. Even a hot tube in the wall or a pool is used as the thermal storage mass.

The general laws of the indirect absorption system of the Trombe walls are as follows:
1-The mass wall should be faced the sun and has the dark color.
2-The distance between the thermal mass wall and glass should be at least 0.1 m.
3-Those valves which are used in the thermal mass wall should be closed at night.

A) If the night removable insulation be used in the thermal wall system, the area of the thermal mass is increased about 15%.
B) If the thermal wall is made of brick, its approximate thickness for the concrete, adobe, other materials and water is 0.25-0.35 m, 0.3-0.45 m, 0.2-0.3 m and at least 0.15 m respectively.

C) Isolation of the house
An isolated system consists of separate parts from the main part of the house such as one solar room and a transfer circuit which transfers the heat from the collector to the house accumulator system. One of the advantage of this system in comparison with others is the insulation of the houses.

The isolated system uses the 15-30 % of the sun light which transferred to the glass for heating the space of the house and also preserves the solar energy in the solar rooms.

The solar rooms or solar greenhouses are a combination of the direct and indirect absorption systems. The sun light which enters into the solar room is reserved in the thermal mass. The sun light is conducted from the shared solar mass wall to the house. This wall is located between the house and the greenhouse.

The techniques of the normal cooling cause the coolness of the house without any energy in the summer. Shadow is one of the practical and important item in the solar passive houses since this structure collects the sun light in the winter. The thermal mass and the constructive materials not only are used in heating appropriately but also are effective in cooling. They are used for reserving the heat in the winter and for cooling the house in the summer. In addition, usage of the windows which make the shadow in the summer and transfer less heat into the house are one of the passive cooling methods.

1) Appropriate windows for ventilation:
One of the primary strategy for cooling the buildings in the warm weather without using the mechanical parts is the utilization of the natural ventilation. The current breezes of the summer are consistent with the big glasses of the southern wall and make the possibility of using the ventilation and solar valve effectively through observing the following strategies.

The windows should positioned in such a way that the best airflow be created and the awning windows which have parasol be opened completely. This window is the best protector against the rain and works better than hinged windows.

2) Parasol
The devices which create the shadow, stop the sun light before reaching to the building. These devices are as follows: parasol, solar plates, rolling curtains, specific diaphragm for the behind of window and vertical wind capture. These devices are controllable and are adjusted by the landlord as required. Usage of curtain in the house is cheap and useful. Another way for creating the shadow is the utilization of a porch or corridor in the eastern and western parts of the building.

3) Affecting walls on the air
Winged walls are exposed to the windflaw and increase the speed of the natural wind through the pressure difference which is made by these walls.

- Thermal chimney
The thermal chimney is used for exiting the air and steam from the building. By installation of the outlet valve in the hot and warm regions, the air is drawn into the building for ventilation. The lower valves of the house are opened into the
northern windows and the inside air of the house exits through the upper valves of the solar room.

The mass wall is made for indirect utilization. The thermal chimneys are constructed as a narrow part (such as a chimney). A metal absorber which is capable in order to be heat is installed beside the chimney and behind the glass plate in such way that it reaches to the high temperature and is separated from the house by an insulator. The chimney is limited to the above of the roof and a rotating turbine locates on the top of chimney which is opened in the opposite direction of the wind and the hot air can go out without any obstacle for entering the wind into the chimney. The thermal chimney is used in those houses which have the corridor and open staircase.

**Solar active systems**

The solar active systems include the solar energy collectors which for example are in the solar and photovoltaic water heaters. Utilization of these intermediate devices and apparatus make the flexibility in saving the energy.

**Solar water heater**

The main and important principles which should be considered in the collectors of the solar water heater are as follows:
- Installation of the collector on the roofs with the latitude angle of the place plus 15°.
- Collectors should be placed in such a way that the amount of shadows of the objects such as surrounding buildings, chimneys and etc. be minimal. When the collectors are installed in the seriate rows, the none creation of the shadow should be considered.

**Photovoltaic electricity system**

The photovoltaic system can be installed and used in every capacity such as another generators and power plants. Even its limitation is very lower than the others and can be produced as the generators with the capacity of MW up to the several MWs. However, regarding to the low efficiency of changing the energy in this system and the high price of its equipment, the produced electricity from this system is a bit more expensive.

Utilization of the solar panels in building architecture causes the reduction of loading expenses of this energy and can be effective in its application development. In combining a photovoltaic system with the architecture and installations of the building, the main equipment of the system remain and other equipment are combined somehow with the similar devices in the building. Some of the accessories of the main equipment can be removed and saved and do not install in the building facade.

One of the application of the photovoltaic systems for heating the building is the floor heating system. In this system, the solar energy and solar panels are used instead of fossil sources for supplying the consumable warm water. The low temperature of the required water (55°C) in the floor heating system as the only heating preparation system, prepares the important and fundamental possibility for using the new energy such as the solar energy.

The optimum conditions in loading the photovoltaic system in building architecture can be investigated from two aspects:
1. Combining the photovoltaic system with the architecture and electric installations of the building.
2. Seasonal designing and calculating the photovoltaic.

The solar energy and the floor heating system play the main role in reducing the pollutants resulted from the combustion of the fossil fuels and utilization of them leads to better life for the next generation.
Components of the solar electricity system

1. Solar panel or solar plate: It changes the energy of sunlight to the direct electricity.
2. Group connection box: It is the connecting medium of the panels to the electric circuit and the protector of the solar panels from the thunder and firelight.
3. Building and mental structures: It keeps the panels in the particular direction and angle.
4. Controlling device: This is the controller of the electricity production, electricity consumption, charge of reserve batteries and regulator of the specifications of the produced and consumable electricity regarding to voltage and ampere.
5. Connection cables: They establish the connections of the photovoltaic system and electric circuit.
6. Reserve batteries: they store the required electricity for hours without sunlight.
7. Inverter of the DC to AC: It changes the AC to the 1 phase or 3 phases DC.

Designing and calculating the photovoltaic system

For designing a photovoltaic system, different factors should be considered and investigated. Some of them are effective in calculating the capacity and output of the system or electricity estimation and others play the role in selecting the type of equipment and their design. These factors are as follows:

Geographical position:
The geographical latitude and longitude and the height of the installation place of photovoltaic system are the necessary factors for calculating the power of radiation of the sunlight.

Time position:
In investigating the time position, the installation place and its conditions based on the sun movement, shadow of the heights and surrounding mountains or even the shadow of the buildings and the determination of the day hours which probably these shadows prevent the direct radiation of the sunlight to the panels, are investigated. The distance of the system to the consumer and the cable rout determine the length of connection cables. The electrical resistance of the cables and energy losses within them are effective in calculating the capacity of the photovoltaic system.
Weather conditions:
The number of consecutive cloudy days is one of the important factors which is determined in investigating the weather conditions. If we want to save some of the solar electricity for cloudy times, this factor is considered in calculation and the capacity of the photovoltaic system is calculated according to the required electricity in cloudy times. In addition, the wind flow and its speed for determining the strength of the building and mental structures, rainfalls and the height of snow for determination the height of panels from the earth surface, air transparency, amount of humidity and dust and their effects on the intense of radiation of the sun light, thunderbolt and firelight for predicting the appropriate safety equipment are some of other factors which are investigated.

Required electricity:
In investigating the required electrical energy, in addition to the power, the voltage and its alternate or direct current and momentary electric amount are considered. The consumed power applies directly in the calculations and the voltage is used for determining the number of solar plates which are parallel or series with together. Momentary electricity amount is related to the time that all the consumers are in the circuit together or some devices enter to the circuit which their required electricity for beginning the work is different with their continuous consumption. This factor is very important for designing the controlling device.

From Cell to Array

Cells: Semiconductor device that converts sunlight into direct current (DC) electricity

Modules: PV modules consist of PV cell circuits sealed in an environmentally protective laminate and are the fundamental building block of PV systems

String: PV panels include one or more PV modules assembled as a pre-wired, field-installable unit

Array: A PV array is the complete power-generating unit, consisting of any number of PV modules and panels

Advantages of the solar energy
1- Production of the electricity without fuel consumption
2- No need to the lot of water.
3- Lack of environmental pollutions
4- Preparation of the regional and small networks
5- Low depreciation and long life
6- No need to expert.
How do wind turbines make electricity?

Simply stated, a wind turbine works the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. View the wind turbine animation to see how a wind turbine works or take a look inside.

Wind is a form of solar energy and is a result of the uneven heating of the atmosphere by the sun, the irregularities of the earth’s surface, and the rotation of the earth. Wind flow patterns and speeds vary greatly across the United States and are modified by bodies of water, vegetation, and differences in terrain. Humans use this wind flow, or motion energy, for many purposes: sailing, flying a kite, and even generating electricity.

The terms wind energy or wind power describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity. (U.S. Department of energy)

Harvesting Wind Power from Tall Buildings

Tall building designers are showing an increasing interest in reducing the environmental impact of the construction of their buildings. One of the approaches being used, and investigated more frequently, is the incorporation of power-generation, primarily solar and wind devices, into the design of the building. The requirements for optimizing the performance on wind generators in an urban environment are quite different from the considerations of the open sites that have traditionally been the domain of wind farms. This requires the use of different design approaches to assess the most suitable generator types, develop building forms that will enhance their efficiency, and predict expected power outputs. (U.S. Department of energy)

Common types of wind turbine

Modern wind turbines fall into two basic groups: the horizontal-axis variety, and the vertical-axis design. Horizontal-axis wind turbines typically either have two or three blades. These three-bladed wind turbines are operated “upwind,” with the blades facing into the wind.

Size of Wind Turbines

Utility-scale turbines range in size from 100 kilowatts to as large as several megawatts. Larger wind turbines are more cost effective and are grouped together into wind farms, which provide bulk power to the electrical grid.

Single small turbines, below 100 kilowatts, are used for homes, telecommunications dishes, or water pumping. Small turbines are sometimes used in connection with diesel generators, batteries, and photovoltaic systems. These systems are called hybrid wind systems and are typically used in remote, off-grid locations, where a connection to the utility grid is not available.

Wind climate

When contemplating the incorporation of wind power generation into a tall building design, the first consideration must be the local wind climate of the area. Bluntly, if there is no wind to start with then the potential for successful use of turbines will be very limited!

The most common statistic that is quoted when assessing wind power potential is average wind...
speed. This is the average wind speed throughout each day throughout the year. Due to the cubic relationship between wind and wind power, this is on its own is not a particularly useful statistic as it does not reveal anything about the characteristics of the underlying wind climate. For instance, many locations around the world experience seasonal trade winds that mean that while high wind speeds will be experienced at some times of year, much calmer conditions, with limited power generation potential, will be experienced for other larger parts of the year. Similarly, many locations experience large diurnal effects with wind speed varying greatly throughout the day, for example as a result of afternoon sea breezes. A better metric for determining the power potential is the annual average wind power density of a site.

