MANZAR, 14(59), 38- 53 / Summer 2022
DOI: 10.22034/MANZAR.2022.304882.2150

Persian translation of this paper entitled:
تجزیه و تحلیل نقش انرژی غیرفعال در ارزیابی خانه‌های کاشان
.is also published in this issue of journal

Original Research Article

Analysis of the Role of Passive Energy In the Evaluation of Kashan Houses*

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Received: 03/10/2021 Accepted: 27/02/2022 Available online: 22/06/2022

Abstract | Today's world has been forced to perform actions based on the principles of sustainable development to compensate for the damage caused by industrialization and the mechanization of nature. However, In Iran, a country with an ancient civilization, ideas based on thoughtful interaction with nature had existed before the emergence of modernism. One of the effects of this interaction is the construction of buildings suitable for local climates without using fossil fuels for cooling and heating. This would result in environmental protection. Coping with the climate in the hot and dry desert regions of Iran has long been one of the most important concerns of Iranian architects. Iranian houses are one of the most durable Iranian buildings. Describing the architecture of the house has a wonderful meaning for everyone and they are aware of its important role in life. Since a significant amount of time in a human's life is spent at home, thus energy consumption in this area is very thought-provoking. This survey aims to investigate the old houses of Kashan city from a climatic perspective and energy consumption. The study examines each space and compares the min terms of passive energy factors to identify climate-friendly designs and to save energy consumption in Kashan homes. In this survey, Kashan city was selected as a sample of a location with a hot and dry climate. The physical features of houses in this city were examined to understand how they deal with climatic conditions. The data associated with the characteristics of twenty historical houses were collected through field surveys and library and documentary studies. The descriptive and analytical method was examined after creating a questionnaire to achieve passive energy solution factors in selected samples. This article first describes and introduces the different features of each house in Kashan, such as courtyard, porch, types of chambers, basement, etc. Then an adaptation between these places and passive energy is done. In the next step, each of the components of passive energy is defined so that it can be used in contemporary architecture to optimize energy consumption. Like traditional architecture in this climate, houses can be designed by the climate with the current climate technology.

Keywords | *Kashan's houses, Hot and dry climate, Passive energy, Climatic architecture.*

Introduction| One of the characteristics of human beings is the ability to deal with the adversities around them. How to overcome these adversities is well visible in the architecture of different regions of Iran. In the city of Kashan, located in a hot and dry region of Iran, measurements have been done to establish proper interaction with the environment, which is a very suitable method for sustainable living conditions in the houses of this city. In this article, by examining 20 residential houses of Kashan city as a statistical population and examining each architectural feature of these houses such as courtyard, summer place, winter place, cellar, etc. with their pictures, we will come up with the rules that we call it passive energy in today's modern architecture, and use them in designing of spaces. With this introduction, we will first introduce the climate and climatic elements of Kashan houses, and then

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we will become more familiar with the how-ness of working these elements and passive energy factors suitable for hot and dry climates. The houses studied are: 1-TheBoroujerdi house/ 2-The Abbasian house / 3-The Al-Yasin house/ 4-The Bani Kazemi house/ 5- The Jahanarai house/ 6-The Dastmalchi house/ 7-The Sajjadi house/ 8-The Saleh house/ 9- The Alaqband house/ 10- The Mortazavi house/ 11- The Tabatabai house/ 12-The Ameriha house / 13-The Isfahanians house/ 14-The Bakuchi house/ 15- The Tahami house/ 16- The Kheiriye house / 17- The Reza Hosseini house / 18- The Sharifian house/ 19-The Attar house / 20-The Karkhanehchi House.

Theoretical foundations

• Climatology of Kashan

According to the Coupon climate system classification, Kashan climate is "BWhsa" and has a hot deserted climate. In this formula, B indicates dryness; W indicates the intensity of drought in which the amount of annual rainfall (13.5) is less than the average annual temperature (19. 7 degrees Celsius). h indicates that the average annual temperature is more than 18°C, s indicates rainfall in the cold seasons of the year or winter, and a indicates that the temperature of the hottest month of the year is more than22°C. Based on the De Martonne climate classification method, which is based on drought coefficient and two important factors of temperature and rain need to be considered. Since Kashan's drought coefficient is 4.5, According to De Martonne'scoefficient, Kashan has a very hot and dry climate, windsoften blow from the northeast, but other winds from the north and east also affect this region in some months of the year (Kasmaei, 2005, 88). According to the PMV index of Kashan city (Fig. 1), in a period during different months, its maximum belongs to the middle of winter and spring and its minimum belongs to summer until the end of autumn. However,the least mean of PMV is -1. 6 is in March and the highest is 4.[5] which is August. If we pay attention to the pattern of frequency of different PMV classes, it can be seen that in this region, both very warm and hot thermal conditions in the warm seasons of the year have considerable frequency and cold to very cold conditions indicated in the cold seasons of the year as well. Therefore (Table 1), there is a high demand for heating and cooling energy to ensure the climatic comfort of buildings (Nojoumian, 2008, 36). To create the necessary thermal comfort, two components must be considered:

1- Climatic factors in the hot and dry climate of Kashan;

2- The use of passive energy to optimize energy consumption by the existing climate of the region.

• Passive energy

It is necessary to know the passive energy and its types to design based on the climate and get benefit from clean energies such as passive energy. Passive energy is categorized in non-renewable energies that are produced, stored, and transferred in a completely natural way without the help of energy producer devices, Its types are as follows (Table 2). According to the studies, the components of passive energy were collected in the Table 1, but to achieve efficient components in hot and dry climates, questionnaires have been collected from the perspective of experts in this field. The questionnaire of each component was examined separately from 5 perspectives:

- The effect on the coldest and hottest days of the year;
- Ventilation in indoor spaces;
- Ventilation in outdoor spaces;
- Compatibility with climatic indicators;
- Energy-saving rate.

First, each inactive component was studied from the above 5 perspectives, and according to the graphs and percentages, these factors were checked with other factors. Finally, for the final result and determination of better efficiency, the AHP method hierarchical analysis was used.

- Passive cooling factors

a. The effect of elements in hot seasons: According to Fig. 2, the components of passive cooling are ranked based on efficiency in hot seasons, with the three components of cross-ventilation, chimney ventilation and outer shell having the highest score compared to the others.

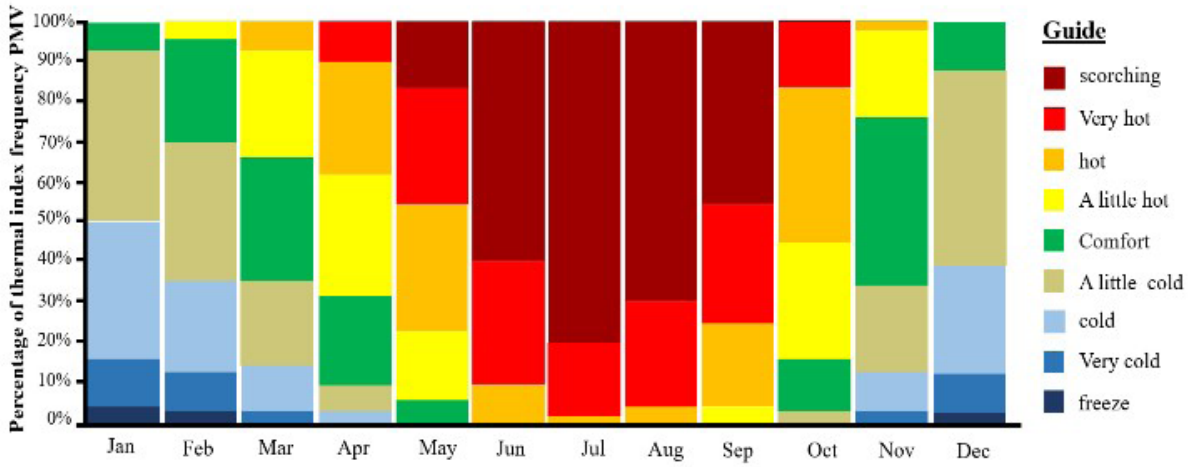


Fig.1.Climatic indicators of Kashan city. Source:Nojoumian, 2008.

