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## Sustainability, architectural topology and green building evaluations of Kashan-Iran as a hot-arid region

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### Abstract

Although Green Building is one of the familiar subjects all over the world, it is a recently known field in Iran. This subject has been developed to expand the communications between domestic architecture and foresight in order to protect the environmental and climatic problems. This work generates a detailed comparison between modern and traditional housings by considering sustainability in energy and resource consumptions, architectural topology and green building evaluations in Kashan as a hot-arid region of Iran. The investigation shows results in several design-related methods which are suitable to contribute as efficient use of energy and domestic resources. Finally, this work puts forward a set of recommendation to enhance the sustainability of future Kashan buildings.

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*Keywords:* Green Building; Sustainability; energy-efficiency; traditional building; Hot-arid region

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### 1. Introduction

Green building (GB) is part of the concept of promoting sustainability [1]. It Should be understood: in the full life cycle of buildings, to maximize conservation of resources (energy, land, water and materials), protect the environment and reduce pollution, provide people with healthy, appropriate and efficient use the space, and natural harmony of the building [2]. The success of a GB depends on the quality and

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efficiency of the installed green systems. If the building lacks these essential features, it will neither accomplish the environmental goals nor generate the estimated benefits. Thus, the market requires a common way to differentiate GBs from traditional buildings through the use of standard, transparent, objective, and verifiable measures of green, which assure that the minimum green requirements have been reached. Because of a high level of economic growth and increasing population in developing countries such as Iran it is necessary to experience a substructure expansion with respect to traditional residential building style. Many years ago, although there was not enough technology in order to provide welfare for inhabitants as much as recent years, Iran had powerful architects who did not have academic education, and also effective architecture, especially in hot-arid regions. However, when compared to current buildings, although the location of the buildings is equal, but the designs are changed. Unfortunately, with regard to current buildings in Kashan the issue of energy and resources efficient throughout a building's life-cycle is not given serious consideration. In addition, Kashan is one of the driest regions in Iran and is facing serious problems relating to water demand. In order to achieve this goal, Iranian architects should make a building in which water and energy consumption are minimized and pay more attention to climate to make a sustainable and environmentally friendly design. The paper firstly provides an overview of traditional status of Kashan city and building in terms of sustainability. Next, depictions are given of methodology adopted in ancient sustainable houses, which were selected as a case study for the purpose of this research. And estimation of energy and water use within this building. Finally, recommendations to enhance the sustainability level within Kashan buildings are set given, see Fig 1

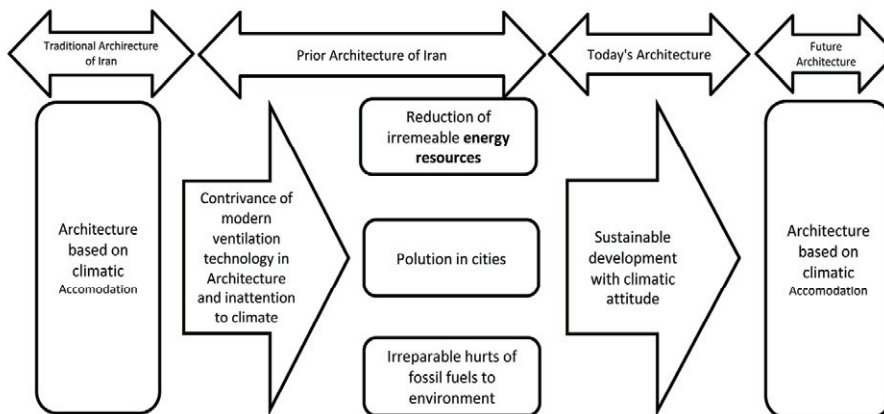


Fig. 1. Gradual process of energy consumption in Kashan Architecture.

