



# The impact of sustainable architecture patterns in optimizing energy consumption (Case Study: hot and dry climate)

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## ABSTRACT

Today, the environment, optimizing energy consumption and sustainable development have become the most important issues at the international level. Increasing population growth has disastrous effects on Earth's natural habitats and issues such as general global warming, increase in greenhouse gases in the atmosphere that cause global warming, air, water and soil pollution all lead to irresponsible consumption of energy. This paper tries to evaluate sustainable patterns in warm and dry areas that with the climate analysis and contemporary comparison of design in hot and dry climate while clarifying various aspects, explain the impact of environmental factors in the formation of sustainable architecture and the use of applied patterns to design a sustainable architecture. It has been used analytical method, as well as library and documentary research in this study.

*Key words:* hot and dry climate, energy, sustainable architecture, optimization

## Introduction

When discussing sustainable development and therefore sustainable architecture, the fact that each building must interact with its own substrate and surrounding natural environment, has become a matter of course. The controversial and considered of this matter is how to interact and considered type of measures. This is something that years ago the inhabitants of this land have benefited from it with special skills and have used it by implementation of specific rules on efficient use of energy and natural resources, especially solar and wind and harmony with the climate and today is forgotten negligently that is obvious not only in environmental fields but also in other aspects of sustainability such as social and economic dimensions. In this article, at first we mentioned the issue of sustainable architecture and then we're familiar with the view of some scholars in this area and by looking at the diversity of Iranian traditional architecture and identifying hot and dry climate we review the characteristics of this climate and the elements and spaces of residential houses in this type of architecture, and optimal use of wind and solar energy as well as thermal capacity of walls and roofs that are of the notable features of this land; by this idea that reviewing of these elements is useful and a source of inspiration and pattern of future designs of this country. Also we try to answer the following questions appropriately: How openings are designed due to

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hot and dry climatic features? How is the orientation of the building in this climate for enjoying more of the sun in different seasons?

What is the role of vegetation in changing the temperature of buildings in this climate?

How to use local materials to reduce construction costs?

In this paper it has been used library research including books, articles and websites to obtain the desirable results and give proper answer to the above questions. Finally, we have tried to analyze and completed the material obtained and brought them to final conclusion.

## The sustainability and sustainable architecture

The Latin root of the verb sustain is *sustinere* composed of two components *sub* (meaning from bottom to top) and *tenere* (means to hold) and is employed in English language since the 1920. The verb mixed with concepts such as "maintain", "support", or "endure" and adjective of sustainable is used to describe "conditions, state or something" which is supported or has continued because of help or livelihood. (Soflaee, 134: 1382) Dehkhoda dictionary means sustainability as durable and lasting. In the dictionaries of Sokhan and Moein, sustainability means stability and resistance derived from the root word "monitoring" means resist and endurance out. The meanings of sustainability includes: stable, enduring and resisting. (Donald Watson, 130: 1376) So the term sustainability do not own its modern sense and relies on the protection and stability. In this paper the



meaning of the term sustainability is also considered as: "What can be continued in the future" (The Shorter Oxford Dictionary, 1996).

In the past it was believed that the entire universe has arisen of four elements of fire and water, earth and air. Although it has been proved today that the creation of the world has had a very complex process, still these four elements provide appropriate solutions for this attitude and the interaction between building and the surrounding area. Sustainable architecture dates back to the 19th century. John Ruskin, William Morris and Richard LA tab are the vanguard of sustainable architecture. Ruskin in his book "The Seven Lamps of Architecture" says that we can pattern after harmonic order existing in the nature to achieve growth and progress. Morris recommends returning to suburban green spaces and self-sufficiency and revitalization of local industry. LA tab in one of his statements wants the architects to be grateful to the order and beauty of nature. All these vanguard have used the term nature and today the only word that could well be replaced by the word of nature is the term sustainability.