Table 1. Hot and dry climate solution.Source: Authors.

Category	Approach	Executive Details
Physical appearance approach	Orientation of the building	south to southeast
	Wall permeability	Low, with an angle of 30 degrees southeast
	Wall height	High for shading
	Wall diameters	Large and thick for heat capacity
Spatial approach	Texture	dense and introverted
	Enclosure	High density
	Appropriate appearance	Like the shape of English letters L, U
Construction method	Color of the building	light color
	Eco-friendly materials	High heat capacity

Table 2. Passive energy. Source: Authors.

Passive Energy	
Heating	**Cooling**
Sunny window Ceiling skylights Trombe wall Roof pool Wall using water The solar room thermosyphon thermal mass	Evaporative cooling Cross ventilation Chimney ventilation Natural ventilation Roof garden Geothermal ventilation Night ventilation Canopy Exterior shell Centeral yard Wall affecting air

b. The impact of elements in interior spaces: The cooling components that provide the highest thermal comfort of the interior space are as shown in Fig. 3, night ventilation and outer shell.

c. The impact of elements in outdoor space: The only cooling component that is most effective in softening the outdoor air in hot seasons is green roof ventilation (Fig. 4).

d. The degree of adaptation to climatic characteristics: Fig. 5 shows the components that are most compatible with the hot and dry climate of the desired area of Kashan.

e. energy-saving rates: Finally, the cooling components according to Fig. 6 are collected based on the amount of energy savings in the desired climate.

By analyzing each factor and specialized survey, the efficiency of inactive cooling factors is collected in the Fig. 7.

- Passive heating factors

a. The effect of elements in hot seasons: According to Fig. 8, the components of passive heating are ranked based on efficiency

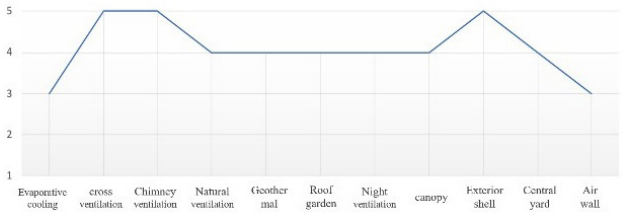


Fig. 2. The effect of passive energy elements in hot seasons. Source: Authors.

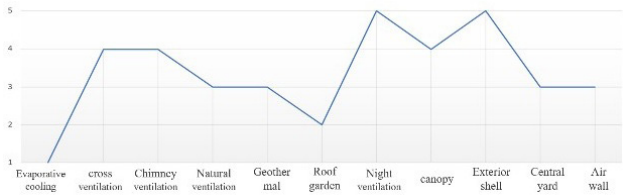


Fig. 3. The effect of passive energy elements in the interior. Source: Authors.

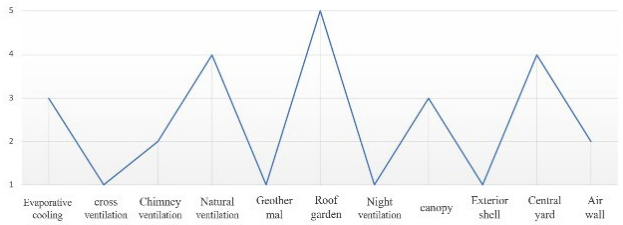


Fig. 4. The effect of passive energy elements in outdoor space. Source: Authors.

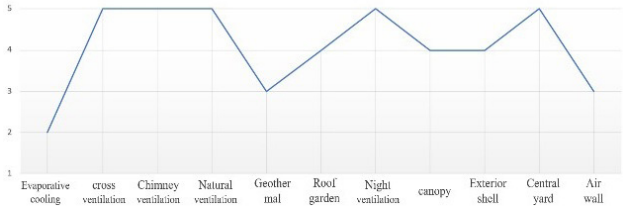


Fig. 5. Compatibility of passive energy elements with climatic indicators. Source: Authors.

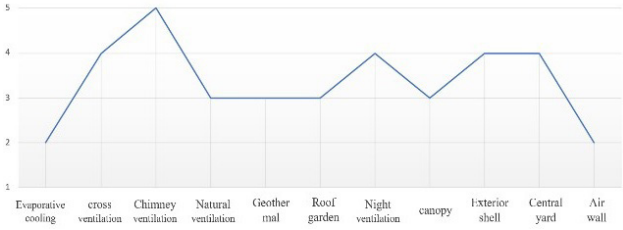


Fig. 6. Energy savings in energy elements. Source: Authors.

in cold seasons, with the two components of solar room and thermal mass having the highest score compared to the others.
b. The impact of elements in interior spaces:
The heating components that provide the greatest amount of indoor thermal comfort in the cold seasons are, according to Fig. 9, solar room ventilation and thermal mass.
c. The impact of elements in outdoor space: The only heating component that has a relative efficiency in softening the outdoor air in cold seasons is the thermal mass (Fig. 10).
d. The degree of adaptation to climatic characteristics: Fig. 11 shows the components that are most compatible with the hot and dry climate of the region of Kashan.
e. Energy-saving rates: Finally, the heating components according to Fig. 12 are collected based on the amount of energy savings in the desired climate.
By analyzing each factor and specialized survey, the efficiency of inactive heating factors is collected in the Fig. 13.
According to the Fig. 13 and the recognition of passive energy elements in two categories of cooling and heating and familiarity with the efficiency of each one in different fields, these elements are classified in the following Table 3.

Research methods

In this study, after identifying the climate of Kashan city as hot and dry and examining passive energies, separation, and analysis of each element of passive energy with the help of a questionnaire under the supervision of experts, we analyzed 20 houses in Kashan. The results show the physical characteristics of twenty historical houses, which were gathered through field surveys, library studies, and documents analysis. The analysis of houses in this city and how – ness of dealing in different weather conditions and its comparison with passive energy solutions has been done. By analyzing two examples in more detail, we will get a better understanding of passive energy solutions to adapt to the climate and use it in today's designs.

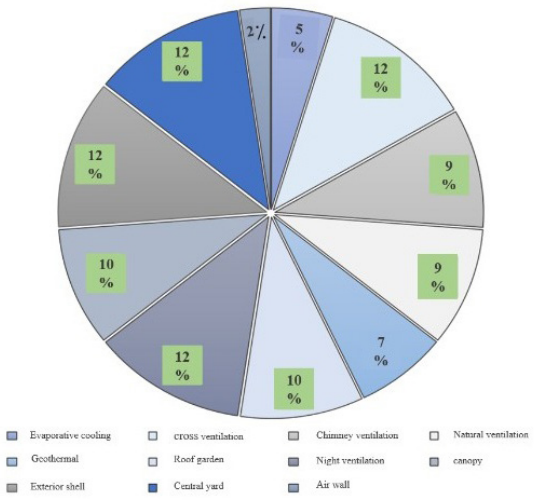


Fig. 7. Percentage efficiency of passive cooling components. Source: Authors.

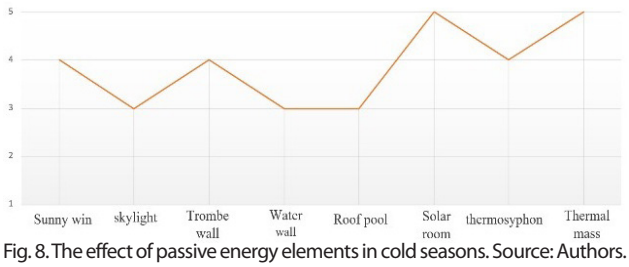


Fig. 8. The effect of passive energy elements in cold seasons. Source: Authors.

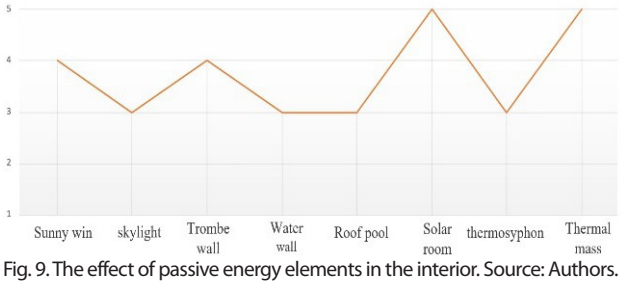


Fig. 9. The effect of passive energy elements in the interior. Source: Authors.