## 2. sustainable statue in Iran-Kashan sector

A green building, also known as a sustainable building, is a structure that is designed, built, renovated, operated, or reused in an ecological and resource-efficient manner. Green buildings are designed to meet certain objectives such as protecting occupant health; improving employee productivity; using energy, water, and other resources more efficiently; and reducing the overall impact to the environment. According to the fact that, in recent years there are concern about environmental and energy resources, there is interest in planning and designing with respect to the concept of Green Building. Green design does not only make a positive impact on public health and the environment, it also reduces operating costs, enhances building and organizational marketability, increases occupant productivity, and helps create a

sustainable community [4]. Green building is respected to notion of climatic and social-responsive places. This places an emphasis upon natural energy sources and systems with the aim of achieving building comfort through interactions between the dynamic conditions of the building's environment. For example, the placement of a window in a sustainable building is of the greatest importance as it could provide effective natural light, comfort cooling and ventilation [5]. These factors are important in Kashan due to the fact that their houses are designed with attitude in which they don't have external design as much as other climate. Meanwhile, they emphasize on central courtyard and natural ventilation. Approximately, all of ancient buildings in Kashan have simple urban facade without special external decoration and pay more attention in saving energies indoor beside focus on internal elevation. They heed more in practical and maintain energy resources more than external design. Unfortunately, this sort of designs are absent in current buildings, which are heavily depended on air conditioning that consumes great amount of energy such as electricity. As a result of these kinds of incompatible designs and also rapid population growth and improvement in urbanism, not only future buildings are not prosperous but it also comprises wasting more than half of the energy demand.

Since modern materials have been entered to the construction the design of modern houses in Kashan is no longer based on the fundamental laws of vernacular architecture. Generally speaking, vernacular architecture tends to emphasize the utilization of local building resources, as well as the use of passive and low-energy strategies that could lead to reducing the need for both air conditioning and lighting requirements [6]. In addition, despite the abundant availability of renewable energy sources, the use of sustainable energy technologies, such as solar photovoltaic (PV), is exceptionally rare in the oil-rich country [7, 8] such as Iran. It should be noted that Iran is the oil rich country and there is a lot of potential of renewable energy resources, unfortunately use the energy-efficient technologies are unusual. Last, there are no regulations, or compulsory building codes, that incorporate the principles of sustainable architecture, in the country. It has been argued by many scholars that setting a coherent set of these codes and standards is one of the most important and cost-effective ways to promote the widespread of sustainable practices, especially with regard to reducing household energy and water consumption [9].

Following the energy crises of the 1970s, such building codes have been widely adopted in developed nations, and more recently in developing countries of Argentina, China and Taiwan. It appears, however, that the sustainable building regulations in some of the countries of the European Union are amongst the most stringent ones. A review of such national codes and building regulations, which is beyond the scope of this current paper, is plentiful in the literature [10]. With regard to water issue, It located at the end of mountains and the beginning of desert, Kashan suffers from any river or lake around it, which makes this city one of the driest cities in Iran. For instance, in ancient Kashan due to severe demand of water, farmers made the prosperous method of digging jug underground and be using the external moisture to farm.

### 3. Methodology

This retrospective study is mainly concerned with assessing the current and potential improvements in terms of energy and water consumption within houses in Kashan. A typical ancient mansion was selected as a case study for this research and the concepts of new residential design, which is based on the state-of-the-art building practical design with Green Building vision recommended. As far as ecology and make use of vernacular materials concern for achieving an environmentally friendly design, the cost-effectiveness studied was aim to proceed. The new designs should be based on the ancient notion and considers of both solar gains through windows, as well as heat conduction and convection between different temperatures during days and nights. This paper is also dealt with the direction and formation characteristics of buildings with regard to the material and kind of energy resources were used and studied within the neighbors. The study was provided an estimation of these building and also energy and water

consumption, and its associated CO<sub>2</sub> production levels, and assessed in order to suggest the potential improvements following both the application of a range of energy efficiency measures. Finally, the paper puts forward a set of recommendation, both to maintain the ancient methods and some details to improve the sustainability of future Kashan.

#### 4. The case study

This study was done on selected buildings located in city of Kashan as a tourist attractive place considering it as a gateway between Tehran (current capital of Iran) and Isfahan (capital of Iran in 16th century). It was at the end of mountains and at the beginning of desert (latitude  $33^{\circ}59'E$  and longitude  $51^{\circ}27' N$ ), See Fig 2.