The wind power density is the average amount of power that is in the wind on a yearly basis, which takes into account not only the mean wind speed for a site, but also the frequency distribution of wind speeds. (U.S. Department of energy)

The directionality of the wind is also important. As will be discussed later, the incorporation of turbines into tall buildings tends to favor limited wind directions, perhaps within a 45° sector, depending upon the building configuration and the location of the wind turbines on the building.

Modification of the wind climate by the urban environment

Most commercial wind farms are located in very open rural environments, often taking advantage of local topographic features to accelerate the flow as shown in the picture.

Wind conditions in urban environments tend to be very different. The effect of urban environments on a boundary-layer is shown in Figure 75. This shows how buildings slow the wind near to the ground, and increase the turbulence in the wind. Turbines work most efficiently in low-turbulence environments so care needs to be taken in specifying turbine types that will cope with both existing turbulence and likely future changes in turbulence as a result of urban development. (U.S. Department of energy)

Urban development is likely to pose one of the greatest challenges to increasing use of turbines on tall buildings. In city center locations, height restrictions often mean that many tall buildings are of similar heights. Even if a building is very tall, if all the surrounding buildings are of similar height then the potential for seeing suitable conditions for efficient turbine installation is significantly reduced.
Basic tall building aerodynamics

As discussed in the previous sections, it is desirable to locate turbines in regions of high wind speed and low turbulence. Describing the wind flow around a tall building can be quite complex and has been studied in depth for many years (Cermak, 1971, 1975 and 1976). A simplified sketch of the mean flow phenomenon is shown in Figure 77. There will be positive pressure on the windward face and negative pressure on the side and leeward faces. As air, or any fluid, will naturally flow from areas of high pressure to low pressure this implies that the most effective locations for wind turbines will be either in the accelerated shear layers around the edge and top of the building or in specially developed passageways linking the areas of positive and negative pressure. Note that wind speeds close to the center of the roof may be low as this area is often in a region of separated flow.

Shaping of tall buildings to increase efficiency of wind turbines

Shaping of tall buildings can be used effectively to enhance the performance of wind turbines. Two examples of this are the Bahrain World Trade Centre (Figure 78) and the Pearl River Tower in China (Figure 79). The Bahrain World Trade Centre Tower is formed to create a venturi effect, placing the horizontal axis turbines between two wings of the building.

This approach clearly works for only a limited number of wind directions, but may be useful in a location with a dominant prevailing wind direction. Restricting the orientation of horizontal axis turbines, however, severely limits the efficiencies gained from using this type of turbine. In the Pearl River Tower slots through the tower are used to relieve the pressure between the front and rear faces of the tower with these slots being aerodynamically shaped to increase flow through them.

Again, this approach is most efficient for only a few wind directions but has the advantages of not only accelerating the flow but by the compressing nature, decreasing turbulence.
Passive Cooling in contemporary

- is based upon climate considerations
- attempts to control comfort (heating and cooling) without consuming fuels
- uses the orientation of the building to control heat gain and heat loss
- uses the shape of the building (plan, section) to control air flow
- uses materials to control heat
- maximizes use of free solar energy for heating and lighting
- maximizes use of free ventilation for cooling
- uses shade (natural or architectural) to control heat gain

Passive solar heating and passive ventilation for cooling assist in creating sustainable building by reducing dependency on fossil fuels for heating and cooling buildings, as well as reducing the need for electricity to support lighting by using practices of day lighting in buildings. Passive strategies are separated for the heating and cooling systems, and work with conduction, convection, radiation and evaporation. They also look to the environment to source or sink heat.

With today's growing emphasis on reducing energy consumption, modern architecture can make use of traditional Iranian methods to utilize air currents and evaporation in cooling and air-conditioning living quarters. Wind towers display the compatibility of human-built architectural designs with the natural environment and the ingenuity of Iranian engineers. Nowadays, natural ventilation has become an attractive solution for reducing the energy usage and cost and providing good indoor air environment while sustaining a comfortable, healthy and productive internal climate.
Geothermal Energy For Building

Usually a question is asked that can geothermal energy be employed at home. Well, the answer to it is that it can be used. It is not necessary that you can enjoy this limitless form of energy can only be enjoyed in equators or in extremely hot region. Many homes can tap into it. Tunnels dug underground vertically or horizontally use geothermal power to bring your home temperature to earth temperature; it helps you to go below or above that temperature that is the house is either cooled or heated. This is called as ground source heating or cooling. (U.S. Department of energy)

How Does the Process of Cooling and Heating Takes Place?

The temperature of the earth remains constant around 58 to 60 degrees. Tunnels dug five to six feet deep or up to four hundred feet long can help us in driving the energy and a noticeable decrease of 70% in electric bills occurs. The setup of these tunnels is quite expensive but if the process starts then the effective cost becomes very less in a short period of time. Actually no matter how much is the temperature outside, the temperature deep down would always be in 50 degrees; which is very near to the ideal.

You can always reach a comfort zone. If it is too cold then you can add some heat to your home by driving energy from the earth. It takes very less time to cool your home in summers as the duct continuously pumps cooled air into every corner of your home.

This means that you can maintain your home temperature without spending much money. The thermostat needs not to be turned up very high or very low in summers and winters respectively. This geothermal source saves almost 40% of what is spent on other cooling and heating systems. (U.S. Department of energy)
Working of Geothermal Systems

The major parts of geothermal home systems are: an underground loop, a heating pipe and a heat dispenser. Plastic pipes are dug into the ground for the ground loop. The depth of these pipes decides the amount of energy provided. It is important that they should reach the energy source.

A mixture of water and anti-freeze goes from the pipes and comes back to the heating pipe where the hotness is removed and the mixture is transferred to the dispenser either by force or by radiant heating, while the reverse happens for cooling in summers. The heat from the liquid is dissipated into the ground and cooled liquid is then processed by forcing air devices which use air coils like air conditioners. This is how it works and serves as a source of maintaining temperature of a home.

Benefits of Geothermal Heat Pump Systems

The biggest benefit of GHPs is that they use 25% to 50% less electricity than conventional heating or cooling systems. This translates into a GHP using one unit of electricity to move three units of heat from the earth. According to the EPA, geothermal heat pumps can reduce energy consumption -- and corresponding emissions -- up to 44% compared with air-source heat pumps and up to 72% compared with electric resistance heating with standard air-conditioning equipment. GHPs also improve humidity control by maintaining about 50% relative indoor humidity, making GHPs very effective in humid areas.

Geothermal heat pump systems allow for design flexibility and can be installed in both new and retrofit situations. Because the hardware requires less space than that needed by a conventional HVAC system, the equipment rooms can be greatly scaled down, freeing space for productive uses. GHP systems also provide excellent “zone” space conditioning, allowing different parts of your home to be heated or cooled to different temperatures.

GHP systems have relatively few moving parts and those parts are sheltered inside a building, so the systems are durable and highly reliable. The underground piping often carries warranties of 25 to 50 years, and the heat pumps often last 20 years or more. They usually have no outdoor compressors, so GHPs are not susceptible to vandalism. In addition, the components in the living space are easily accessible, which increases the convenience factor and helps ensure that the upkeep is done on a timely basis.

GHPs have no outside condensing units like air conditioners, so there’s no concern about noise outside the home. A two-speed GHP system is so quiet inside a house that users usually do not know it is operating. (U.S. Department of energy)

Smart Material

In third millennium, we confront new modernization in more efficient multi-functional material. More efficiency means increase of resistant, formability, durability and more ability than traditional material (Golabchi et al., 2011). The materials (smart material) feel environmental events and process information and appropriately react to environment and its circumstance (Sadeghi, 2011). In other word, they have natural ability in rapid response to the environment. These materi-
rials not only increase useful life of houses, but have significant role in reducing maintenance costs of buildings.

**Definition of smart materials**

Smart material is a new terminology for material and productions that have capability of perceiving and processing environmental events and show proper reaction to them. In other word, these materials has capability to change and are able to reversible change their form, color, and internal energy in response to physical or chemical effects of surrounding. If materials are classified in three groups of non-smart, semi-smart and smart. First group, non-smart materials don’t have above-mentioned special characteristic. Semi-smart materials are just able to change their form in response to environment effect, for once or short time; while in smart materials these changes will be repeatable and reversible. Smart materials are also known as “flexible” and “adaptive”, and this is due to their particular feature in adjusting with environmental conditions. The effect of chemical and physical variables is stimulants that smart materials react against them.

**Types of smart materials**

In general, housing material, whether traditional, artificial and natural, is classified according to their properties such as appearance, texture, chemical composition, mechanic and physical properties, environment effect etc. In classification of smart materials not only these features, but other characteristics that relates to distinguishing smart material from traditional material are considered. In fact, classification of smart material suggestions is presented based on three following features:

- **Capability to change intrinsic properties**
  - Modifying smart material
  - Color changing smart material
  - Bounding changing smart material.

- **Capability of energy exchange**
  - Light emitting smart material.
  - Electricity producing smart material.
  - Energy saving smart material.

- **Temperature responsive smart materials**
  This type of materials has intrinsic property that enables them to reversibly react to surrounding temperature. Temperature changing may have an inactive effect; so that materials constantly balance their inner temperature with natural surrounding by their outer skin and if the effects are active a kind of active heating is created with applying and electricity field by contact. An example of thermal expansion material (TEM) is expansion materials with thermal expansion coefficient. But their most important application at architecture is in heating thermostats for building services and also as especial stimulant at greenhouses and building facades for energy control and management. Another application of them is in air conditioning system of rooms. The system works in a way that in special temperatures the system opens or closes to provide appropriate conditioning. They also can be designed as elements of air conditioning system in facades of buildings by automatically raising or lowering parts of roofs covers. Implementation of these smart materials in the building, rejects the need for complex systems and high expenses by appropriate air conditioning, and considerably lowers energy consumption (Ritter Axel, 2007).

- **Color changing smart materials**
  These materials are able to reversely change their color or visual features in response to one or several external stimulant. With respect to its stimulations these materials contain different types but the most applicable types in architecture include: photo chromic, thermo chromic and electro chromic material (Addington et al., 2005). Currently, the material that are highly regarded by architects are called photochromic material.
Although these materials were primarily implemented because of their aesthetic (its color spectrum against the light), but researchers have done many studies to use them in other applications such as decreasing energy consumption or thermal changes of these covers. Electro chromic materials are also used in electro optical glass architectural. These materials change their visual feature (i.e. their transparency) exposed to solar radiation (Ritter Axel, 2007).

**Energy Saving Smart materials**

 Transparency and heat conductibility can be used simultaneously.