The aim of designing sustainable buildings is to reduce the damage of them on the environment in terms of energy and the exploitation of natural resources, which include the following rules:

- reduce the consumption of non-renewable resources
- Development of natural environment
- Remove or reduce the use of toxic or harmful substances to nature in the construction industry

In this regard, in general, the following definitions of sustainable architecture can be raised: A building which has the least incompatibility with its surrounding natural environment and in wider range with region and the world; the creation of the human-built environment and its responsible managing based on the eco- friendly principles and resource efficiency. These principles are: to minimize the consumption of non-renewable resources, upgrade and improve the condition of the natural environment and the least ecological damage to the environment (Charles K. Barrett, 1994)

– Explaining the symbiotic and more balanced relationship of architectural work with the environment which is based on conscious reaction of the architectural work to environmental conditions. (Hagan, 2001)

– Sustainable architecture contains a combination of aesthetic, environmental, social, political and moral values. (Samuel Mook. B)

– Sustainable design will basically results from the location. The process that leads to the revival more than undermining and is indeed the science and art of making a proper communication between the human environment and nature. "(Van Rijn) (Asadpour, 1385: 66)

**The principles of sustainable architecture**

**First:** any building must be constructed in such a way to minimize the need for fossil fuels as possible.

**Second:** Buildings must be constructed in such a way that they are able to take advantage of the local climate and energy sources.

**Third:** each building must be constructed in such a way to minimize the use of non-renewable resources as possible and at the end of their working life, to create a source for building another structure.

**Fourth:** meet the needs of residents: meet the spiritual and physical needs of the residents is of great importance in sustainable architecture.

**Fifth:** coordination with the site: building should be located in the ground of its site gently and be compatible with the surrounding environment.

**Sixth:** holism: all principles of sustainable architecture should be embodied in a complete process which leads to the creation of a healthy environment, (Qyasvand, J., 4: 1385)

**Sustainable architecture patterns**

Today, the buildings are also part of the environment and make much of environmental pollution. The construction cannot be stopped but with an exact thought, design and planning, you can make buildings that have minimal impact on the environment. Sustainable architecture is one of the planning and design ideas for making such buildings. There are three main pillars in the definition of sustainability in general:

- improving the quality of life and health of the humans of the present generation and future generation
- providing routine needs of human beings
- maintain the ecological systems and energy resources

The overall goal of sustainable design in a building is to minimize the adverse impact of buildings on the environment through the correct productivity of energy and natural resources. At the same time, a sustainable plan seeks to achieve aesthetic, environmental, social, economic, moral and spiritual values. So we can



propose the following patterns of sustainable architecture:

- minimize the exploitation of non-renewable resources and use of natural and renewable energy
- improve the quality of the environment and development of the natural environment
- eliminate or minimize the consumption of polluted and toxic substances
- Preservation of cultural and ethnic identity
- promoting healthy living
- wise use of land and harmony of building form with the environment
- Making the construction economical by using efficient alternative technologies
- avoid making noise and air pollution

Therefore, sustainable architecture will help to create a healthy environment based on resource productivity, conservation of non-renewable resources, reduce the use of renewable energy and improve the quality of life. (Hatami Gulzar, 1387)

#### **Variety of residential architecture in Iran**

Great land of Iran, is one of the few countries that have historically been able to create varied architectural by its cultural features and geography. This diversity, with a little consideration, is well visible even in the geographical divisions of a restricted area. For example, residential architecture of deserts of Iran in Abyaneh, Natanz, Kashan, Kerman, at a distance of 50 to 60 kilometers away from each other represents this matter very well. (Memarian, 5: 1387)

#### **Climate & Architecture**

##### **Climate and Climate typology**

The word climate derives from Greek "klima". (Memarian, 26: 1390). In Moein dictionary, the equivalent of this word is an area of the Earth that is distinguished from other parts of the country in terms of climate and natural conditions, and has been mentioned the country, state and province as well. (Moein, 326: 1364). In the International Glossary of Meteorology, climate is changing of collection of weather conditions specified by the quality and development of weather conditions of a specific area. (Faraji, 7: 1378). The similarity of climatic elements of different places, make climatic typology. Coupon method is one of the most common of climatic typologies in which the relationship between climate and distributed of vegetative growth, monthly and yearly average

of temperature and rainfall are taken into consideration and the world is divided into five climatic categories (Kasmaee, 81: 1382, Faraji, 183: 1378).