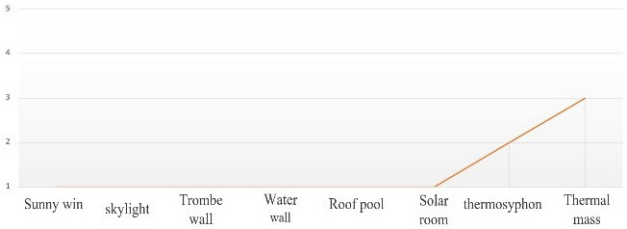


Fig. 10. The effect of passive energy elements in outdoor space. Source: Authors.

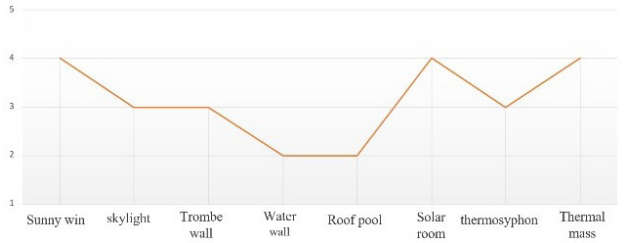


Fig. 11. The degree of compatibility of passive energy elements with climatic indicators. Source: Authors.

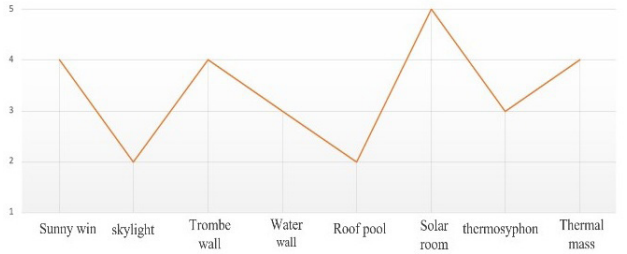


Fig. 12. Energy savings in passive energy elements. Source: Authors

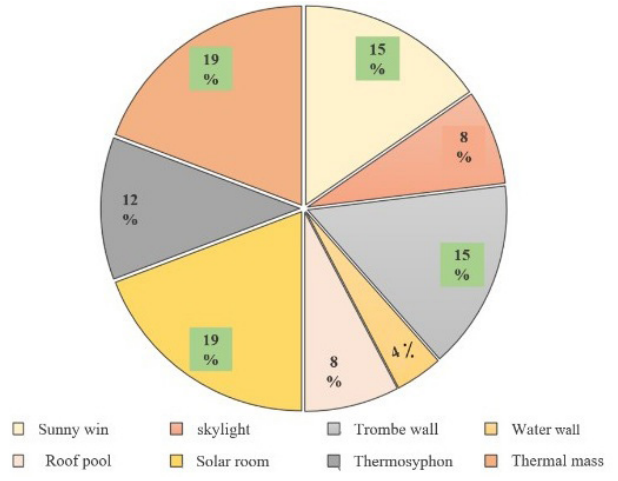


Fig.13. Percentage efficiency of passive heating components. Source: Authors.

Table 3. Passive Cooling and Heating factors. Source: Authors.

Passive energy factors		
Cooling	**Cooling**	
Sunny window	Crossover ventilation	Night ventilation
Trombe wall	Chimney ventilation	Canopy
Solar chamber	ventilation with water and plant	outer shell
Thermal mass	green roof ventilation	Central yard
ceiling skylight	geothermal heating ventilation	Evaporative cooling

Discussion

In this section, the various spaces of the traditional houses of Kashan were investigated in terms of using passive energies. This study attempts to examine which type of passive energy strategies for supplying and storing natural energy has been used in each of the spaces. Such strategies can still be used in sustainable houses.

• Limitation and introversion

The architecture of the traditional houses of Kashan reflects the ancient history and culture of Iran. Introversion and sanctity, roof alignment, and symmetry in architecture are considered inevitable principles and have taken a special place among the principles of Islamic architecture.

- Characteristics of introverted houses

1. Lack of direct visual connection between indoor spaces with outdoor urban spaces.

2. Its various spaces are organized by an element such as a courtyard or covered slabs and openings spaces face towards these elements.

The confinement and introversion of Kashan houses, in addition to the cultural reason, have also been affected by the climate of this region. The above-mentioned feature implies shading which is considered one of the passive energy cooling solutions and close spaces increase the amount of shading in open environments in hot seasons when the sun is vertical and there is the least amount of shading, and thus the amount of solar heat is controlled (Memarian, 2008, 256).

• Compatible elements in the house

The pioneering repetition of different spaces in the four directions of the yard, along with other elements such as canopy, walls, openings, etc., creates the interior of houses (Fig. 14). These elements have changed concerning the building area. Different spaces of the house are usually constructed at a higher level than the surface of the yard, Atrium, ventilators, and basement entrances have been installed (Pirnia, 2004, 140). Brickwork is done on the plinth and is usually sailor/ shiner or flowered (Fig. 15). Structural and non-structural elements such as walls, canopy, and openings are placed on the plinths. Rooms with doors and windows, in addition to two rafters, also have vertical and horizontal canopies, and between the canopies, geometric patterns and knots style bonding are placed. Roof light with colored glasses (Goljam) was placed on top of the canopy so that balanced and sufficient light could enter the room. The above factors refer to the dual shells being of buildings and canopies of the southern openings, which are inactive energy cooling elements. The Exterior rafter works as a Trombe wall in cold weather due to its heat capacity and prevents the interior spaces from cooling down.

In addition, its materials and colors attract the viewer's attention that is a combination of White Mountain plaster inside the halls and porches and brown color of the thatched walls. The reason for using thatch has several reasons; In addition to being coated, this material has a beautiful and calm color and is also a material resistant to sunlight, which is one of the inactive energy solutions in line with the use of thermal mass (Kasaei, 1984, 892).

• Yard of desert houses in Kashan

The courtyards of the desert houses are a complete manifestation of introversion and the environment is completely different from the outside space. In this small garden, the residents have created a pleasant environment by planting beautiful trees and flowers and building a pond. The yard has been used in different ways in Iranian houses; which include:

- as a sign of privacy;
- Unifying several elements of the house;
- Multi-space connector;
- To create a green and lively environment;
- As a natural ventilator for proper wind flow;
- An important element in organizing different spaces;
- As safe and quiet privacy for the comfort of the family.

Among other uses of a yard is to create a green and live space with a water pool in its various shape and using the yard as a beautiful view for the residents inside the rooms or spaces such as halls and living rooms, sometimes for evenings and

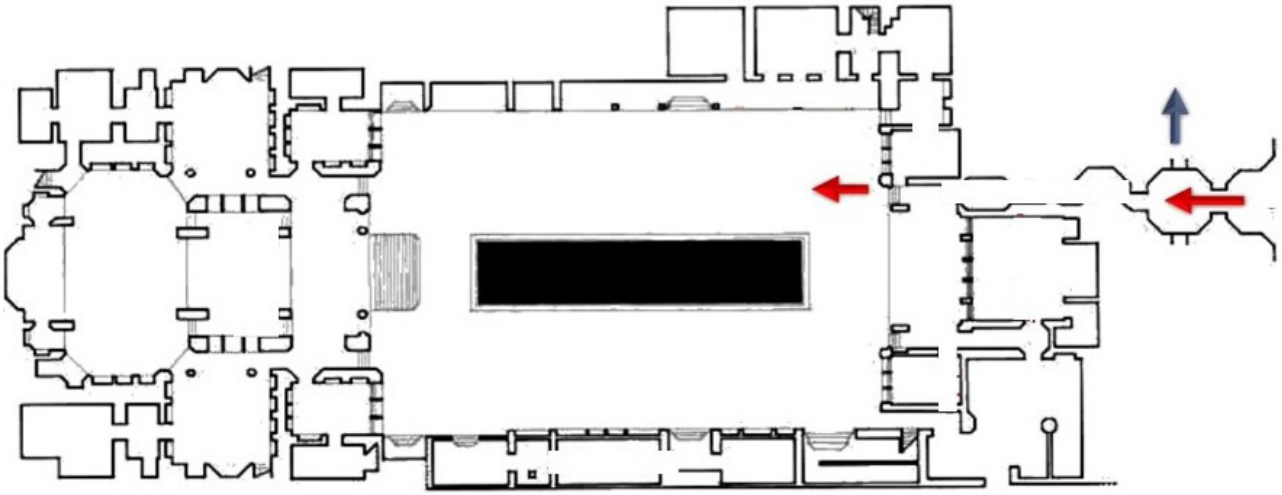


Fig. 14. House plan in Kashan. Source: Mousavi Rouzati, Haji Ghasemi & Soltanzadeh, 1996.