 Whenever the internal temperature of the building is more than external temperature, a bidirectional flow will be established; radiance energy transfer into inner space while inner heat energy lead to outer. Changing the amount of absorption of glasses finally effect their pure conductivity and change equilibrium of these flows. Many different materials can be used in construction of smart windows such as photo chromic, thermo tropics, electro chromic materials, fluid crystals and suspended particles system. In many cases smart materials used for windows can be used interchangeably. For example, electro chromic, fluid crystals and material with suspended particles are all applicable in controlling heat and light conduction. The most difference of these materials are their activation by electricity (Kienzl, and Schodek, 2005). These materials and products are able to save energy visibly or hidden; for example, in the form of light, heat, hydrogen or electricity. It is worth to note that these materials are also reversible. Thus, these materials are able to save energy in different forms. But heat saving smart materials is more considered.

These materials have a kind of intrinsic specification that enables them to latently save energy as heat or cold (Addington, et al., 2005). These materials are more applicable at architecture. The most applicable materials is known as mode changing material, referred to phase changing material (PCM) that can act as thermal adjusting intermediates. For example, as cold or heat saving element, they have features to change their status from liquid to solid by final PCM of room thermal adjusting. It is necessary to say that material with high heat saving and low heat wasting capacity are not placed in this class of smart materials.

 For instance, we can mention windows in which salt hydrate are used in hollow and transparent plastics blocks. In this system, summer, the solar radiation is reversed outside by prismatic panels in the summer and in winter, the sunray that has less angle crossing from system and in addition to heating inner space, heat the panels. This heat change salt hydrate from solid into liquid and obtained heat is saved in saving system as inner heat. When the heat of room is lower than 26°C, for example during the night or in the cloudy days, then salt hydrate are crystallized and release saved heat energy in the room. (Ritter Axel, 2007).

Another advantage of this system is charging or non-charging status of heat storing system is visible from its appearance. So that, if appearance is opaque, the salt hydrate is not charged, means it does not have heat storage but if the appearance is transparent or semitransparent, salt hydrate is charged and its storage and heat storage is full (Ritter, 2007).
THE HIGH-RISE BUILDING AS SUSTAINABLE SOLUTION FOR THE PRODUCTION OF ENERGY

Evolution in perspective of a tall building

Nowadays, environment saving in fossil energies consumption and sustainable development have changed to the most common and important issues in the international conventions. Moreover, continuous increase in the world population has confronted the nations with the energy shortage more than ever and this threatens human’s life.47

According to the PNUD (Program of the United Nations for the Development) until 2030, in urban areas throughout the world 5 billion people will live. Whereas in 1950, 30 percent of the world population lived in urban areas, and in 2000 the proportion of the urban dwellers climbed to %47 and it is projected to rise to 60 per cent until 2030.48 Energy shortage, global warming, urban sprawl, air pollution, overflowing landfills, water shortage and disease will be the legacy of the twenty-first century, unless we move quickly towards the notion and implementation of sustainability.

Considering the increased population and its consequences, the vertical development of the cities seems the best and inevitable solution for the problem which will change our urban design method for ever. Due to the importance of environment issue, green architecture and sustainable architecture affects our present and future design. This vertical development will be effective when it is designed sustainable.

Until recently, tall buildings have been viewed as mega-scale energy consumers with little regard for sustainable architecture. However, this is changing with a new generation of high-rise buildings that have been designed with energy conservation and sustainability as their principal criteria. (WCED 1989)

A high performance tall building is one that achieves the peak efficiency of building functions while meeting the requirements of optimum performance employing green technologies. These technologies and innovations offer radical changes to the built environments in terms of energy usage, structural performance, and environmental effects. Designing a sustainable tall building, therefore, requires a 360-degree view of the entire building enterprise considering the local and global environment, the availability of renewable and non-renewable resources, community impact assessment, and the collaborative input of architects, planners, engineers, social scientists, behavioral scientists, and other community-based groups. (Donaldson, 2000)

Thus it is an integrated process because of tall buildings’ scale and the fact that green design affects so many different elements of a building, such as day lighting, which in turn concerns sitting, orientation, building form, facade design, floor to floor heights, interior finishes, electric lighting controls, and cooling loads, among other things. (Malin. 2006)

The construction industry is under growing pressure to incorporate renewable energy systems in the design and construction of new developments, but this will require a big change in the industry’s current attitudes and ways of working. (U.S. Energy, 2007)

Sustainable Architecture

Sustainable development is a wide and ideal term which has various and different meanings. Consequently, different meanings of the term, requires different reactions of the thinkers. In 1983, the United Nations established the World Commission Environment and Development in attempt to resolve the conflicts arising out of the aspirations of the developing and developed worlds. In 1989 they published “Our Common Future” or the Brundtland Report, which launched the concept of “Sustainable Development” and was reinforced in 1992 at Earth Summit in Rio. It called for “Development which meets the needs of the present generation without compromising the ability of future generations to meet their own needs.” Sustainability essentially aims for ecological balance.49

Sustainable development relies on three main principles: environmental sustainability, economical sustainability and social sustainability. The principle of environmental sustainability relies on the fact that, land should be used in the way that it would be also usable for the next generation. Human activities should be done without lessening resources and increasing environmental destruction, Hence the recyclability of the natural resources should be taken into consideration when using them. Environmental sustainability development emphasizes on the reduce in using...
of natural resources, renewable energies, prevention of energy resources loss, reduce in production waste and emphasizes on reusing and recycling wastes, using materials which can be returned to the nature and thus, reduction of pollution production in industries and agriculture. Sustainable architecture is not a style rather it is a holistic approach which focuses on the interactive relationship between the building and its field context. Sustainable architecture is a logical reaction to difficulties and problems arose in industrial era. Such definitions consider sustainability as the most important purpose of the architecture and introduce reducing energy using and natural resources conservation for future generations as the most important and necessary measures taken to achieve sustainable patterns in architecture. Sustainable architecture is an informed and Economical environment in energy consumption, using renewable, respondent systems and materials. Ecological and environmental concerns beyond the issue of nonrenewable energy resources consumption have been developed widely. Following principles are those which should be taken into consideration in a building to make it become among sustainable building classifications: First principal: saving energy, second principal: compatibility with climate, third principal: reducing new resources consumption, forth principal: supplying needs of dwellers, fifth principal: compatibility with site, sixth principal: being holistic.

The High Performance Tall Buildings

Tall buildings are massive consumers of the energy. They are the dominant elements in urban architecture due to their scale and purpose, and should be the focus of sustainable design. So many architects (such as Ken Young) believe that, the danger of skyscrapers to the environment is more threatening than air pollution, so they propose green architecture to prevent such problem. The Lack of space and the population growth are the main problems which are threatening the environment, seriously. Skyscrapers and other mega structures which are built to keep balance of population growth and needed space, consume considerable amount of energy in construction process and next that, resulting in environmental pollution and overflow of the wastes and generally they deprive their dwellers of natural weather and light. Meanwhile most designers, engineers and architects believe that, if the buildings of big and populated cities are designed and built under appropriate conditions, they can indicate sustainable development and green architecture. Believing in such attitude, inappropriate factors influencing the environment will be minimized while keeping health and welfare of the dwellers.

Clearly, the design process is significantly complex since the designer has to understand the building performance in terms of different design factors and variables and under differing conditions. Some overall benefits of high performance design are: energy efficiency, design flexibility, resource conservation, indoor environmental quality, etc.

The principal design factors that are crucial for achieving a high performance tall building are: site context, environment, structure and use of materials, energy consumption, use of water, ecological balance, community development, etc. Because of these diverse aspects of design for tall buildings which have enormous scales as a building type, the amount of information that guides the design is often very complex, and shared by professionals of different disciplines. Further, the design factors assume different forms, such as conceptual, schematic, physical, economic, environmental, and socio-cultural. This demands smart and integration design, which hold the key to high performance buildings. The design team comprising different professionals must aim for the common goal set early on that “the building will offer optimum performance” and must have a respect and understanding for each other’s mission. Integration and rigidity of an elegant building produces such strategies. Building construction requires solidarity and integration. It is such integrations and rigidity that result in change of mental structure of the human. In most cases, green buildings are defined as the building which has less negative effects on its surrounding environment.

Strategies for Achieving Sustainability

In most countries, sustainable development and specifically sustainability in architecture, design and implementation of buildings compatible with environment are the main and macro issues. Thus, some countries which are leading of this field, has thought about designing an evaluation system immediately. Nowadays various ranking and evaluation methods have been developed for building
sustainability evaluation in all over the world. Systems such as Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Methodology (BREEAM) and Polar Environment Atmospheric Research Laboratory (PEARL) are of this type that we will introduce hereunder the most important and applied system (i.e. LEED point system).

LEED is a term which means the management of energy and environmental design. LEED certificate was developed by U.S Green Building Council. The first edition of LEED certificate was used to evaluate green buildings in 1998. Although LEED certificate is called U.S standard for evaluation of green buildings, international community also accepted it as a criteria of evaluation in designing construction and establishment of buildings which claimed green function to surrounding environment.

LEED presents solutions in seven chapter and the buildings which observing following items be succeeded to get LEED certification for green buildings and they are ranked based on their obtained point. The main indicators of maximum point are: Sustainable sites, water performance and efficiency, energy and atmosphere, materials and resources, indoor air priorities. quality, innovation and design/build process and regional.

**Sustainable Site:** Preventing pollution while construction (obligatory), the appropriate site selection, obtaining optimal density in built environments and vicinity to urban services, restoration of damaged sites and environmental pollutions, providing easy access to public transportation systems, invention appropriate parking capacity, maximizing outdoor, qualitative and quantitative management of rainfall, preventing heat island in non-roofed buildings and preventing heat island in roofed buildings, Reducing light pollutions.

**Water Efficiency:** Reducing water consumption (obligatory), saving water consumption of irrigation systems, waste recycle by using the innovative technologies.

**Energy:** Assurance of energy systems performance accuracy in the buildings (obligatory), minimum use of energy in the buildings (obligatory), preventing reduction of ozone layer through cooling instruments(obligatory) optimization of energy consumption in the buildings, using renewable energy resources, distinguished and evaluated energy consumption in building.

**Materials:** Gathering and saving renewable material (obligatory), reuse of the building with keeping non-structure elements of indoor building, managing wastes produced by construction, using recycled materials, using local materials, using materials with immediate recyclability.

**Indoor Air Quality:** Achieve to minimum desired air quality of indoor building (obligatory), controlling the amount of tobacco smoke released of the environment (obligatory), installing carbon dioxide measurement systems of building output air flow, increasing ventilation system, managing the quality of indoor air before operation of the building and at the time of construction, using materials with less pollution (including adhesives and linings, colors and covers, roofing and wooden products), controlling lighting systems, controlling heat and ventilation systems, heat comfort system design, providing natural light, providing appropriate view.

**Innovation:** Innovation in designing with the desired LEED factors

**Regional Priorities:** Importance to the local priorities.

**Strategies for Green Tall Buildings**

There are other approaches to the design of sustainable tall buildings. For example, energy consumption by elevators is significantly high as the cost of operating and maintaining them is also high. Because of the construction of many super-tall buildings, elevator technology has been a topic of continuous research and development. Significant improvements have been made in this technology to make the elevators safe and the mode of travel efficient and comfortable (Beedle et al., 2007).