#### **Factors influencing the climate**

The following are important factors in determining a region's climate: (Yaran and oven Mehranfar, 1392)

- The angle of the sun
- The wind speed and direction of prevailing winds
- Elevation
- Closeness to a body of water
- Land cover
- Humidity

#### **Hot and dry climate**

"Coordination with the climate" and "Coordination with the site" are the necessary principles for a building to be considered sustainable. (Qyasvand, 25: 1385) Hence, the climate recognition is the first step towards providing design solutions. The main context of present research is hot and dry climate. In this climate, which is included mostly subtropical regions, because the winds blow from the South West and North West to the tropics, the weather is very dry. These winds lose most of their moisture when crossing the big continent. In addition, in subtropical regions where are among the areas with high air pressure, weather is warm and dry because of moving from the upper atmosphere to the bottom. It is of great importance to pay attention to the dryness of the weather of these areas that is associated with other features in terms of human comfort and therefore building design. In these areas direct sunlight is intense and produces 700 to 800 kcal energy per hour per square meter in horizontal surfaces. Even the intensity increases when radiation reflected from the surfaces of barren land is added. The sky of these areas is cloudless most of the year, but fog and dust storms usually occur in the afternoon as a result of warming and displacement of air layer close to the ground. Low humidity and cloudlessness makes these areas experience the most dramatic swing in temperature variation. On summer's day, the sun heats the Earth's surface to 70 ° C, while at night the ground surface temperature quickly dropped to 15 ° C or less. Of course swing of temperature is lower nevertheless the amount of variation reaches 20° C. In the Central Iranian Plateau- the largest region of Iran surrounded by high inequalities -dry weather dominates which its



characteristic is hard, cold winters and hot and dry summers.

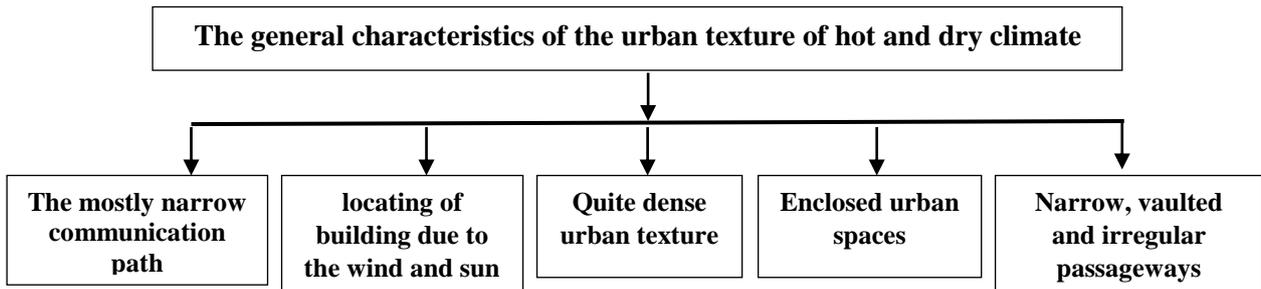
In a large country like Iran with different climatic plating, traditional architectures of the past found a series of logical solutions for human comfort. One of the principles necessary for living and continuity of buildings is their adaption with environmental conditions."Early man built his house for protection from rain, wind, sun and snow. So the purpose of construction was to protect from the

environment, providing welfare and even survival."( Tanhaiyan and Kazemi, 1391)

**Urban context**

Plasticity of urban and rural context and adapting the living conditions with natural factors and the use of these factors in very adverse weather conditions in these areas are considerable. One of the important achievements of our architecture is making adaptation and provide the adequate environment to live in these dry and barren areas. Urban context are as follows:

**Table 1. Source (Author)**

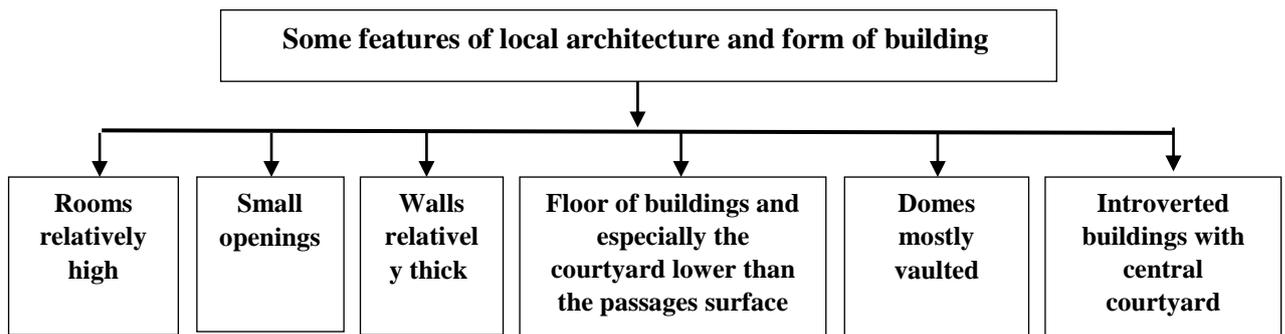


Existence of high walls along the passages is effective because of making the shadow as well as protection against the winds of desert. Winding alleys hot and dry regions is climatically considered an advantage; because in direct and wide paths, desert winds can blow quickly and cause problems in routine life. (Carlo, 2003,49). Unfortunately, in relation to climatic issues, many of the lessons of the

previous Iranian architecture for designing new buildings have been forgotten and in the warm season, , comfort conditions for humans except in closed rooms under electric air conditioners is not provided in other parts of the modern city. (Qobadian, 1381).

**Characteristics of local architecture and building for**

**Table 2 Source (Author)**



**Introversion and central courtyard**

Courtyard in Dehkhoda dictionary means an open area of ground surrounded by walls and house or home. Terms such as precinct and shan have the same meaning. Courtyard in Iranian houses has been used in various forms, including:

- as a sign of privacy
- unifying several elements at home

- connecting some spaces at home
- to create a green and joyful environment
- an artificial ventilator for passing good winds
- an important element in organizing and dividing the various indoor spaces
- a safe and secure privacy for family comfort



Courtyard, In fact, with the establishment of the main summer and winter enclosure on different directions connects the main parts of the house. Some homes have several public and private Courtyards. In hot and dry areas courtyard is used to create a green and pleasant space with a pool in its various forms and as a beautiful landscape for the residents inside the rooms or spaces such as hall and platform and sitting-place in the afternoon. (Memarian, 13: 1387)

The central courtyard in hot and dry areas is the heart of the building. Proportions are determined relatively based on the latitude and the need for shade. central courtyard is narrow enough that the walls of courtyard can provide shade in warm seasons and large enough to get sunlight in the summer. This type of Courtyard provides a safe, private and comfortable environment inside the buildings and elements such as trees and flowers plays an important role not only in beauty of space to but in increasing the moisture content. (Soflaee, 2005) moreover, being pool and the water fountain in the middle of courtyard help providing of the humidity. This element involves in placement of building situation leading to create the Four Seasons houses (Nikpour, 2011).

Studies conducted by Ratti et al (2003) suggest that in hot and dry areas, in computing various environmental (the amount of solar lights received, amount of shading, distribution of light and other relevant factors) the structure of the atrium better responses than other types of pavilion. "What is the best structural form to take advantage of the land and its position? "If the interpretation of the" the best "in environmental factors is drawing a plan regardless of underground spaces, the best answer for hot and dry climates is courtyard form. The combination of:

- Large surfaces and thermal mass storage
- Receiving sunlight through the courtyard with form of shallow Plan
- Narrow spaces for shading and improving comfort in terms of the amount of temperature

This is possible if the energy saving techniques exist between the restrictions of weather conditions. The first feature of these courtyard is that they can prepare a small climatic environment which is quiet and people can often do their personal tasks. As a result, people will have positive interaction with this small climatic environment, climate. (Carlo, 2003, 53)

One of the theories which even exists in cold and temperate climates is this features of the courtyard that forms can take better advantage of their surroundings. (Carlo, 2003, 59)

#### **Extroversion**

Typology of extroverted faces with a type of housing architecture having features such as direct visual and physical connection with the outside of the house, having no courtyard, increasing the height and spatial organization compared to another space, such as corridors. (Memarian, 7: 1387)

#### **Use of appropriate materials**

The use of local materials with appropriate heat capacity due to climatic zone is one of tricks used in residential architecture in Iran. By doing this, not only the proper materials of every climate are used but cost-sides like transportation are also saved. An obvious example is applying wood in northern areas and using soil and making mudbrick and brick in central and desert regions.