Fig. 15. Yard and view of Boroujerdi house. Source:Mousavi Rouzati, Haji Ghasemi&Soltanzadeh, 1996.

sunsets in hot and deserted areas. Organizing different spaces according to the effective factors has been one of the most important functions of designing a yard in the house plan. Due to the effect of sun rotation on the different directions of the house, its builders have assigned each direction to a different season. Concerning this point, the direction which faces the sun is for winter residential rooms and the direction which is back to the sun is for summer residential rooms (during a few hours of a day) and the western direction is allocated to some cold winter days. Also, entrances to the basements in the yard have been constructed to spend hot summer days. In Kashan, a large part of the yard has been built in the shape of a garden pit, thus in addition to better access to the underwater aqueducts and wells, to create a cool environment by planting green spaces (Ghobadian, 2008, 128). Different spaces of a house are located on one to four sides of the yard according to the needs of the homeowner. In general, houses can be divided into the following types in terms of internal migration and division of spaces into summer and winter sections:

Another factor in the organization has been the creation of a safe and quiet space for the comfort of the family, which in introverted houses with yards they have created a space in a corner of the yard outside the family's private environment or by built another yard called the exterior yard. The houses in this area are divided into two main groups in terms of the number of yards.

- Houses with one yard
- In the previous space, there is only a hall and in the winter section, there is only one room.
- There is a space + hall in the previous direction and across from it, there is a room and corridor.
- The two spaces next to the hall in the previous direction and on the winter section there is a combination of three spaces.
- Four spaces exist next to the hall, the hall is in the center and there are two more spaces on each side, in the winter section.
- Multi-yard houses
- The main axes are parallel,
- The main axes are parallel but not side by side,
- The main axes are perpendicular to each other,
- A combination of the above three.

The main axis is the axis that connects the hall to the winter residence section. These houses are a combination of single-yard species that are organized into several yards; Of course, it can be considered that the main motive of this design was belief attitude. The inner and outer courtyards can be connected in two ways, one: on one level, usually through various corridors

on the ground floor, and the other through basement paths that lead to the garden pit (Memarian, 2008, 347).

Kashan houses have all used one or more yards in different ways, such as Al-Yasin House and Tabatabai House, with two separate yards with perpendicular axes, or as Isfahani, Abbasian, Saleh, Bakuchi, Jahanarai, and Reza Hosseini houses with parallel axes or other houses such as Bani Kazemi and Abbasi and Alaqband that have used several backyards (ibid., 370).

The existence of yards, as mentioned above, are central in this area (Fig. 16), which itself acts as a passive cooling solution, and whatever these yards extend with the help of backyards and other atriums it helps to create air blinds and natural suction and shading with Its centrality increases.

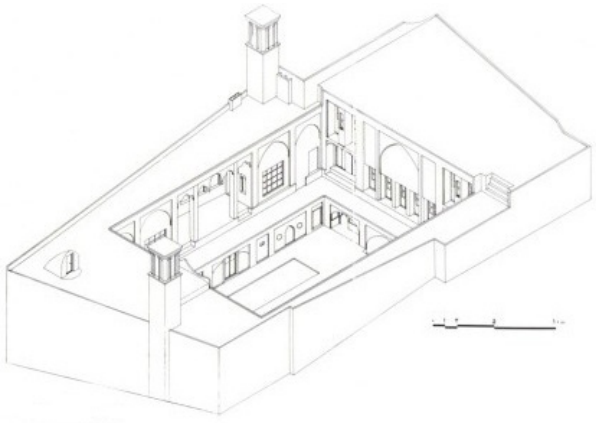


Fig. 16. Tahami House. Source:Mousavi Rouzati, Haji Ghasemi&Soltanzadeh, 1996.

• Garden pit

A garden pit or garden was built in the middle of the central yard and it was dug as deep as one floor. Examples of this space can be seen in very arid desert climates, like Kashan and Nain. In addition to providing the soil needed for the bricks used in the building, the garden pit, also provided access to the aqueduct water. Due to the smaller and lower level of these yards and the use of soil moisture and coolness, in addition to plant moisture and water coolness, a much more climatic space has been created than the yard. This feature helps natural ventilation with elements such as plan cover and water, as well as natural geothermal ventilation, all of which are passive cooling solutions (Parsi, 2008, 370).

The garden pit of Pirnia House in Nain and the mosque of Agha Bozorg School in Kashan are good examples of these spaces. Also, the houses of Tahami, Mortazavi, Bakuchi, and Abbasian in Kashan have used the garden pit (Fig. 17).

Fig. 17. Abbasid House .Source:Mousavi Rouzati, Haji Ghasemi&Soltanzadeh, 1996.

• Winter residential section

The winter residential section does not mention any special space. All the spaces that are built on the north side of the yard to use the winter sun shining through the rooms at right angles are called the winter residence section and a certain set of spaces with special relationships make up the winter residence section, which consists of Se Dari, Panj Dari[1] and a Shekam Daride[2], which are located on the main axis. The main wintering area is located on the main axis and most of the windows are made of a large sash to allow more sunlight to enter. Inside the central spaces, due to the closure of the space, complex decorations such as Mogharnas and mirror works can be seen. The winter residence section has a short roof and a heavy volume compared to the summer residence section, and this has no reason other than better control and retention of heat. Due to the solar heat, this space naturally creates thermal comfort in cold seasons. One of the passive heating solutions is the solar room. Winter riddance section with vast windows creates a greenhouse space that, in addition to warming the space, absorbs the sun's heat during the day and releases it at night. In greenhouses practical, the storage process can be done on the wall, floor, etc. It should be noted that in summer glasses should be covered. The stored heat enters the desired space by opening doors, windows, or vents that have been installed for this purpose. Heat can also be radiated and transmitted through a common wall between a solar room and other spaces. The hot air that goes to the upper parts can be directed through the duct to the lower levels of the building, which is colder (Haji Ghanbari & Samaei, 2016, 370). If the solar room is considered as a living space, comfort along with space efficiency in terms of energy will be considered.

An atmosphere that should stay warm in winter and cool in summer, with the least levels of dazzling and annoying light, with mild and moderate humidity.

• Summer residence section

The summer residence section also has a similar situation to the winter residence section, with this difference that it is located on the south direction of the yard to be protected from direct sunlight in summer, and on its main axis, a semi-open space with a hall is usually located. These halls and porches have been the most important living space in the house except in the very cold times of the year. The summer residence section has a high ceiling, with light and hollow volume to provide better ventilation and air cooling.

This process reinforces cross-ventilation, and the space of the front porch acts as a canopy for the summer residence section and controls the entry of sunlight (Kheradmand & Satari, 2018, 73).

• Room

The rooms were used according to their function and were divided into do Dari, Se Dari, Panj Dari, Tehrani, etc., the function and location of some of them were as follows:

Se Dari: study and work, sleep, breakfast in spring and autumn and especially winter residence section.

Panj Dari: family gatherings and guests, the dining room in spring, autumn, and winter residence section (Fig. 18).

Large sash or Tehrani: parties, dining room, the congregation of elders in early spring, autumn, and winter residence section (Abolzia & Ghezelbash, 1985, 41).

Upstairs: Bedroom and study First of spring and autumn and winter residence section.

Gooshvar[3]: home, sleeping, privacy and library' From the mentioned rooms, autumn and winter residence rooms are located in the west and north direction, and summer residence rooms are located in the south direction. The kitchen is usually built near the winter residence section. The rooms are arranged in a special order on different sides of the yard and are connected to the yard through corridors. In a common type of house design, a winter residence room or Tehrani was built along its main axis, in the direction of the hall. This section, along with the hall in front of it, has brought more emphasis to this axis in the overall organization of this section of the house (Pirnia, 2004, 142).