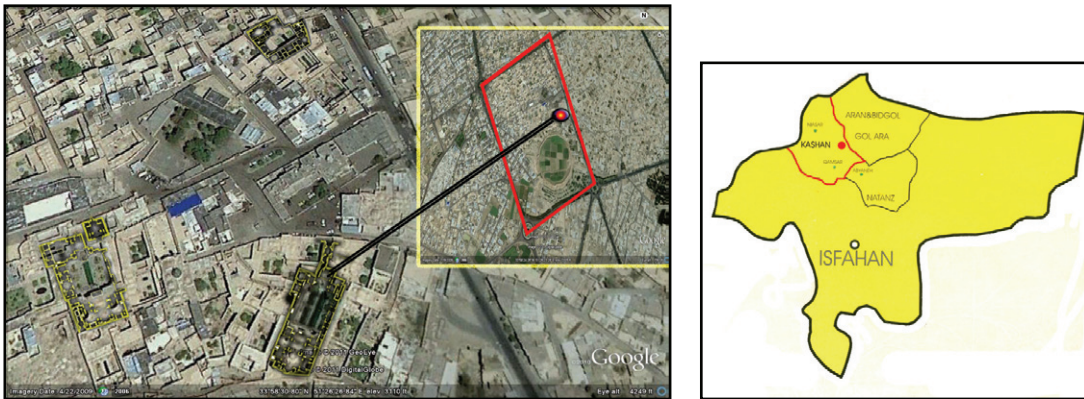


Fig. 2. Location of Kashan and aerial view of case study and its urban context. (source: Google Earth)

The number of study mansions is more than 600 and all of them have been constructed in 14 centuries. Some of the important mansions are located in SoltanMirahmad region as the best historical mansions of Iran. Their unique architectural reflections were fully in conformity with Iranian culture and environment. These mansions have similar models about their courtyards, which are situated in underground. It means that they dug the ground and constructed the building several floors under ground level. It was one of the contrivances, which was used against the severe hot weather in summer days and also protect against the Desert winds. Moreover, it made easy to use the water from aqueducts, which passed from the underground. Finally, the soils from the digging were used for constructing the building. When conducting on analysis on these contrivances and energy use and/or water consumption of these buildings, it is useful to consider the climatic conditions that affect it. The climate in Kashan during summer is characterized by fierce heat, which tends to be unbearable towards the end of the summer season. During winter, it is cold and sometimes. It is rainy in November and December. Detailed information on temperatures and rather high solar radiation levels in Kashan are given in Table1.

The case study is named Brujerdi-ha Mansion where it is one of the most famous houses of Kashan, which today houses are the Cultural Heritage Office of Kashan city. The edifice compromises of two stories and one Cellar (basement). Fig 3 illustrates the floor plans, section and elevation of the case study.

Table 1. Kashan climate

Climate Components	Rate
Average Max. temperature in summer	40-50c°
Average Min. temperature in Winter	0-5c°
Altitude	955
Longitude	51° 27'
Latitude	33° 50'
Average rainfall	142.2mm
Max. daily rainfall	31mm
Average number of frost days	48.8
Average comparative humidity	44.81%
Average air temperature	19.29c°

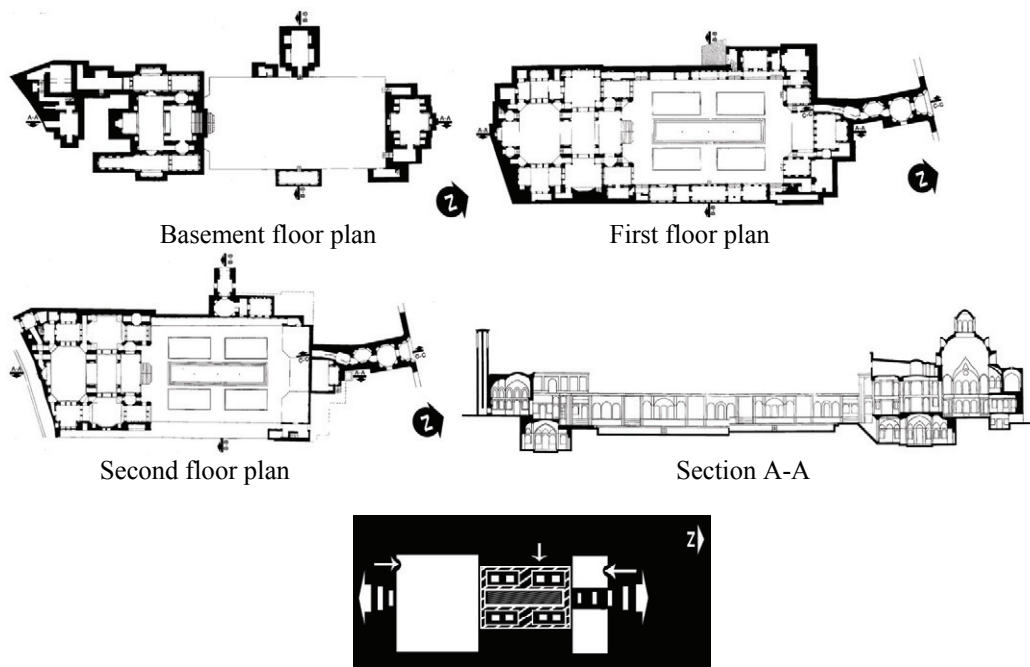


Fig. 3. Floor plans and section of the case study.