Rainwater harvesting collects the rain onto roofs, then stores it in a tank, intended for eventual use. When required, the water is pumped to the point of use, thus replacing what would normally be a demand for regular water. The size of the storage tank is determined considering the amount of water available as a function of roof area and local average rainfall. The recycled water is used for toilets, washing machine and outside tap use. Grey water recycling is another process in which water from bath, shower, and hand wash basin is reused. This “grey water” is more suited to residential tall buildings in which sufficient amounts are generated regularly for reuse in toilets, wash-
Harnessing Solar Energy

There are two categories of solar energy: passive and active. Passive solar energy is put into practice as a design strategy to accomplish direct or indirect space heating, day-lighting, etc. Active solar energy is implemented through technical installations such as solar collectors and photovoltaic (PV) panels. The average annual growth rate of PV cells has been at 30 percent in recent years (IEA, 2003).

The application of photovoltaic technology for tall buildings can be significant since they provide an opportunity for a clear path of direct sunlight by towering over other buildings.56

Maximum advantage can be taken of daylight by shaping the plan arrangement of a building to suit the activities within. The Service center of a building should be in the place where has access to daylight, natural ventilation in its lobby, elevator and staircases.56

Structure and Material Preferences

At first sight it is hard to relate sustainability to the structure of a tall building. However, steel and reinforced concrete buildings are typically the materials of choice. In addition to, the core provides structural stability and its positioning is important for sustainability.55 For example, concrete structures can be used for controlling of the cold nights in desert climates and convert it into the cooling energies at day hours. Also, steel frames can be built with recycled materials.57

Facade Technology

Day-lighting and shading are usually the key aspects to facade design for typical green buildings. The façade covers over 90 to 95 percent of the external building surface area in a tall building. Thus, the energy gain or loss for a tall building depends very much upon the materiality and technology employed in the facade treatment. Facades not only offer the aesthetic look and the building’s architectural expression, but it can also be advantageously used to control the internal conditions of the building.55 Hence it is better to build openings to North-South, except they could have better view in other areas. In the areas that are not affected by adequate sunlight, they should be closed walls.

It is common the application of two layer coating, sometimes three layer coating and view with ventilation system.59 Double glazing with argon filled cavities, triple glazing and glass coating increase U Values.59

Orientation and Walls

Skyscrapers are strongly influenced by external temperature especially sunlight. Hence buildings orientation is widely important for energy survival. If the building width is designed to north-south, energy consumption will occur in the best way.

External walls should also have filtering capability. So, external walls should have adjustable mobile parts and openings and it should have appropriate solution for air conditioning, lighting and storm rain.

Harvesting Wind Energy

Wind is a renewable energy source which can be advantageously tapped at higher altitudes of tall buildings where wind speed is considerably large. Tall buildings can be shaped to funnel wind into a zone containing wind turbines without having negative effects on the structure, its surroundings and the occupants. By such profiling of the structure, wind speed can be amplified that can produce more energy.

Biomass Energy

In addition to solar and wind energy, another source is the bioenergy. Biomass is the sum total of all the Earth’s living matter within the biosphere. More specifically, it refers to the concept of growing plants as a source of energy. The energy reaching the planet is equivalent to about seven times its primary energy expenditure. When biomass is converted to a fuel as a store of chemical energy the process is carbon neutral, that is, the carbon emitted when it is burnt equals the carbon absorbed during growth. Biomass fuel, such as waste paper can be used for generating electricity and steam for high-rise
buildings. A 73-story multi-use high-rise project was investigated by Alfred Swenson and Pao-Chi Chang of the Illinois Institute of Technology, Chicago in this regard (Ali and Armstrong, 1995). Substantial amounts of biomass are ubiquitous in tall office buildings in the form of paper, most of which is used only briefly and trashed. The use of gas turbines with biomass fuels was investigated at the Princeton Center for Energy and Environmental Studies (Larson and Williams, 1990). Biomass energy generation does not contribute to global warming.

Geothermal Energy

Geothermal energy is one of our most plentiful resources. The “geothermal gradient” i.e., the rate of increase of temperature according to depth in the ground, averages 36.5 to 37.5 degrees F (2.5 to 3 degrees C) per 330 ft. (100m) of depth. Modern drilling techniques can penetrate up to about 6 miles (9.5 km). The most common surface manifestation of geothermal energy is simply hot water from springs. Natural hot water has been used since the nineteenth century for industrial applications. The first geothermal power station was built in 1913 which produced 250 kW (Smith, 2001). Another source is the high-temperature dry rock. The geothermal heat has to be brought to the surface. Water is pumped through boreholes and returned to surface to provide space heating a process known as borehole heat exchange (BHE) system. A significant area of innovation is the pairing of geothermal energy with heat pump technology. This technology has incrementally been improved, especially in the U.S. During the last five years the number of geothermal ground-source heat pumps has grown by 59 percent with most of the development in the U.S. and Europe (Smith, 2007). Development and refinement of this technology and its application to tall building design could prove to be more relevant than any other building type.

Case Studies:

Hereunder a few case study building examples are presented which represent the new generation of sustainable tall buildings that are setting trends for future projects incorporating innovations in materials and building systems. Understandably, this is not a fully comprehensive and global look, but the case studies provide angles though which to examine the movement.

The Hearst Tower (New York City, US)
The Hearst Tower is New York’s first skyscraper to receive the gold LEED certification. Nearly 80 percent of the steel used to create this structure was recycled, as well as much of the interior’s flooring and ceiling materials.60 The triangular framing pattern provides superior stability with less material than the typical steel; the diamond-like shape of the structure also ensures copious amounts of sunlight are being taken advantage of. The Hearst tower also makes excellent use of rainwater; the water comes from rainwater, and cools and humidifies the lobby air.61

Figure 88: The Hearst Tower.
Source: www.archdaily.com
Bank of America Tower
(New York City, US)
This tower is one of the first skyscrapers that were built using largely recycled and recyclable material as well as being LEED Platinum certified. It can also be considered the greenest skyscraper yet in the entire country. This tower has an on-site cogeneration plant that produces two-thirds of the building’s energy requirement. A sophisticated rain water capture system is also in place, as well as windows that maximize sunlight along with smart and efficient LED lighting.

The Pearl River Tower
(Guangzhou, China)
This skyscraper is known for its net zero-energy goal, meaning that it will conserve and generate enough power to meet its energy demands. It has a curved glass façade that directs air flow through narrow openings in the facade that will drive large, stainless steel wind turbines to generate electrical energy. The building’s aerodynamic shape, which resembles airplane wings turned vertically that serves to funnel wind into the tunnels.

The Burj al-Taqa
(Dubai, UAE)
This green skyscraper has a cylindrical shape that is designed to expose as little surface area to the sun as it can. A protective solar shield reaches from the ground to the roof and covers 60 percent of the building. It protects the side most affected from the sun’s glaring rays. The remaining 40 percent has diffused light that is tempered by a mineral coating on the windows. The building also has an incredible air conditioning system that draws the air from outside and cools it with seawater before distributing it around. Finally, there will be a 60-meter turbine on the tower roof and two photovoltaic facilities that will produce the electricity to meet the needs of the building.
The Lighthouse Tower
(Dubai, United Arab Emirates)

Designed by the Atkins Group and standing at an astonishing 400 meters with 66 floors. The Dubai International Financial Center plans on inhabiting this skyscraper dubbed in this tower. The green skyscraper will house three large 225 kW wind turbines, which are 29 meters in diameter, located on the south facing side of the structure. In addition to the wind turbines, there will also be 4,000 solar panels to generate additional energy needed to accompany the skyscrapers daily operations. The tower hopes to reduce its overall energy consumption by 65% and its water consumption by 40% when compared to an equivalent building of the same magnitude.

World Trade Center Towers
(Manama, Bahrain)

The Bahrain World Trade Center is first skyscraper in the world to integrate wind turbines into its design. Three different bridges, all of which house a 29-meter turbine, connect two separate towers. These towers face north to capture the winds from the Persian Gulf. The building assumes a sail shape so as to maximize the amount of wind funneled through the towers. The “S” shape flow is ideal because it ensures that any wind coming within a 45 degree angle to either side will create a wind stream that is perpendicular to the turbines. These turbines are intended to provide 11% to 15% of the towers total power consumption.

CIS Tower
(Manchester, England)

The Cooperative Insurance Solar Tower in Manchester, England set a new benchmark by retroactively installing renewable energy technology onto the service tower during a renovation in 2006. Boasting over 7000 solar panels and 24 wind turbines, the CIS tower no doubt represents a stunning achievement in what be accomplished when you combine skyscrapers and clean technology.

Currently, the structure can generate more than 10% of the energy it needs, but it’s still a technological marvel that serves as a great example of integrating renewable energy technologies into preexistent architectural design.

Chicago’s 340 on the Park
(Chicago, US)

Chicago’s 340 on the Park is the first residential tower in Mid-western America to attain the silver LEED certification. Featuring high tech insulation and rainwater capture systems, this structure really sets the environmental benchmark for residential skyscrapers in the US. 340 on the Park was designed with the energy consuming human in mind, and thus integrates only the most efficient of technologies within the living and common spaces; there’s even a two story winter garden starting on the 25th floor that makes great use of the special windows designed for optimal sunlight dispersion throughout the building.
Agbar Tower  
(Barcelona, Catalonia, Spain)  
Ateliers Jean Nouvel

It is one of the latest architectural icons of Barcelona’s skyline. It houses the headquarters of the AGBAR Group (Barcelona water supply company). Built in 2005, the tower is the work of the French architect Jean Nouvel. It is 142 meters height and has 31 floors with plenty of light, no columns dividing its useful space, and 3 technical floors, with control the building’s management systems. La Torre Agbar was awarded of the Green Building signet by the European Commission, which recognizes those non-residential buildings that respect the environment and exceed legal energy efficiency requirements. A very important part of the tower is a double skin. The inner skin is formed by a concrete wall with openings and coated with insulating material, finished with corrugated aluminum plates. The outer skin consists of steel frame and glass slats oriented to minimize solar radiation on the façade. It has 4,200 LED luminous devices that allow generation of luminous images in the façade. In addition, it has temperature sensors in the outside of the tower that regulate the opening and closing of the glass shutters of the façade of the building, reducing the consumption of energy for air conditioning. (www.barcelonatossee.com)

Torre Agbar has 4,500 windows to maximize natural ventilation and reduce energy costs by optimizing sunlight usage. One of the key features of the tower is its nocturnal illumination. It uses 4,500 RGB LED luminous devices that are computer-controlled and help generate luminous images in the façade. Energy consumption for air conditioning is reduced through the temperature sensors on the exterior of the tower that regulate the opening and closing of the glass blinds of the façade of the building.