The shape of the rooms and their plan is usually obtained from a part of a golden rectangle-the Persian rectangle- The cruciform shape was also used in the Tehrani room design. The lighting of the yard-faced rooms was done by doors, windows, and Logjam. These elements in their original type were among the vertical and horizontal canopies and finally, all of them were placed inside a frame, and the rooms that were not skylights were illuminated by Ceiling skylights and Horno[4]. Depending on the angle of sunlight, the summer residence rooms have vertical canopies and the recesses in the facade are controlled, which are inactive design solutions. Winter residence spaces are solar rooms with sunny windows and skylights (Haji Ghanbari, Samaei, 2016, 48).

• Korsi[5]room

This room was built in a winter residential complex. It is often in the corners of this section, which has fewer doors and windows overlooking the yard so that it can be warmed in winter by closing the doors and windows. In the middle of the room, there was a Korsi, and the dimensions of the room depended on the dimensions of the Korsi, as its walls were used for back support. This space exists in all cold and mountainous climate houses. This room was dug in steep areas inside the mountain and had no windows. This section was placed on the main axis, in houses that had a Shekam Daride section or a cross-section in their outer yard. In Pirnia's house in Nain, this room, located on the main axis, has very delicate decorations with a layer of plaster (Parsi, 2008, 370). This space acts more based on its walls that are like a Trombe wall, where the stored heat is gradually transferred into the building during the day. The Trombe wall allows the heat of the sun to be used efficiently and its efficiency depends on the thickness and color of the surface, and this works with the passive energy solution, thermal mass (Falah & Heidari, 2016, 117).

• Windcatcher

The job of the windcatcher is to direct the proper wind to the summer residence section of the house to create air movement and cool the environment. Basically, according to the function of wind catcher, they can be divided into two general categories:

1. Purely functional wind catcher: Mostly seen in ordinary houses.

2. Symbolic functional wind catcher: It can be seen in some houses, which in addition to its special function, has also represented the social level of the owner of the house; in some houses, its dimensions are more than the "Se Dari" room has increased (Bahadorinejad, 2002, 6).

Each of the constituent elements of the wind catcher is effective in Its final shape. The wind catcher consists of different parts

Fig. 18. Five doors belonging to the Abbasid house. Source:Mousavi Rouzati, Haji Ghasemi&Soltanzadeh, 1996.

from bottom to top, including base, stem, chains, shelves, and chains again. The windshield is usually in the form of an incomplete pyramid. The different adjustments of the upper part of the wind catcher are done through this part. In some types, this part is as tall as a human height. The shelf section consists of several parts such as vertical arched blades, round frames, and Gooshvar. Shelves are usually open front or closed front. Shelves are usually the ways for wind inlets into the room. There are usually two shelves for each air inlet duct (Eslami, 1977, 96).

In four-season residential houses with a central yard, a wind catcher is usually constructed in the summer residence section of the building, and this wind catcher is connected to the main room or the hall or basement of the building. A clear example of this construction can be seen in the house of the Boroujerdis (Fig. 19). In this part of the building, in addition to the wind catcher, the vents installed on the dome of the hall also help to ventilate the interior environment. In this building, the cooling function of the wind catcher is done only by air movement. Of course, in the case of the basement, because the body of the wind catcher is located underground and therefore is slightly humid, thus the evaporative coldness also has a small effect on cooling the space. Other features of the wind catcher include the effect of the chimney. When the wind is not flowing, hot air rises inside the building and is transferred to the outside of the building through the wind catcher, thus still maintaining an airflow inside the building, although its intensity is less than when the wind is in is flowing outside (Ghobadian, 2008, 17). The late Pirnia describes how the wind catcher works: 'The wind catcher work is based on the fact that it uses wind to drag pleasant air into the building and uses its reaction, suction, to drive hot and polluted air. It may not be necessary to explain that because the wind strikes obstacle or wall of the wind catcher's inner blades, it is forced to land (Fig. 20), but it is necessary to note that the other wind catcher cracks, which face backward drive polluted and hot air and do the work of the ventilator or a suction device." The wind catcher are usually located behind the hall and have strengthened the symmetry of the façade. It should also be added that many wind catcher in Kashan act like wind turbines and work with different air pressure.(Bahadorinejad & Dehghani, 2008,8).

As mentioned above, wind catcher are natural ventilation that works by suction with the help of wind and other cooling elements, which in the table of categorizing passive energy they are a part of passive cooling solutions.

• KenoBandi

They were sometimes do concave structures in curved coverings. The Keno was a small arch that covered between an arched or domed two arches or two adjacent domes and flattens the work. Thus it creates a space. This structure was also used to flatten a curved arch and dome and they could flatten the roofs of the arches and domes and use the roof as a terrace (Pirnia, 2004, 139). This space has different efficiency in terms of energy depending on the proximity to other spaces, which is an inactive energy solution in winter residence sections with terraces and skylights (Bahadorinejad, 2002, 8).

• Porch

The most famous indoor space is called the porch. The porch is a space that was considered a necessity of the house and used to create shade direct communication in Iranian houses until the early 20th century. The porch is a covered and independent space with a high arch that is intended for a set of life activities. One side of the porch is open and overlooks the yard and the other two sides are half-closed and the fourth side is closed. The closed side usually leads to the royal rooms and when the windows and doors of these royal rooms are open, the royal space is combined with the porch space (Haeri Mazandarani, 2009, 129). In some of the studied examples, the porch is located in the upper part and has an independent space; like the house of the Abbasian (Fig. 21) and the house of Alaghebandan. The porch serves as a canopy for adjoining rooms. Laminated ceilings and walls act like outer shells, blocking direct sunlight and preventing it from self-storage inside (Bahadorinejad, 2002, 14).

• Patio

The patio is also used to create a cool airflow at night. The patio

Fig. 19. Boroujerdi house windbreak. Source:Mousavi Rouzati, Haji Ghasemi&Soltanzadeh, 1996.

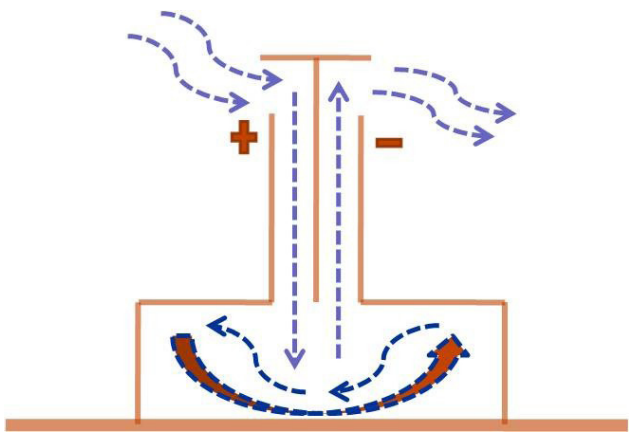


Fig. 20. How the windbreak works to create positive and negative pressure. Source: Mousavi Rouzati, Haji Ghasemi & Soltanzadeh, 1996.

provides light and is located next to the royal room. The patio comes from Padiavo which consists of two parts Padi means sun and avomean water (Ayvazian, 1998, 88). An example of this type of space can be seen in the house of Tabatabai in Kashan (Figs. 22 & 23). Chimney and ventilation function is done with the help of vegetation and water element which is used for ventilation and cooling the interior space by creating airflow and circulation.

• Cellar

A cellar is a house built in the basement to shelter in the heat and keep water there to stay cool (Ghias). It is an underground building in which water is placed in summer to keep it cool (Dehkhoda, 1998, 121). Thenave is synonymous with the winter residence building, and also the pavilion in the garden or any building that is suitable for the use of heat is also called the cellar (Fig.24), which later referred only to the basement (Pirnia, 2004, 165). Al-Yasin House has three cellars, Boroujerdi House has two cellars, Tahami House, Sharifian, Attar, Alaqband, and Mortazavi have one cellar, Dastmalchi House has large cellars on the southeast, southwest, and northwest directions which are considered as specialties of this house, and Saleh and Karkhanechi houses have a cruciform shape cellar.The cellars use geothermal ventilation, ground energy, which in this part, despite the pond and wind catcher, chimney action occurs and the space gets cool (Torabi, 2018, 5).