In order to mitigate the impact of buildings along their life cycle, Green Building (GB) has emerged as a new building philosophy, encouraging the use of more environmentally friendly materials, the implementation of techniques to save resources and reduce waste consumption, and the improvement of indoor environmental quality, among others [11, 12]. Moreover, the construction elements used in the mansions were domestic (vernacular) which were adopted in the country those years. These types of material don't have any harmful effect on environment, because of the fact that when buildings are

demolished, there is hope to quick resumption of material to the nature unlike current building. For instance, Sialk hills are the good example of sustainable building, which was made about 7000 years ago. It can be named as a sustainable complex. Although it is demolishing these days, it never pollute the environment due to the using the proper material. Unlike, if the current buildings are demolished, it can provide a lot of pollution. It can be named as a sustainable complex. Although it is demolishing these days, it never pollute the environment due to the using the proper material. Unlike, if the current buildings are demolished, it can provide a lot of pollution.

## 5. The case study interpretation

Iranian architecture that first emerged in Plateau of Iran and later in other territories influenced by Iranian culture, similar to all other architecture that has roots in native culture, takes the subject of climate into consideration, valuable examples of this architecture, up to the 14 century, still exist [13]. It was revealed the spaces that were formed exclusively on the basis of climate specifications and where the issue of climate has been the main concern. Most of the names of these spaces have been derived from climatic specifications, such as the “Korsi” room (a small coal heated table covered by quilts and blankets), the winter room, cellar and, etc.

### 5.1. In terms of Energy

When conducting an analysis on the energy use and/or water consumption of Brujerdi-ha mansion and other similar mansions in kashan it is useful to consider summary of different kinds of properties in Iranian ancient buildings which have significant affect on make a green building and environmentally friendly design. Central courtyard is symbol of settlement between human and environment which is used in the case study. Although these courtyards are the climatic answer to the open space of the house, where creating a space with trees and decorative pool, safe from the warm winds the sweltering sunshine was the best reason for building a courtyard in the center of the house, and this type of building can be found in other places with similar climates. Which it shows the settlement between human and environment, unfortunately, in current design; sophisticated ventilations are the main reason of wasting energy. Evaluation of Sunken yard or “Baghchal” in terms of energy use in the case study which was built in the middle of the central courtyard and one level underground. Examples of this type of space are observable in very dry desert climate such as Kashan. In addition providing the necessary dirt for constructing adobes buildings, the sunken courtyard also provided access to the Qanat water (a system of subterranean channels). In this method no pollution treated the water on its channel, Due to the location of sewage and water channel are separate from each other.

Roof and ventilation property In Iranian architecture which is part of the living space and in addition to its complex and picturesque solids, it is used as a yard as well. So, instead of using ventilation, by making the desirable location could live easily in such a fierce heat.

The winter room and make use of irradiation energy In winter which refers to all the space that was built in the north wing of the courtyard, in order to benefit the most from the tilted winter sunshine. The main section of the winter room consists of a set of space including “Sedari” (a room with three doors), “Panjdari” (a room with five doors), and “Shekamdaride”.

The summer room a structure in interaction with sun which is similar to the winter room except that it is built in the south wing of the yard to be protected from direct summer sunshine. Usually a semi-open space with the hall was built on its main axis.

Baharkhab(terrace) is an arena for human compatibility with sun that is similar to the loggia, this roofless space was built alongside the yard and above the first floor. It was the place where people slept during the summer months.

Korsi room and profound effect on energy-efficiency that was a part of the winter room and was usually built in the corner of the room which had the least number of doors and windows towards a yard, so that the residence could warm up the room in the winters by closing the doors and the windows. The Korsi pit was located in middle of the Korsi room and size of this room depended on the size of the Korsi, since the walls were also used as a backrest. All the houses in cold and mountainous climates included this space.