Regulation of air flow and natural ventilation is increased through double glazing in the dome. This also helps reduce the temperature of the building because of the chamber of air formed between the two skins. (www.barcelonatossee.com)

Elevator routes have been optimized through computer systems to prevent unnecessary consumption. The energy gain to incident solar radiation proportion touches an average of 25.11%. Materials containing formaldehyde, asbestos or lead, especially in paints, have been avoided. Coolant glasses that do not contain CFCs have been used to avoid ozone depletion. (www.barcelonatossee.com)

Bioclimatic architecture
An example of bioclimatic architecture: In the Agbar Tower, functionality and design merge with environmentally-friendly building materials and elements that take advantage of climatic and atmospheric conditions to improve comfort and reduce energy consumption.
environmental conditions to achieve a significant reduction in energy consumption and improve the quality of life of residents. In 2011, the Agbar Tower won the European Commission’s Green Building award for its energy efficiency and low CO\textsuperscript{2} emissions.

A spectacle of light and color
One of the Agbar Tower’s most unique characteristics is its night-time illumination, which is achieved with more than 4,500 LED lights. The system enables more than 16 million colors to be projected, creating stunning images of light and color on its façade. The tower is illuminated every night from 7:00 pm to 11:00 pm in winter and 9:00 pm to midnight in summer. It is a spectacle that is worth viewing from close up, but is also visible from many parts of the city. (www.barcelonatosee.com)

Concept
The building is formed as the union of two opposites: the lightness of glass that covers the building in the form of slats 120 x 30 cm, forming a large brise-soleil and the massiveness of the concrete structure, creating between one great fractal.

Spaces
Between the core and the outer 34 floors above ground, diaphanous without interior pillars are deployed. Of these 28 are for offices, 3 are technical plants, one plant to the cafeteria, 1 floor for multipurpose rooms and at the top of the tower’s top floor was allocated to overlook.

Offices properties
- The offices provide completely free of columns surfaces
- Ceiling Height 2.60m
- Raised floor encapsulated with 15cm height free and finished in galvanized steel, supporting 1,500kg/m\textsuperscript{2} overload.
- False ceiling plate making galvanized sound-proof interior and concealed
- Luminaires recessed ceiling lighting and direct traffic areas and elevator lobbies. Emergency lighting. Spark lighting by motion detectors.
- Centralized fire detection system. Sprinklers in the ceiling.
- Furniture for integrated facade modules.
- Fixed and casement windows.
- Voice-data wiring and electrical boxes installed under the floor and perimeter facade socket.
- Kitchen - office per floor.

Underground Floors
The 4 underground floors are distributed as follows: 2 floors house the auditorium for 316 people and services such as goods receipt, storage or files. The other two underground floors are for parking.

Structure
Structurally, the building corresponds to a model of the core and outer perimeter which transmit bearing loads of free plants span. The tower is composed of two central one dense concrete modules, and other peripheral. These two oval cylinder with central elliptical shape and perimeter, not concentric and crowned by a dome of glass and steel. The tower is not, in fact, circular floor, but slightly elliptical. From the ground floor to the 18th floor the building is completely straight, from the 19th floor to 26 drops gradually to 26 section where concrete is interrupted and continues glass dome with metal frame. Latest 6 floors consist of post-tensioned concrete slabs, are suspended cantilever.

(www.barcelonatosee.com)
The inner cylinder of concrete having a thickness of 45 cm at the base and 25 cm in the upper area. The outer cylinder has thicknesses of 50 cm on the basis that they are reduced to 30 cm in the upper area. The wall of concrete corresponding to the outer perimeter is perforated with openings 4349 corresponding to different types of windows. These two modules are joined together by radial beams perforated steel to increase the flexibility of services.

The concrete is covered with aluminum plates that give color to the whole, with a faded area of 16,000 m². The panes of glass have different inclinations and opacities that play of light, depending on the time of day and season, with lacquered aluminum sheets that cover the concrete. The form of “bullet” of the cylinder is formed by two concentric cylinders of oval not until the plant reaches 26 outer ring, this plant from a lightweight glass and steel dome rises. The inner cylinder contains the vertical circulation core, lifts, stairs and facilities abroad has openings, windows (4,349 in total), forming a large fractal. Lower floors are formed by light platforms while the upper floors have floors reinforced and prestressed concrete, cantilevered from the central stem.

**Partitions**
Molded panels were lifted and placed prefabricated steel cages and subsequently filled with concrete before being set. For the construction of the internal partitions a patented system was used.

**Planking**
The adjustment of the wall formwork was modulated every 10cm. The inner core formwork, hanging from the metal structure is separated from the external barriers as work platforms can not climb to the top of the dome. These walls were subsequently hormigones with the slab. The interior formwork, by contrast, climbs up along with the platforms above.

The cylindrical core and facade walls of this office building were performed using the self-climbing formwork system PERI ACS. The floor slabs are then executed. A major challenge was the positioning of the anchors for this type of form between the windows distributed irregularly. This system allowed for progress in construction finishing every 5 days an entire floor. In addition to the formwork, scaffolding and work teams used the ACS-P (platform), which allowed retailers up concrete variant. The climbing is done entirely without a crane through driving climbing PERI ACS 100.

**Materials**
Agbar tower consists of two dense bodies of concrete, one central and the other peripheral. Both joined by radial beams that fasten the various forged shaping each of the levels of the tower. The module perimeter concrete is coated with a first skin created by modules lacquered and tinted aluminum in earth tones, blue, green and gray which decompose as you get higher, giving the tower its characteristic hue during the day. The Edge module with aluminum panels are in turn covered by a second skin, a brie-soleil 59,619 la
mas formed by transparent glass and translucent security. These lamas mobile 120x30cm electronically can be oriented according to the weather conditions of light, wind, etc. The building is crowned by a dome of glass and steel. The pieces of brise-soleil on the north side are different from the south side. Those on the north side are translucent, even transparent as a window on the concrete wall. On the south side are all transparent.

Were used in its construction 25.000m3 of concrete, steel 250.000kg, 59,619 glass slats, 4,500 window frames and 40 different colors are combined.

Respect to the environment
· The building has temperature sensors in the outside regulating the opening and closing of the glass blinds of the facade, reducing the consumption of energy required for air conditioning.
· In order to reduce energy consumption and achieve natural ventilation have been designed 4,500 windows, plus ventilation, allow the use of natural light. Air circulation is regulated through the dome with double glazing.
· In its construction have not used materials containing formaldehyde, asbestos or lead in paints.
· Formation of a cavity between the two skins covering the building reduce overheating, favoring ventilation.
· Through a computer system is optimized travel lifts, avoiding unnecessary consumption.
· We have allocated spaces for bicycle parking.
· The proportion of energy gains relative to the incident solar radiation reaches a mean value of 25.11%. Free of chlorofluorocarbons refrigerants materials are used to avoid damaging the ozone layer.
· The groundwater are used for cleaning floors and ornamentation.

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CHAPTER FIVE:

Discussion, Findings, Conclusion, Recommendations

“Being traditional in architecture does not mean the renewal of the past as in other cases but we should utilize it with contemporary facilities”

(Louis Kahn)
Discussion

As mentioned in this thesis, Yazd region is based significantly on environmental architecture. Courtyard plans, roofs, high ceilings and large walls of summer parts, low ceilings and small walls of winter parts, pools and basement spaces and material that provide natural ventilation, shading areas and indoor environment comfort for inhabitants.

Yazd city is built with consideration of the hot and dry characteristics of this region with regional factors taken into account such as undesired winds, sun and have affected the planning of each space whether it is full or empty, such as the courtyard with tall and shaded walls, enclosed spaces, porches, rooms facing different directions, corner rooms with wind-catchers and ponds, basement and the roof which is meant for special hours of the day and night (for both cold and hot seasons).

In addition to this, all vernacular buildings of Yazd, both in the architectural and in the constructional fields, are planned in a way that utilize the maximum amount of sun radiation during winter and have the maximum amount of shade during the summer periods in order to exploit the natural ventilation properties and to provide peace and comfort for the occupants.

The previously used construction materials and common techniques had high maintenance costs, energy storage and the potential of temperature balance in the constructed buildings which were heavy compared to the relatively low weight of construction materials used today. The vernacular materials and techniques were utilized for the sustainability factor of the buildings and also in the main load bearing elements of buildings such as walls and ceilings or to be more general, the vertical and horizontal elements of the buildings.

It is worth mentioning that in the construction of sustainable buildings, only a very small amount of the buildings built are incompatible or inconsistent with the surrounding natural environment of the region and the country. Construction techniques are put in place in order to provide the highest quality and achieve a higher degree of economic, social and environmental conditions.

Therefore, in order to inhibit the buildings from using high amounts of energy, buildings are constructed in a way that uses natural resources for maximum sustainability and efficiency. Not only using natural resources is saving energy, but it also results in having a better, more technical, scientific and aesthetically pleasing buildings. Undeniably, the overall objectives of sustainable buildings can be the issue, which are the proper utilization of resources and energy, preventing pollution and complying with the surrounding environment.

According to this section, vernacular architecture of the Yazd region and the features that have an effect on the design characteristics of environmental factors such as climate, renewable energy usage, water consumption and sustainable building materials could be good steps to follow for contemporary architecture. With the collection of important vernacular architecture components (air circulation and ventilation, Wind-Catcher, roof, pools, fountain, material, thickness) compared to environmental sustainability, these factors can be used and geared towards today's architecture. There are some positive and negative explanation these factors have that can be solved with the aid of science and technology and due to the perseverance and efforts of architects that strive to live comfortably in the Yazd region.

Moreover, the air circulation of vernacular houses in Yazd city which is connected to environmental sustainability to clarify Circulation of air is the function of natural cooling and ventilation elements in a vernacular house in Yazd. According to the science and knowledge of people in the past, the vernacular houses were built in a way so that protected in cold winters, hot summers and harsh weather due to the geographical location they were in.

According to the orientation (direction of the houses) and the design, vernacular houses were built in a way that had harmony with the environment.

Furthermore, Wind-Catchers are environmental and sustainable energy systems for air circulation and cooling purposes. However, wind catchers have several benefits that among them are ventilation and cooling and act like air conditions. There are some disadvantages as well that includes bringing dust inside the house that makes it unusable in winter but due to the improvement of technology in today's architecture there should be a way to make it usable in the winter time.

According to the shape and form of roofs in vernacular Yazd houses, the shape and the way the arches were built was the reason that heat
wouldn’t come into the houses and were resistant towards earthquake. The shape and the way they were built should be developed in modern and new houses.

However, the characteristic of pools (Hoz) and fountains is Persian tradition design for ventilation and decoration that shows the quality of life of the house owner. Due to the science and technology pools and fountains should be controlled in a manner that in hot-dry climates these pools and fountains could create a comfortable and easy to live in summers and winter time.

Thickness of the wall plays a significant role in the comfort factor of a building. The disadvantages are the thickness, heaviness and not being economical. These problems have to be developed and its isolation techniques have to be made usable in today’s architecture.

Due to the progress and improvement of technology and science the positives and negatives of vernacular architectural components of Yazd could help for a path towards environmental sustainability architecture.