#### **Roofs**

- Flat roof

The form of roofs in introverted houses with central courtyard is generally flat and has a small parapet wall with the height slightly higher than the level of visibility which covers around the edge of the roof. This parapet is designed not only to create privacy and security for sleeping and sitting at night but to protect the building from direct sunlight during the day. It should also be noted that the roof is more exposed to solar radiation and heat of it than walls of the house. In hot and dry climates usually square bricks named "Farshi" are applied for flooring the flat roof. These bricks will receive the most solar radiation during the day and began to rise early in the morning and in the end it will start to decline that changes the intensity and angle of radiation of the sun.

- Dome-shaped roof

In these areas, domes used as roof covering. This coverage uses in residential buildings, mosques and bazaars. The cause of using this coverage is that the height of the room from floor to arch is high and it can be a vertical natural ventilation in the room. Since warm air is lighter and climb to the top and is replaced by cooler air, by installing a few vents around the room or tip of it, hot air exits of vents and a natural air flow is established from the bottom up.

Another point is in relation to the angle of solar radiation in the summer. In this season flat arch



receives the greatest amount of heat from radiation compared to other surfaces, because angle of sunlight is almost vertical. But the tilt of arched and domed surface relative to sunshine and also the surface curvature of the arch that causes part of it to be always in the shade helps to reduce heat absorption. This type of coverage due to the three-dimensional structure has better resistance against lateral forces such as wind and earthquake. (A'zami, 2005)

#### **Walls**

Thick walls with an average thickness of about 1 m, are considered as an important element of local homes in warm and dry climate. The advantage of thick walls, is thermal properties mentioned. Neither bricks nor concrete are good thermal insulation, but have the property of heating storage, and spread it slowly to the interior of the building. In all of these materials there is something called latency, which is the time delay between the capture and storage of heat on one side of the wall and release it on other side. In addition, if the wall has a calculated thickness it will be able to transfer the heat several hours after warming by the sun and also hold the heat naturally in itself with the least temperature fluctuation. With this feature, a building can be designed to absorb heat during the day and to release it at night and when it needs. Another benefit of thick walls in this regard, is the amount of heat they can absorb without rising temperature. Thick walls, lose heat through radiation transport at night and the temperature remains low to moderate during the day. If the wall temperature is lower than the temperature of human skin, the human body will radiate it, even if the air temperature is high. So Thick walls act this way in traditional homes in hot and dry climate and will provide the highest comfort by absorbing radiation from the public during the day and enough cold for them through radiation or convection at night. (Zomarshidi, 1377)

#### **Windows**

In hot and dry climate, in general, windows are small and are placed almost in the upper part of the walls and under roof and large windows are used less due to thermal effects, especially if it is not prevented from sun penetration into the interior of the building by awning or proper orientation. Even if the sun is completely removed or windows remain completely closed, due to the low their thermal resistance and the influence of the sun through cracks and pores

around windows are considered as weakness in terms of energy transfer, and the materials used in hot and dry climates are clay, brick, stone and plaster. (Qobadian, 1378)

#### **Color**

Color of the walls and the roof in the hot and dry climate where the intensity of solar radiation is higher than in other areas, will have the greatest impact on the absorption of solar radiation. Color is a crucial and controller factor in various orientation of the building and in different directions of solar radiation on the walls and the roof where receives and absorbs the maximum amount of solar energy. The difference of heat (temperature) between a white roof and a black roof is k40. Of course the amount of the heat received in the interior depends on the thermo-physical features of layers, but in any case, color is an important factor in this regard.