• Springhouse[6]

In the Iranian house, by placing a small pool under the dome of the house, various features such as coolness, humidity, and reflection of beautiful images are created. This set of spaces is called springhouse. Bani Kazemi'sspringhouse is in the basement and Isfahanian'shouses are onthe same level as the yard (Fig. 25) also Al-Yasin, Bakuchi, Khairiyeh, Attar houses have springhouse, and the Abbasian house has a high leveled yard (Haeri Mazandarani, 2009, 130). The existence of a springhouse in the basement, which is located at the bottom of the wind catcher, helps to suck in the wind and cool the hot weather of the day. The existence of these structures in the yard strengthens the natural ventilation and cools the air by creating an evaporative cooling system and helping its rotation.

• Roof

The roof is a part of the living space in Iranian architecture and in addition to having complex and beautiful volumes, it has also been used as a yard. The existence of a yard on the roof, in addition to being insulation for the lower floor, has used passive energy by evaporative cooling that creates. In cities such as Nain, in some buildings with porcelain box walls were raised around the roof by about a meter and a half, and created a kind of yard on the roof that was used for sleeping on summer nights. These walls also had a secondary climatic role by shading a part of the roof at different hours of the day. Such spaces have also been used in mosques. The house of the Abbasian in Kashan has such a yard on its roof, in which

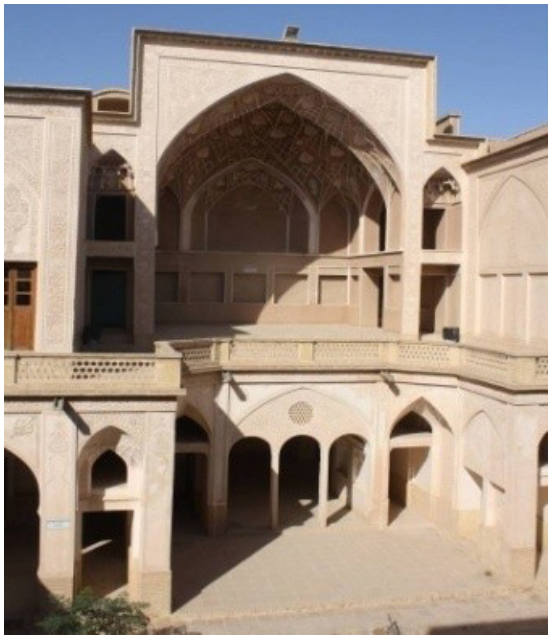


Fig. 21. The porch of the Abbasid house. Source: Mousavi Rouzati, Haji Ghasemi&Soltanzadeh, 1996.

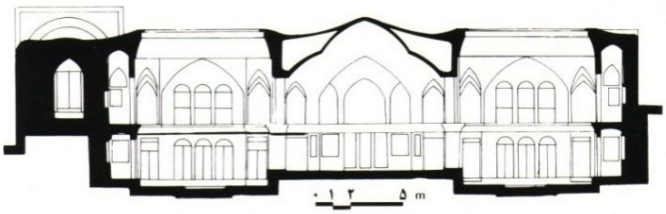


Fig.22. Excerpt from the patio of the Tabatabai House – Kashan. Source: Mousavi Rouzati, Haji Ghasemi&Soltanzadeh, 1996.

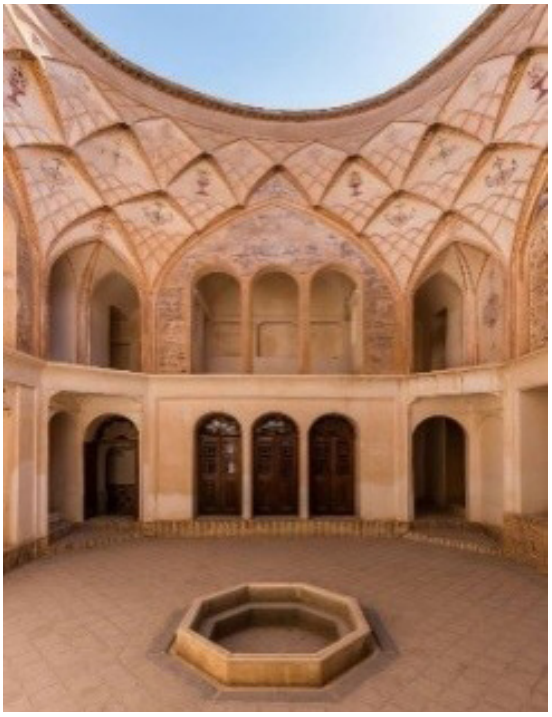


Fig.23. Patio House of Tabatabai. Source: Mousavi Rouzati, Haji Ghasemi & Soltanzadeh, 1996.

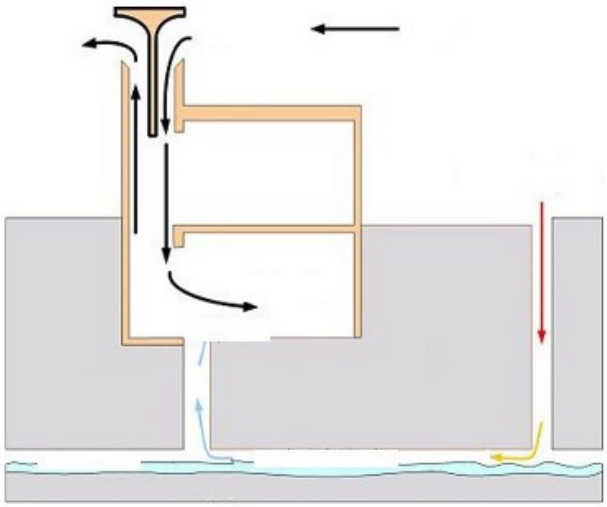


Fig. 24. How the cellar works. Source:Mousavi Rouzati, Haji Ghasemi&Soltanzadeh, 1996.

Fig. 25. Pool house of Isfahanis. Source: Mousavi Rouzati, Haji Ghasemi & Soltanzadeh, 1996.

the architects have provided the possibility of ventilation with delicate frames of the brick lattice (Memarian, 2008, 259).

Analysis of two samples of Kashan houses, Climate study and passive energy in it

• Abbasian House

The Abbasian house was built in 1869 AD at the same time as the Qajar period, which is divided into two parts, inner and outer, even the design of the rooms is also nested. The different parts of the Abbasian historical house are quite symmetrical and include winter and summer residence parts that people lived in the relevant part according to the climate (Fig. 26).

• Sharifian's House

Sharifian's house dates back to 1851 AD. This beautiful mansion was built in the Sadre neighborhood during the Qajar period, which consists of three different spaces. Its two-story buildings in the northern and southern parts of the yard are among the most important spaces of the house. In the southern part of the building, there is a large royal hall that connects to a springhouse with anoctagonal shape, and in the northern part, the yard can be reached through its large porch (Fig. 27). One of the features of this building is its arched shape, which protrudes slightly from the whole view of the Sharifian house, and the walls and ceiling of the porch of this house are beautifully decorated with plaster and Yazdi decorations. Also, Sharifian's beautiful house has a yard on the outside section with three open directions in addition to the inner yard, which is closed on four sides. Important and practical spaces of Sharifian House include the cellar, the royal residence, the summer porch, the terrace, and the entrance (Mohammadi&Mokhtari, 2018, 89).

Conclusion

In this section, we examined and measured the passive energy solutions in relation to the spaces in the houses of Kashan (Tables 4 & 5). Then, in general, the characteristics of climate design and the use of inactive energy are given in 24 cases.

• Passive energy

According to the Table 6, passive energy was adapted to the traditional architectural elements of Kashan and studied in the sample of historical houses of this city. Because the purpose of this article is to become more familiar with passive energy and its use in today's designs to optimize energy consumption with the help of traditional architectural elements in this climate, passive energy can be used. Therefore, after recognizing the design of traditional houses in Kashan (Fig. 28) and simulating the components, the passive energy is defined in two categories of cooling and heating in two Tables 7 & 8.