Pros and Cons of Environmental Sustainability elements of Houses in city of Yazd

Environmental Sustainability Factors:
Climate, Renewable Energy Usage, Water Consumption, Sustainable Building Material

Figure 102: Urban fabric of Yazd. Source: Ahmadkhani Maleki, 2005

**Environmental Sustainability Factors:**

**Climate: Air Circulation and Ventilation**
- Favorable: Orientation of houses that considering the wind direction specially summertime cold winter time hot indoor spaces
- Unfavorable: It needs large space to organize indoor and outdoor courtyards

**Renewable Energy Usage:**

- **Wind Catcher:**
  - Favorable: Cold inside of the house during summertime - don’t need the electricity
  - Unfavorable: Dust and animal going inside of house - Winter time it’s not useful

- **Dome Roof:**
  - Favorable: Save energy – Control heating and cooling during summertime and wintertime
  - Unfavorable: Need to space - it’s not useful to the apartment - cannot use other flat

- **Flat Roof:**
  - Favorable: Radiation sun - Thermal heating and cooling
  - Unfavorable: Its not save energy (Heating and cooling) - during summer time to much hot and winter time too much cold

**Sustainable Building Material**

- **Thickness of Wall**
  - Favorable: Considering the isolation in order to protect the building
  - Unfavorable: It’s too much heavy - costly - not suitable for new technology and structure

- **Traditional technologies in the contemporary**

One of the specifications of the technology is its attempt to solve the local attributes inside itself and just demonstrates its culture as the valid one. The expansion of this feature in architecture which is a derived activity from the environment and is in accordance with the culture is a critical issue and has the strategic importance. Therefore, for guidance and control of the effect of technology on the architecture systems, there is need to more hesitation and contemplation (Shayanfar...
Today technology has not considered the climate specifically and believes that the modern technologies of the architecture can use in every climate. But it should be noted that the opinions of the architects are very different and they believed that each climate has its own designing, materials and technology.

Indeed the architecture could be based on the region and have the highest efficiency with the least energy if our architecture was developed in accordance with the needs of certain era and had the continuity in its own technologic view and today locates in another position. The problem is that in one hand we could not investigate this technology and in the other hand, we try to use the world modern technology regardless the cultural and ecological remarks. Therefore, this technology in convicted to failure instead of development. Hence, the combination between the specifications of this era and the past logic namely the ecology will be the intermediate solution (Pirnia Mohammad Karim).

As mentioned before, the dwelling is one of the primary and essential need of the human which justifies the importance of paying attention to the appropriate dwelling and totally has two dimensions: the qualitative and quantitative dimensions. Therefore, today Iranian dwellings should be developed in these both fields. Investigation the position of the ecological science in development process of technology demonstrates this science as one of the most important sources in developing the today Iranian dwellings. This active and dynamic science is beyond the theory and this is considered as one of its outstanding features. This science has been obtained from the experiences of the past and indigenous people of each region instead of repetition of the old methods and imitation from the forms and materials of the traditional buildings.

According to the performed researches in this thesis, it is possible to use the modern form of the traditional technology in designing and constructing in order to make the higher quality houses and reach the sustainable architecture in the contemporary period.

For example, one of the solution for air flow in the building is the wind catcher which its traditional form has been described in the first chapter. Meanwhile, the wind turbine is another choice which has been explained in the forth chapter. Therefore, their modern forms can be used in contemporary architecture (see forth chapter) in order to frugality in fossil energy consumption through the natural wind energy which can be possible by applying these technologies.

Moreover as explained in the forth chapter, the intellectual materials such as the halo-chromic and photochromic windows and photomechanical materials can be used in the structure of the buildings in order to save the energy.

To summarize this discussion, contemporary architects and designers have much to learn from the architecture of the past and vernacular methods. A particularly pressing issue is the almost complete absence of vernacular methods in new developments in many parts of Iran, including Yazd. In addition to the absence of vernacular methods, contemporary housing designs also overlook cultural and environmental conditions, which result in generally unsuitable architecture (Afshar Ali, 1975 & Foruzanmehr Ahmadreza, 2010).
Findings

As we investigated the Vernacular houses in the first chapter which had used the renewable energies such as the wind catcher, cistern, qanat and etc. through the most attractive technologies, it can be found that the construction of a structural building complex is possible through the renewable energies and elimination of the fossil energies. Therefore, the sustainable principles can be used in modern structural building complex regarding to the Iranian traditional architecture specifications.

According to the previous studies in renewable energies and the necessity of their usage in the modern building construction in the second chapter and also in the rest of this chapter, regarding to the investigation of the zero energy and passive energy houses, it can be concluded that there are some buildings in the world and even in Iran which can minimize the percentage of the energy consumption through new technologies of utilization of the renewable energies which aspired from the traditional technologies and prove that these energies are completely cost effective and useful for the humanity, posterity and society economically.

After investigating the traditional houses and buildings of the Yazd in the first chapter and attention to the benefits and structural models of the zero energy and passive energy houses in the second chapter, it is possible to inspire from the traditional architecture in order to preserve fossil energies and better present and future life. But there is no need to the imitation from the traditional form and materials and the new form and materials should be used instead of them.

According to the studies which mentioned in the third chapter of this research, it can be found that one of our current important problems in building is the energy. As we know, the energy loss was very high in the modern architecture. For example, one of the complete and attractive sample is the “Bauhaus building” which in despite of all its beauty, unfortunately caused the high energy dissipation due to its many one-glazing windows. In the modern architecture, energy saving was not considered by the architects but near 1960 until 1970, this gap was felt in the architecture that without paying attention to the traditional architecture, history of the past and frugality in the fossil energies, further developments are impossible and the tradition should be considered in the new structures since the energy saving was very important in the traditional architecture.

Therefore, it can be called the sustainable architecture. This time coincided with the Louis Kahn’s more attention to the history after his travel to the Europe and especially to the Italy which led to the beginning and emergence of the post-modern architecture which is the combination of the modern and traditional architectures. With investigating the traditional (past), modern and contemporary architectures and the works of some architects such as the Venturi Robert, Mirmiran Seyed Hadi, Diba Kamran and etc. in the world and the Iranian contemporary architectures, it can be concluded that it is possible to use the traditional architecture in the contemporary architecture such as the modern architecture and achieve the favorable environment and eco sustainable architecture through inspiration from the traditional technologies and their modern implementations in term of cultural and social aspects.

Finally, according to the studies which mentioned in the forth chapter in the new methods and modern materials for using the renewable energies such as solar energy, wind and etc. in the modern buildings with passive and active systems with the purpose of frugality in fossil energies consumption and investigation of the sustainable architecture, high-rise eco sustainable building and the smart materials and technologies which have been used in them, it can be proved that the utilization of these methods can decrease the energy consumption to a large extent. As mentioned in this chapter, utilization of the intelligent materials and technologies in Agbar Tower in Spain led to the 34% frugality in energy consumption.

After finishing the mentioned studies, my main suggestion for the modern construction at the present and for the future is the construction of buildings on the heights. It means that in the city of Yazd, the horizontal construction should be replaced by the vertically constructions (high buildings / towers) which constructed by the modern and intelligent materials. This suggestion will be explained in the part of suggestions completely.
Conclusion

In this thesis, the sustainable buildings should be designed in a way to be able to use the local climatic and energy resources. The recent case studies indicate that the uncontrolled growth of Yazd is a traditional and a modern challenge of urbanization. The most important factor of these challenges is the distorted and the unbalanced developments of the urban and the spatial dissociation of the city. Abandoned lands in the city boundaries, the proportion of poor urban concentration, lack of compatibility with the geographical situation, reductions in the security and safety of the suburbs, increasing costs and cost-effective urban transportation facilities and a lack of infrastructure in some parts of the city exist.

The most important issues that are considered are things that resulted in these problems, which are the improvement of incompatible elements of nature and the environmental factors such as climate, renewable energy usage, water consumption, sustainable building material, reducing waste and open space or greeneries as well as ignoring and forgetting vernacular architecture that is compatible with the regional climate of every region. The effect of the development stages of Yazd city on the urban pattern of this city have been analyzed in different historical periods.

The traditional and modern urbanizations are not only in conflict with each other, but they are in the process of achieving sustainable development and localization of complements unlike some of the engineers and architects. Furthermore, there are a lot of sand storms because of the desert-like location in the area. Flat and domed roofs are one of the solutions applied in Yazd city.

In a vernacular house, the usage of natural resources as well as energy is one of the principles of architectural designs regarding their construction and spatial organization. Other characteristics of the old houses in the deserted region of Yazd include, being mainly located in the direction of Qeble (direction of prayer for Muslims). The orientation of the climatic conditions has created spaces for summer rooms in the house. The courtyard is enclosed from all sides with the help of the indoor spaces, and the cool night air is saved in the pit and is utilized during the hot summer days.

Moreover, the studies made in sustainable architecture and courtyard along with their role in the sustainable architecture of Yazd, it can be concluded that today, they should prepare a strategy to renew the yards, pools, gardens and equip and supply the same cells and take advantage of vernacular architecture. Perhaps one of the biggest decisive components of the environmental conditions should be reviewed and evaluated based on experience, in order to form stable structures.

The other significant point for a suitable utilization of energy and sustainable architecture is a yard design with the pool in the center. Although, the central yard has resulted in the better utilization of wind flow as well as building single layered walls, the best ventilation performance would be achieved by opening the windows that are facing the yard and the alleys. In this type of width ventilation performance, the heat concentration and the humidity decrease.

In this research, the findings are a proposal for the new buildings that are matched to the environmental sustainability and also transmit vernacular architecture into today’s architecture in the city of Yazd; Orientation of the houses such as air circulation, Wind catcher, Roof structure, Pool, Fountain, Material and thickness of Yazd city.

In conclusion, vernacular architecture of the Yazd region and the features that have an effect on the design characteristics of using natural energy sources and environmental factors could be good steps to follow for contemporary architecture. Entrance (Hashht), Pool and Garden (Hoz and Baghche), Living room (Saloon), Wind Catcher (Badgir), Basement (Sardab, Shabestan) and also natural material are the considerable specifications needed in hot-arid region in comfortable indoor spaces. With the arrival of modern architecture and the utilization of mechanical facilities, the role of climatic conditions in the buildings has become very important.

However in today’s world, with a lot of attention towards the climate and the environment, environment friendly technology related to architecture and with the utilization of pure energy such as solar energy, wind and water, broader range of sustainability in our constructions can be arranged. From this revolution, in the architectural field, environment and climatic conditions play an essential role in building design. Moreover, it should be mentioned that the subject of environmental sustainability issue should be considered regardless of the effects of today’s limitations and struggles with the issue. Therefore, to achieve better results, appropriate training and awareness is essential in order to benefit from the advantages of environmental sustainability architecture and to be able to utilize it universally.
Recommendations

According to the researches and studies which performed in this thesis, it can be concluded that one architecture style can not be used in different cities and climates and each climate has its own special architecture.