The impact of bright colors in reducing the daily temperature of the external surfaces of the building that is the result of reflecting radiations of the sun-the biggest and most important heat source- is very impressive and increase stability and heat capacity and ultimately provides comfort in evenings. But if whitewash (plastering) is not performed in building frequently, it is natural that the building due to its external surfaces will receive and absorb the most amount of solar energy.

#### **Green space**

Garden with roots, trees either shallow water, while providing shade and play a role in the production and creation of beauty, poverty compensated humidity environment. Gardens with roots and trees which need little water, while providing shade and play a role in the production and creation of beauty, compensate the lack of the humidity of environment. These green surfaces with absorption of the solar rays prevent from re-reflection of rays and increasing unwanted heat. (Asadpour, 74: 1385). Sometimes these trees the play role of windbreak.

#### **Layout of spaces**

From the perspective of typology there are two types of houses with central courtyard in the hot and dry climate. The first type consists of large houses with two central courtyard, which contains larger interior courtyard called "Andaruni". The main courtyard is intended for the accommodation of intimates and the second courtyard which is smaller called "Biruni" is devoted to the reception of guests. Between these two courtyards there is a large room called

double-door room. Along the longitudinal axis and in front the porch, a large room is located called "Aftabru" that is winter room facing the south West. Basement that is located about 3 meters lower from the courtyard is used to store food and as bathroom and kitchen and sometimes living room to relax in the hot summer. In the second type of house with a central courtyard where plants and pool are used for decorating and raising the relative humidity spaces in these houses contain of a semi-open porch and windward and basement. In fact, change of the daily space is called a Local Climate Adaptation. Also there is a type of an annual space change in the houses with central courtyard and that's why the northern part is called wintry living room and the southern part is called summery living room.

#### **Orientation**

The use of natural resources and energy is one of the principles of construction and spatial organization of building. For instance, old houses in hot and dry textures are built in the direction of Mecca unless being annoying wind; this orientation in terms of climate created conditions for winter and summer spaces to find their place in the design of living spaces logically. Proper orientation in addition to protecting residents against the direct heat unfavorable prevented from entering winds. (Asad, 70: 1385)

In Iranian traditional buildings three directions meaning Rasteh (northeast - southwest), Isfahani (northwest - southeast) and Kermani (east - west) demonstrate the best direction for construction of building in each climate. Rasteh includes central cities such as Tehran, Yazd, Jahrom and Tabriz in northwestern of Iran, Isfahani includes the cities of Isfahan, Istakhr, and Shiraz etc. And finally, Kermani includes Kerman, Hamedan, cities of western Azerbaijani, Khoy (Pirnia, 155: 1382 and 2)

#### **Conclusion**

By keep pace with the architecture of the modern world and use of renewable energy in the building and construction in harmony with the climate energy will be saved and environmental pollution will be reduced. In addition to these matters the use of valuable patterns of Iranian traditional architecture is very important and useful. Iranian traditional architecture in hot and dry climate is symbol of providing comfort and logical design in this region; existence of the element of central courtyard and the features such as thick walls and dome etc.in the houses of hot and dry climate indicates that these buildings

use clearly the environmental conditions ; Iranian traditional buildings prepare the maximum amount of sunlight in winter and shade in summer in order to use the natural ventilation and to provide comfort of residents and also the central courtyard in this climate is formed on the basis of climatic factors and applied to create a sustainable architecture in hot and dry climates. By analyzing the central courtyard as a private open space and then, directing the building and placement of it in the best possible direction to get the maximum sunlight in winter and maximum shade in summer along with the central courtyard in this climate is observed that existence of a central courtyard with different sizes do not lead to create a house with the same sizes which can be regarded in the hot and dry climate as an outstanding element of sustainable architecture used as a good model in contemporary architecture design and to design and development of sustainable architecture.

Through analyzing the local architecture of hot and dry areas it becomes clear that the Iranian architect have had a purposeful design in his mind that it can be noted as follows:

- Principles of Iranian architecture
- Designing in harmony with the climate
- Reducing energy consumption and greater use of natural resources
- Providing maximum comfort for the people of this climate

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