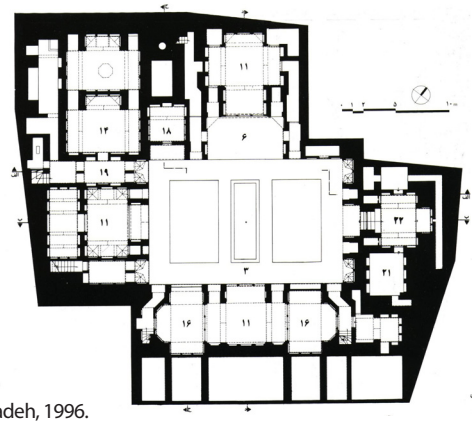


Fig. 26.Photographs of Abbasian's house. Source:Mousavi Rouzati, Haji Ghasemi&Soltanzadeh, 1996.

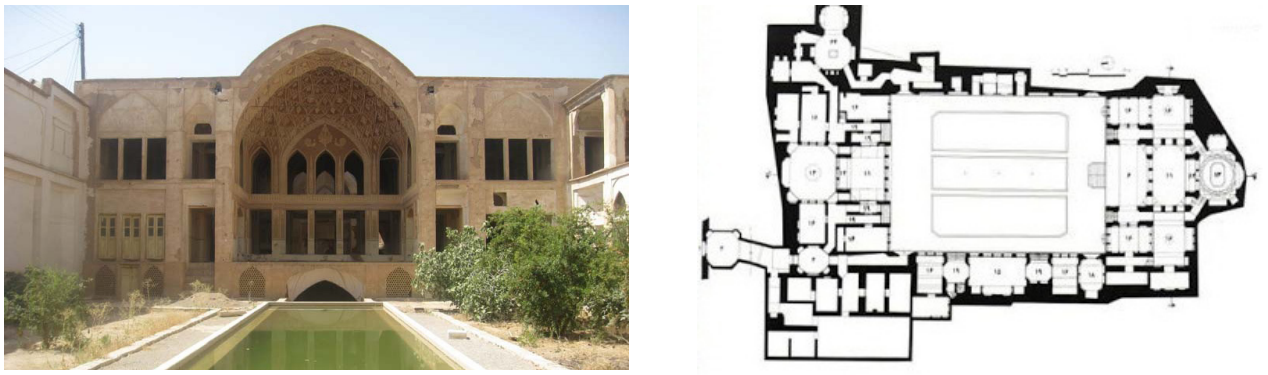


Fig. 27.Left: View of the courtyard of Sharifian's house, Right: .Sharifian's house plan. Source:Mousavi Rouzati, Haji Ghasemi & Soltanzadeh, 1996.

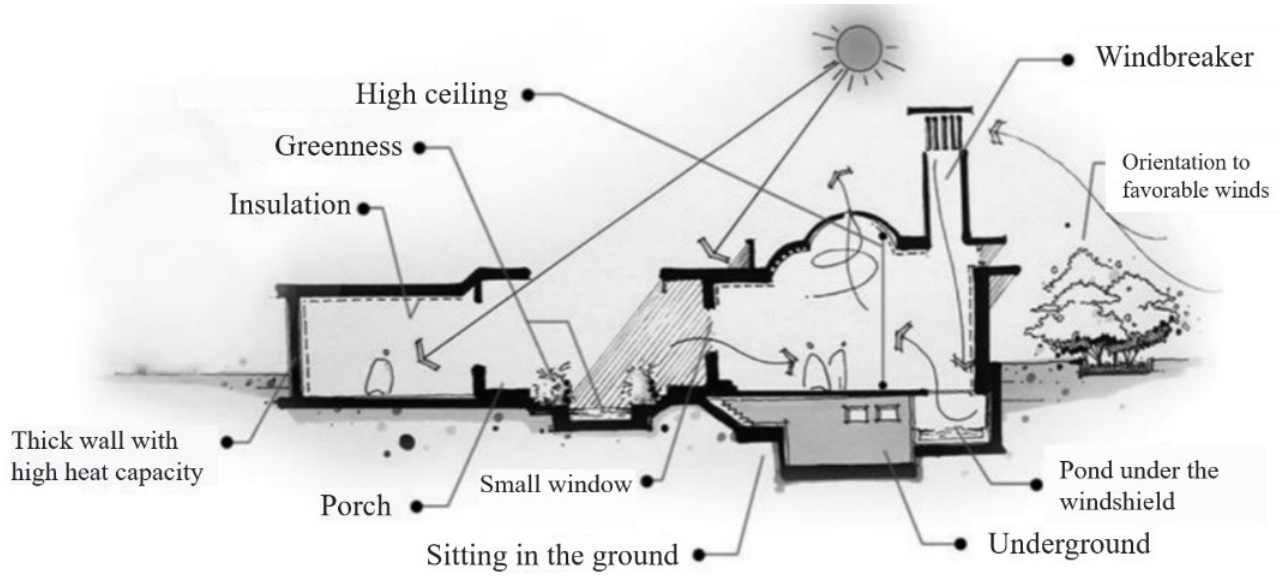


Fig. 28. A section of desert houses. Source: Shahram Pourdeihimi et al.

Table 4. Characteristics of Passive Energy of Kashan Abbasian House. Source: Authors.

Passive energy solutions		Method of use
Cooling	Cross-ventilation	Summer residence section with high level without doors and windows: air circulation and proper ventilation.
	Chimney ventilation	Lattice design of doors and skylights: air passage and suction for better ventilation and skylight. Use of pressure difference in the windcatcher of this house: to direct hot and unpleasant air outside.
	Ventilation with natural elements	Gardens and pool design and locations: Creating air conditioning using plants and water.
	Green roof	Roof yard to increase airflow.
	Geothermal ventilation	The cellar was cool in and has little light: even without a windcatcher, the pressure difference causes the air to cool.
	Canopy	Porches and ledges act as canopies.
	Outer shell wall	Use of natural and light colors: controlling the temperature of the walls with the help of two shells.
	the central yard	Placement of space around the yard to increase shading in the inner space and a narrow alley around it.
	Evaporative cooling	Creating a garden pit: The alley is 3 meters higher so that water can be mounted and enter the house from the aqueduct.
Heating	Sunny window	Settlement of winter residence section on the southern front: Utilization of solar energy according to the seasons.
	Roof skylight	There are skylights around the room.
	Solar room	Wintering with a heavy volume of full veto and low ceiling: creating heat and then maintaining the required heat.
	Trombe wall	The cellar is warm in winter: the use of soil heat capacitydepending on the function of the wall.

Table 5.Characteristics of passive energy in Sharifian's House in Kashan. Source: Authors.

Passive energy solutions		Method of use
Cooling	Cross-ventilation	Alcove with high height and various openings: for better ventilation in hot seasons of the year.
	Chimney ventilation	Windcatcher and pergola: providing light, air conditioning, and air cooling by placing a pool under it.
	Ventilation with natural elements	Gardens and small pool design and locations: Creating air conditioning using plants and water.
	Geothermal ventilation	The cellar was used in the summer from noon to afternoon: about 15 degrees cooler Shrinkage of the opening 2 -Shrinkage of the length to control the required temperature better.
	Night ventilation	The dual shell of the dome, which due to the type of material with high heat capacity and color, stores solar energy during the day and gives it to the surrounding rooms on cold nights.
	Canopy	Existence of a domed roof: refraining from direct sunlight and placing part of the roof in the shade.
	Outer shell wall	Use of natural and bright colors: controlling the temperature of the walls according to the color of the outer shell.
	The central yard	Creating a garden pit: below the level of the alley so water can enter the house from the aqueduct. Other reasons such as the use of soil in the central yard.
	Cooling Evaporation	Despite the large pond in the middle and the pits of the surrounding gardens in the central yard, cooling evaporation takes place and causes ventilation.
Heating	Sunny window	Window to direct sunlight in cold seasons.
	Roof skylight	There are skylights around the room.
	Solar room	Winter residence section: Using the sun's natural energywinter residence section with one side open: to make it easier to control the temperature and movement.
	Trombe wall	The cellar is warm in winter: using the heat capacity of the soil.