Yazd which located at the center of Iran, in despite of all its beauties, colors, alleys and traditional architecture can not meet the needs of its inhabitants. The traditional buildings of this city are mostly one or two floors and city has the horizontal form. According to the expensive price of land and installations, the horizontal In the fourth chapter, the usage method of the renewable energies such as the solar energy, wind energy and etc. through the application of the modern technologies and new materials and architecture in the modern buildings and especially in the highest ones have been investigated. Moreover, some high towers such as the high-rise buildings and their samples such as Agbar Tower in Spain have been studied.

of the city more than some certain amounts is impossible, therefore, we should achieve our purpose in using the modern and correct architecture through maintaining the values which will be practical definitely.

The past architecture of the Yazd was very logical, sustainable and correct and the reason of attention to the Yazd in this thesis is the frugality in energy consumption. It means that in this city, some technologies have been used in the traditional houses based on the climate which have used the natural energies in order to frugality in fossil energies (these technologies have been investigated completely in the first chapter).

It should be noted that the termination of the fossil energies, existing pollutions and our uncontrolled growth of birth will encounter us with many problems in the near future and the traditional architecture of the Yazd can not response to the current and future needs. According to the purpose of this study namely the access to the sustainable modern architecture in the Yazd with the hot and arid climate, the following solutions and suggestion will be presented.

For designing and constructing of the building, the following principles and issues should be considered as far as possible:

Planning with the ability to return to the life cycle
In this plan, the emphasis is on using the method which leads to the recycle and reproduction of the used resources. Indeed in this phase, the designer should focus his mind on the process which the used resources in the plan can return to the main nature cycle after destruction and disposal. It means that our resources change from one form to another form but they can still be used after this transformation.

A design for the human
This principle is probably considered as the most important principle of the sustainable designing. In this principle, the more efficiency and protection of the natural resources were considered. Whereas in this principle, the emphasis is on the maintenance of the life quality of the all ecosystem components but this principle can be considered in the direction of the humanitarian purposes which respects to the principles and different life resources. Indeed with more contemplation in this philosophy, it can be realized that the chained and mutual needs of the different life components and their roles in continuation of the human life should be considered seriously since in today's modern world, although the human is the axis of all changes and transformations but this central role never be in order to violate the rights of other alive creatures but it is along with them and constantly interact with them.

Environmental sustainability
The idea of the environmental sustainability is the leave of earth in the best form for the next generation. It means that the human activity will be sustainable environmentally just when it can be implemented without decreasing the natural resources or degradation of the natural environment.

The principle of the sustainable designing is based on this point that the building is a small part of the surrounding environment and should act as a part of the ecosystem and be in the life cycle. Therefore, the sustainable designing is not a formal style and does not derive from the transient conditions and immediate emotions but it has the deep concepts inside itself which connect the human, nature and architecture.

Energy conservation
Each building should be designed and construct-
ed in a way that its need to the fossil fuels be minimized as far as possible. The necessity of the acceptance of this principle in the past eras is not deniable indubitably due to the construction manner and it has been probably forgotten in the building due to the great diversity of the new materials and technologies in the contemporary era. Therefore, in this time, the buildings change the environment based on the needs of users through using the various materials with different combinations of them.

Relation with climate
The buildings should be designed in a way that they have the capability of using the climate and local energy resources.

The formation and arrangement of the building and the place of its internal spaces should be such that which promote the inside comfort level of the building but the correct insulation of the structure decreases the consumption of the fossil fuels. These two mentioned processes overlap between each other and have many common points.

The Romans followed the solar designing principles based on their learning from the Greeks’ experiences but they used the transparent windows for increasing the obtained heat. These windows were innovated in the first century AD.

With increasing the shortage of the wood as the fuel, the usage of the south facing facade in constructing the houses of the rich and the city public bathrooms became common. The climate-oriented designing tradition for creation the comfort inside the building was not limited to the heating rules but in most of the climates, the architects were obliged to design the cool space inside the building in order to make the favorable conditions. The common solution in the present era is the utilization of the air ventilation systems which is only considered as the inefficient process in contrast with the climate and is associated with the high consumption of the energy and even in the time of cheap and abundant energy, it is considered as the wrong solution due to its pollution.

Reduction in the usage of the new resources
Each building should be designed such that it can minimize the consumption of the new resources and can create the source for making another structures at the end of its useful life. Although the direction of this principle such as another mentioned principles is toward the new buildings but it should be noted that the most existing sources of the world have been used in the current artificial environment and the restoration and improvement of the current buildings for decreasing the environmental effects are the issues which are as important as the creation of the new structures. Meanwhile, this point should be considered that there are not sufficient number of sources for creation the artificial environments in the world which we can use some new amount of them for restoration of each buildings’ generation.

Sustainable architecture approaches
The sustainable architecture can be explained in three categories of Eco-Tech Architecture, Green Architecture and Energy Architecture:

Eco-Tech architecture investigates the technological and semi-technological solutions in the sustainable architecture. Meanwhile, the green architecture pays attention to the more usage of the nature in the buildings and the energy architecture discusses the energy maintenance and avoidance of its undesired penetration (energy dissipation).

Green architecture
We must live a little lighter on the earth since the deep of excavation and our other interferences in the natural bed of the earth for construction not only is related to our needs in the spaces of a building but also effect on the organisms of all creatures and the plants of the environment. Totally, the green architecture is based on 4 principles: (1) protection of the water, wind and other natural energies, (2) preparation the health of our environment, (3) development of the economy in the country and (4) supply the higher quality of life for the citizens.

A green building such as another things needs a creator before creation. Construction of a green building helps the health of a person who resides in it and its surrounding environment, supports him/her and leads to his/her satisfaction and productivity. Utilization of the sustainable nature, high quality source of the materials, rely upon the sun for thermal usages, electricity power and daily light and also recycling the wastes and delicate constructional union create these strategies.
Wall color
It is possible to control the thermal effects of sunlight in the inner spaces of the building through its external surfaces. The light colors may reflect up to 85% of the solar energy but the reflection of the dark colors is just 15% or less. In this research, the relation between the energy dissipation and the color of external walls in three moods of light, medium and dark has been investigated and the results has been mentioned in the table.
- Light color with absorption coefficient of 45%
- Dark color with absorption coefficient of 90%

Wall insulation
Energy is dissipated through all surrounding surfaces of the building including the walls, roofs and floors which relate to the external space or uncontrolled space from one hand and the internal controlled space of the building in the other hand due to the inappropriate thermal insulation of the building. Therefore, observance of the thermal insulation in designing and constructing the buildings decrease the need to heating and cooling and prevent the loss of the produced heat and cold and lead to the considerable frugality in energy consumption. The main insulations in Iran are the rock wool, slag wool and polystyrene foams. In selecting the thermal insulation of the walls and roof, the resistance of the insulator against the heat, applied forces, reaction to the fire and absorption its water should be considered.

Modern technologies in optimizing the energy consumption
Nowadays in all around the world, utilization of the sustainable architecture’s technologies and especially the construction of the green buildings have been considered as the most important issues due to the some essential problems such as warming the earth, air pollution and the irregular usage of the energy and its high economical expenses.

Green wall and roof
Green roof is a lightweight engineered system which provides the possibility for growing the plants on the roof and also protects that. The green roof is not only a green surface but also it is a living surface on the roof which consists of the growing plants in the soil. These walls prevent the spread of the dust in the air and protect the building against the Ultraviolet ray, rain and wind pressure.

Double - skin facade for optimizing the energy
Some of the words which are the synonyms of the “double-skin facade” and have many usages are as follows:
- Two -sheets facade
- Double-skin facade
- Double facade
- Double coverage
- Two-glazing glass facade
- Ventilation wall facade or ventilation facade.

The double-skin facade is one pairs of glass skin which are separated from each other by the air corridor and the main glass layer is insulted regularly. Therefore, the air space between glass layers acts as an insulation against the minimum and maximum temperature, wind and sound. Sun protection device locates normally between two skin. All the elements can be arranged and put in order differently through some permutations and combination of the solid and transparent membranes. Four main types of double-skin facades are as follows: protective facade, air extractor facade, twins facade and hybrid facade (combined facade).

Nanotechnology in building
The nanotechnology is one of the newest modern technologies in the world which has influenced in all areas including the buildings. The construction science is based on the investigation of each atom and its intended features and it is at the beginning of its roots and very bright future is predicted for that. This science promises the discovery of the nature’s secrets in all areas through controlling the materials in molecular scale. One of the high achievements of this technology is its application in production, transmission, consumption and saving the energy with high efficiency and reduction the environmental contaminations which can create wonderful development in this area. Nanotechnolog y is the fundamental change of the route which leads to production of the materials and tools with required specifications. The possibility for synthesis of the Nano structural blocks in appropriate size and combination has been controlled precisely and then putting them in greater structures with unique features and applications creates the revolution in the materials and their production processes. Therefore, the researchers will make some structures of the materials which are not in the nature and the current chemistry has not been able to create them. Some of the advantages of the Nano structures are the lighter, stronger and programmable materials, reduction in the expenses of the work life through reducing the number of technical deficiencies and new tools based on the new architecture and principles.
One way of using the nanotechnology in green buildings is the utilization of the Nano materials for preventing the energy dissipation inside the building. These Nano materials act as an insulator and are useful for reducing the energy dissipation inside the building through using the solar energy and developed purification of the water and air.

Photovoltaic

Photovoltaic panels change the sunlight into the electricity. Photovoltaic phenomenon is based on the absorption of the light photons, production of the electron-hole pairs, separation of the electron and produced holes by the electrical field inside the semiconductor material. Therefore, one of the best methods for saving and using the solar energy is the utilization of the photovoltaic panels.

Wind turbine

The origin of the wind is a complex subject. Since earth is unevenly heated by the sun, thus the thermal energy of the poles is less than the tropical regions. Meanwhile, the temperature of the lands is changed more quickly, therefore, the earth lands are heated and cooled sooner than the seas. This difference in global temperature causes the global system of thermal exchange which acts as an artificial roof from the earth surface up to the air. The more energy of the wind movement is found in higher levels of the atmosphere where the continuous speed of the wind reaches to 160 km/h. Finally, wind losses its energy due to its friction with the earth surface and atmosphere. Meanwhile, there is a possibility for saving required energies by the wind force in the potential regions.

Glass

Glass is one of the weakest parts of the building in thermal exchange. Emergence of the reflex glasses, double-glazed windows and utilization of the special gas in them have optimized the Low-C thermal performance of the building’s windows. Fortunately today, the safety and security of the building glasses have been increased and their usage in building facades regarding to their thermal and optical features, amount of energy transmission and its reduction with the purpose of decreasing the expenses of the cooling and heating have had a significant importance. Since the transmitted solar energy from the glass is one of the main sources of entering the energy to the inside of the building, one of the effective factors in selecting the appropriate glass for the building is the entrance amount of solar energy to the building.

Two-glazed glass consists of two glasses which are separated from each other at around by a spacer. These spaces are sealed to the surrounding environment of the glass by the impervious sealant under the plant controlled conditions. The space between these two glasses has been filled by the special gas such as Argon, Krypton, Xenon and etc. This type of glass can be produced in different forms such as simple colored glass, reflex glass, laminate glass, security glass and opaque glass.

Window

Decision making in changing the windows of an old house or selecting the window for a new house has an important role in energy consumption. 30% of the total thermal loss in the old houses and 15 to 20% of total thermal loss in the new houses are through the windows and depend on the dimension of the window, seaming the window and usage of appropriate glasses in the building. The frame of the window has the great impact on the energy efficiency. The best frames of the windows are wooden, aluminized and vinyl P.V.C. frames which have the more efficiency due to the low thermal loss and recycling possibility. Moreover, the dimension of the window has considerable effect on the energy consumption.

Insulation

Insulation has the very important role in warming the building in the winter and its cooling in the summer. It is possible to maintain a house 5 degree warmer in the winter and 10 degree cooler in the summer through insulation. Therefore, in addition to reduction of the energy consumption, the environmental pollutions will be reduced and the energy sources will be preserved for the posterity. The important factor in selecting the insulations is their thermal resistance and as far as this value be more, the insulator passes the less heat through itself and increases its associated frugality. Therefore, instead of comparing the insulators’ thickness, their thermal resistance should be compared. Different insulators with equal thermal resistance are similar regarding to the energy frugality and their only difference is in their prices and application places.
Solar system

In each solar system which is used for warming the space, there are three expected performances: (1) collection of the solar energy, (2) storage of the energy in the battery or capacitor and (3) distribution of the energy in the space. There are two different solar systems including the passive and active systems. The active solar system uses the mechanical devices for circulating the air or liquids through the collectors and thermal batteries. Therefore, there is need to the fan and pomp for entering the saved heat in the reservoir to the intended space. Active systems are relatively complicated and need the external energy resources for their performances. In the other hand, the performance of the passive solar systems is not dependent on the electrical energy or fossil energy but they use the natural methods of thermal transmission such as thermal conductivity, convection heat and radiation heat. In these systems, at the first the sun light impacts on one thermal absorptive surface which is at the southern part of the building and then be reserved in the intermediate space between the absorptive surface and the building. Finally, this reserved heat will be transmitted to the inside of the building through the natural ways.

Structure of the Trombe wall

Trombe wall is one of the indirect absorption systems. In this system, the energy enters in to the life and work spaces indirectly. Therefore, one of their advantages compared with the direct absorption systems is the capability of entering the required amount of the energy into the space.

Types of intellectual glasses technologies

- Thermo chromic glasses: The color of the thermo chromic glasses is not changed by the heat and they are adjusted for special thermal range. The important issue of these glasses is the removal of glass control mood on the visible part of light spectrum. These glasses have the best performance in near region of infrared of the sunlight spectrum. The disadvantage of these glasses is the low degree of their transmission (27-35%) in the visible part.

- Gasochromic glasses: These are multi-glazed glasses or at least double–glazed glasses which have been coated by given coatings. In addition, the space between the glasses has been filled by various gases.

- Thermo tropic glasses: These glasses react to the same environments such as the thermo chromic glasses but the difference in their internal mechanism lead to more extensive practical potential of the thermo tropic glasses. More daylight provision during the reduced visibility, change in conductivity capability, glass thermal transmission and thermal conductivity are the features which lead to more acceptability of these glasses.

Phase-change windows:

One of the method which has been discussed in the recent years for controlling the heat flow is the utilization of the thermal barriers which act based on the thermal independent phase-change. Phase-change means the change of material from solid to liquid, liquid to gas and vice versa. In the point of phase-change, one fundamental change occurs in the material structure. Moreover, only the materials have the capability of phase-change which can absorb or release the required thermal energy for phase-change of the hidden heat without any change in the temperature. This released energy is very high. Therefore, various ideas have been introduced to the world based on the utilization of nanotechnology and the phase-change specifications of the materials.

Nano sunscreen intellectual glasses

These intellectual windows have been developed considerably in the recent years. The electro-chromic intellectual glasses can control the temperature in addition to the light. These electro-chromic glasses have been coated with a trioxide layer and react to created voltage and cause the lightness and darkness of the glass. This process begins immediately after touching a button or by a sensor and increases the darkness of the glass and prevents the entrance of the external undesired infrared waves which warm the inside spaces and therefore decreases the consumption of the required energy for cooling the building. The darkness of the glasses has been made automatically and is reversible. Meanwhile, all of these processes are performed without need to the constant flow of electricity.
Strategies for achieving sustainable design in warm and dry climate

1. Utilization of the removable cover in front of the building facade to prevent the entrance of the dust into the buildings through its openings during the sand storm.

2. Utilization of the deep of earth for preventing the abrasion and protecting the buildings in atmospheric oscillations.

3. Utilization of the curved forms based on the nature of the smooth sands. Whatever the form be softer, the movement on it will be slower and therefore the abrasion and destruction will be decreased.

4. Utilization of the walls with heavy materials at the southern side of the building.

5. Appropriate designing of the building form for creating shadow in the summer and obtaining suitable heat in the winter.

The Use of High-Rise Buildings as a Design Solution, in an Exploratory Process Between Present and Future Needs

The case studies on chapter 4 of this thesis, have shown that it is possible to create solutions to environmental issues limited to Yazd environmental territory. The guidelines of these case studies identified the solutions that ensure the energy efficacy of the designed projects.

These high-rise buildings with specific characteristics, usage of smart materials and new technology lead to a new era on architecture and preserved non renewable energy sources.

This is the core of the proposed design of the tall building that could successfully be an alternative to entire urban areas with horizontal structure in Yazd territory.

One of the most important advantage of using tall buildings is that they are nature friendly. The shapes and function of tall buildings are in harmony and there will be no threat to the environment and no conflict to the traditional architecture. Although we need to make sure that the proposed design matches the traditional buildings of Yazd.

The use of geothermal energy and wind power systems has made a major change in the new design. It has specifically more attention towards human health by using natural energy sources.

Use of natural materials such as wood and stone and deploy green as prominent color by choosing material from the earth such as grass, flowers, the native plants, are our goal on matching our design to the nature as much as possible.

The skyscrapers are city’s identification. The perspective building interprets the contemporary design. The height and large surfaces of the skyscrapers allow them to actively and passively take advantage of solar energy and have a greater thermal insulation than other types of buildings. They can also be used as wind turbine (active) and/or wind tower (passive) and create new source of energy without using one.

Interestingly, we still can find so many active Qanats in city of Yazd.

They are valuable sources of water. It would be our best interest to build the skyscrapers in the circuit of active Qanats in order to use the full
benefit of the natural energy sources by using pumps and water purifiers. This way we can benefit from water energy source both in constructions and more importantly drinking water.

To summarize, The use of high-buildings would be the best solution for resolving the architectural issue in the city of Yazd. It would be economic since we can use the energy source from active Qanats and also environmentally friendly due to usage of goods and natural energy sources that have minimal or no harm upon ecosystem. It will be also beneficial due to creating energy (electricity, etc) by using natural sources such as energy of wind (wind turbine and wind tower) and energy of water (Qanats) without using any of the non renewable energy.

Relevant Model

In this example we will study a residential complex building which was designed by Vincent Callebaut and has been started to be built on 2015 and it is planned to be completed by 2019. The important reason of choosing this project is the similar hot and arid climate of Cairo and Yazd. All the information presented in this section is retrieved from www.designboom.com which discusses Vicent Callebaut Architectures work.
The scheme boasts eight green architectural features that are integrated within the project:

1. **windcatchers**

Nine windcatchers, which reference traditional Egyptian architecture, stand as huge trees in the middle of each green patio. Each of these structures can function in three different ways: directing airflow downward using direct wind entry, directing airflow upwards using a wind-assisted temperature gradient, or directing airflow upwards using a solar-assisted temperature gradient.

2. **passive geothermal cooling and heating**

Passive cooling is a building design approach that focuses on heat gain control and heat dissipation in a building, in order to improve the indoor thermal comfort with low or nil energy consumption. Integrated air shafts naturally ventilate each apartment, while geothermal heat pumps move heat energy back and forth between the building and the earth to provide an efficient and environmentally friendly method for heating and cooling internal space.

**Green Living at Cairo’s Gate Residences**

Architect Vincent Callebaut, has revealed plans for a multi-use complex to be built in the Egyptian capital city of Cairo. Envisioned as a symbol of the country’s desire for a progressive type of architecture, ‘the gate residence’ combines vegetation and structure, metamorphosing the city into a vertical, green, dense and hyper-connected ecosystem. The main objective behind the urban proposal is to raise awareness of sustainable architecture designed to combat global warming and maintain an eco-friendly global environment.

Unifying the complex, the entire scheme is enclosed beneath by a solar roof that covers the green rooftop terraces and sky villas. In addition to supporting solar panels and heating tubes, the canopy also provides shade where necessary, thus decreasing the reliance on mechanical ventilation systems. In total, 1,000 apartment units are contained within a series of rectangular volumes that are subsequently organized around a central boulevard. The program provides four floors of underground parking, with a supermarket positioned directly above. Three levels of commercial outlets starting at ground level are connected with the adjacent street, while nine floors of housing are integrating with three further levels of offices.
3. solar photovoltaics cells
most conventional solar cells use visible and infrared light to generate electricity. in contrast, the innovative new solar cells developed as part of the project also use ultraviolet radiation. used to replace conventional window glass, or placed over the glazing, the installation surface area could be large, leading to potential uses that take advantage of the combined functions of power generation, lighting and temperature control. in the project, the solar roof will be covered by walkable solar panels that create shadows above the patios and the promenade, generating a big part of the electricity necessary for the building.

4. solar water heating tubes
solar water heating systems have been incorporated within the design to deliver hot water to all the bathrooms and kitchens of the building throughout the year. glass-metal tubes collecting the warmth of the sun will be integrated in the elliptical shapes covering the mechanical rooms in each core on the roof.

5. vertical axis wind turbines
located along the inner street, helical wind turbines benefit from the site’s prevailing winds and generate a great deal of electricity. the new self-sufficient prototype entitled ‘the phylolight’, is a hybridization between an urban light and a vertical wind turbine.

6. rooftop community gardens
community gardens are proposed to transform the roof into a place of innovation for all the residents of the project. the ‘big garden in the sky’ will integrate playgrounds for the children, sports areas, food gardens and orchards. a green roof will compensate the high density of the construction serving as a perfect insulation coat above the residential levels.

7. green/living walls
reducing overall temperatures within the building, 9 megatrees will be covered by living green walls. along the inner street, curtain walls will be punctuated with areas of plantation, designed to identify the main entrances of each individual housing block.

8. smart homes with automation
multi-sensors are used to detect number of people in each room, motion, temperature, and light level, while natural HVAC automation enables inhabitants to choose their optimal climate.
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