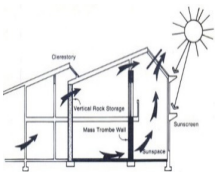
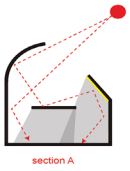
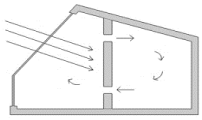
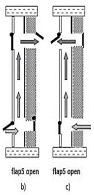
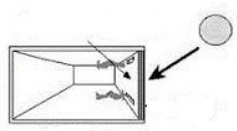
Table 6. Characteristics of passive cooling and heating energy in Kashan Houses. Source: Authors.

Passive heating energy	spaces of Kashan houses	Sample of Kashan houses
Sunny Window	Winter residence section	Most houses except Alaheband house
Ceiling skylights	Using Keno	Jahanarai, Abbasian, Mortazavi, Tahami, Attar, and Kheiriye houses
Ceiling skylights	Winter residence section	Most houses except Alaheband house
Trombe wall	Korsi room	Sharifian, Tahami, Ameri, Attar, Isfahanian, and Kheiriye houses
Thermal mass	Faced practical elements	All samples
Passive cooling energy	Space in Kashan houses	Sample of Kashan houses
Cross-ventilation	Introverted design, Summer residence section	Both types are available in all samples
Chimney Ventilation	Windcatcher, Patio, Underground Springhouse	There are windcatchers in most houses except: Bani Kazemi and Alaqband houses with backyard and patio Ventilation of natural elements of the Springhouse.
Ventilation With Natural Elements	Springhouse Garden pit	Water element and pool are present in all samples GodalBaghche: Tahami, Mortazavi, Bakuchi, and Abbasian houses.
Night Ventilation	Twolayersof domed roofs	In Bani Kazemi, Hosseini, Abbasian, Tahami, Ameri, Isfahanian houses the layer is very thick, and the multi-layered dome roof of the summer residence section acts as an outer shell.
Green Roof Ventilation	Roof	Roofing in most homes is like a second yard and can be used, but this component requires special plant cover that should be paid more attention to today.
Geothermal Ventilation	Basement Garden pit	Almost all the houses use the underground space, which is above the ground level, for the exchange and flow of wind, except for the Bakuchi house, whose underground space does not have the status of a cellar and a cooling element.
Canopy	Introverted texture Summer residence section facade element Porch and hall	In all samples with introverted design and vertical elements, shading has been done. Also, the hall and porch are constant elements of this type of design. But in the houses of Sharifian and Alaqband, these roofless halls do not have the function of shading. And there is no porch in JahanAraee's house.

Rest of Table 6.

Passive heating energy	spaces of Kashan houses	Sample of Kashan houses
Outer Shell Wall	The double shell of the domed roofs	Bani Kazemi, Hosseini, Abbasian, Tahami, Ameri, Isfahanian houses are very thick and the multi-layered domed roof of the summer residence section acts as an outer shell.
The Central Yard	Central yard and outdoor space	Available in all samples Al-Yasin and Tabatabai houses with two separate yards Houses of Bani Kazemi, Abbasian, and Alaghebandan with numerous backyards
Cooling Evaporation	Yard and garden pit Springhouse	In all samples, the presence of the central yard and vegetation creates evaporative cooling, but in some garden pits and Springhouse, this issue is strengthened.

Table 7. Passive Heating Energy Explanation InKashan City. Source: Authors.

Passive heating energy solutions		
Picture	**Designing methods**	**Elements**
	Southside windows.	Sunny window
	The building's upper openings with limited widths provide agreat deal of light and desirable warmth to the environment in cold weather.	Ceiling Skylights
	Terraces on the south and southwest sides that are exposed to direct sunlight with moving glass that closes in the cold season and traps energy.	The Solar Room
	The wall of the solar room, which is mostly used in winter, and the vents that open at night and transfer stored heat to the living room or other rooms.	Trombe Wall
	The dark color on the trombewall can act as athermal mass in cold seasons.	Thermal Mass

Endnote

*This article is taken from "Parasto Jafari" master's thesis entitled "Design of a climate-friendly residential complex with emphasis on utilizationFrom passive energies" that was done under the guidance of Dr. Ali Yaran in 2021 in the Faculty of Art and Architecture of Iran University of Science and Culture.1. Is a traditional element of vernacular Persian architecture] The word comes from "panj" (five) and "Dar" (window or door) , meaning "five windowed room".

2. In the winter residential section, there is a cross-shaped space called the ShekamDarideh

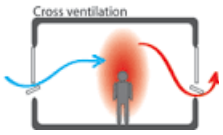
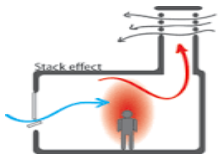
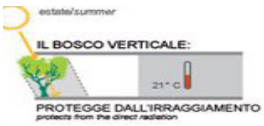
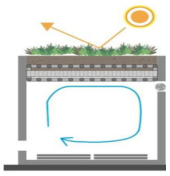
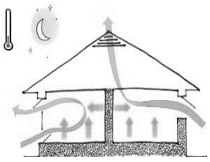
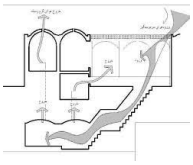
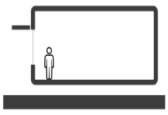
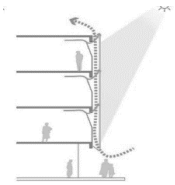
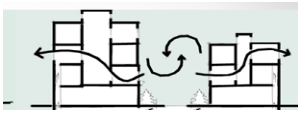
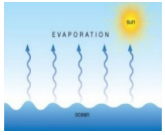
3.A structure to convert a square into an octagon for the dome. It is a protrusion of the corner inside the building, with the help of which the quadrilateral sections can be turned into 8, 16, 32, and finally into a circle.

4. Horno in traditional Iranian architecture is called skylight.

5. Korsi is the name of a room used in cold seasons. To keep this place warm, only a few windows are used.

6. It is a summer space and is usually octagonal in shape which directed the wind to this space, so it was a suitable place for hot summer days, which was also called summer residence section. Another feature of this space is its efficient communication with other spaces in the building.

Table 8. Description of passive heating energy in Kashan. Source: Authors.

Passive cooling energy solutions		
Picture	**Designing methods**	**Elements**
	Openings in the opposite direction help the air to circulation. One of the openings should be in the southwest and west direction.	Cross ventilation
	Using windcatcherwhere the openings are on the east and northeast side in the direction of the prevailing wind in the summer and it ends in a small pool in underground space and placed around the windcatchers.	Chimney ventilation
	Use of the garden pit in the yard with at least 1.5 meters below the floor of the passages. Use of green facade in buildings and irrigation with rain system. Ponds around the yard and spaces under the windcatcher for airflow.	Ventilation with water and plants
	The presence of more green space helps to cool the environment. The green space of the roof, in addition to softening the air due to evaporative cooling, causes shading so that the upper floors also have cooler air.	Green roof ventilation
	Uses suitable materials and heat mass to store the heat of the day and release it at night	Night ventilation
	The use of geothermal energy that has a good thermal comfort in desert areas by going to the heart of the earth, and by using natural elements such as water, it is possible to cool the space.	Geothermal ventilation
	Existence of awnings with 45degrees angle for openings and entrances.	Canopy
	Movable shells for south and west windows that are closed in the cold season and receive energy but control the amount of radiation in the warm season.	Exterior shell
	The central yard and atrium are used by the surrounding spaces due to shading. The central yard and atrium create air blinds for better wind rotation.	Central yard
	Based on the evaporations that take place they cool the space. The higher the water levels and vegetation, the better this component works.	Evaporative cooling

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HOW TO CITE THIS ARTICLE

Yaran, A. & Jafari, P. (2022). Analysis of the Role of Passive Energy In the Evaluation of Kashan Houses. *MANZAR*, 14(59), 38-53.

DOI: 10.22034/MANZAR.2022.304882.2150

URL: http://www.manzar-sj.com/article_149839_en.html