### *5.2. In terms of water consumption and environmental design*

Understanding the current water consumption is the first step in improving water efficiency within the building [15] In follow assessed different types of properties which have significant impact on water consumption and environment of buildings in Iranian ancient Architecture which are used in the case study.

Cellar is an artifact kip in interaction between human and water which is used in ancient buildings of hot-arid region of Iran. Although sometimes the main hall of the summer room was called the “Hozkhane, Distinctly this was the name of the cellar built under the summer room, that similar to a veranda had a semi-open space often a decorative pool as well. By conducting the air of central yard to the cellar and pass away from the water pool in underground can make a fresh air in cellar space.

Badgir simian technology with environment in ventilation is any room in the first floor of the summer room that uses the wind is called the Badgir. The decorations of this space are similar to that of the veranda.

Sarabestan decreasing thermal exchanging in desert that was a small garden built alongside the house and had a positive effect on the climate of the house.










## **6. Rendering the analytics**

From the above mentioned analysis the following is summary of recommendation in order to make a Green Building and Sustainable sector within Kashan, in terms of energy and water consumption. Few modifications underneath have a significant impact in terms of energy efficiency as will illustrated later in this section. With regard to united insulation improvement, the air gaps in the external walls can be replaced by foam insulation. as a result, the U-value (i.e. thermal transmittance) for external walls will decreased saliently. Moreover, an additional layer of polyurethane insulation was added to the roof; consequently, the U-value for the building’s roof will decrease. It should be noted here that since the U-values measure the rate of heat transfer through a building element, reducing the U-values should lead to energy savings through lower solar cooling loads [14]. Another important property for improving energy efficiency is thermal inertia (or thermal mass), which represents the capacity of a material to store heat. High thermal inertia walls, whilst not necessarily have good insulation properties, have the ability to provide better indoor comfort through delaying and reducing the impact of outdoor temperature changes on conditioned indoor environments. In other words, walls that are constructed from materials with high thermal inertia will prevent heat to enter indoor by storing it during the day and releasing it during the night when the temperature cools down. It is widely accepted that the use of high thermal inertia walls, with excellent thermal insulation, in buildings would usually result in a reduction of energy requirements

for both cooling and heating [15]. If a building has the characteristic which above mentioned, it will have a reduction in energy consumption.



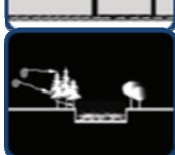
6.1. In term of Energy

Due to there is high level of economic growth and increasing population. There are not adequate available free lands to housing. Afterward, it is essential to make use of efficient-energy in designing.


When designing new houses in order to improve the energy performance of building, follow the fundamental laws of climate-responsive design, as well as vernacular materials.	
In order to achieving both low U-value and high thermal inertia of construction, use sufficient insulations with good properties in wall and roofs.	
Use energy-efficient appliances and lighting equipment (e.g. use of fluorescent lights instead of incandescent lamps).Based on this study’s findings, it is recommended that at least 70% of the building’s lighting should be of the fluorescent type.	
Not only there is high level of solar irradiation in Kashan but also the largely amount of available inutile area on the roof of the building, to use solar PV panels could be fitted in order to supply amount of household electricity and heating.	
Not only using the rough and translucent surfaces to prevent reflection of irradiation on external walls but also using dark colors to absorbing thermal energy of the environment during the days and releasing it during the nigts which it has beneficial effect on practical design.	
By recognizing the useful winds through the environment which can be used in optimum usage on formation and direction of a building.	
Using double glazed windows and fit external shading devices in order to shade building and environment. Position of these devices not only is important to reduce solar gain but also put to use natural light.	
The use of free cooling to reduce electric load of air conditioning system by the aim of wind-fans in Badgirs and integrate with other zero-carbon technology such as pumping.	
To speed the wind input this can be simply created track in through the Badgir channel, that it make happens turning wind rapidly and better quality in whole of rooms.	

6.2. In terms of Water consumption and Environmental issue

Water conservation or management strategies include measures that optimize the consumption of potable water and the reuse of non-potable water around the home [16].There are a number of different ways to conserve water resources and usage of vegetation within such destitute city like Kashan. It is important to recognize here that the rational use of water and other natural resources is embedded within Islamic principles [17].

By using water scattering through the Bedgirs due to refining and refreshing the winds which are caught.	
According to the fact that water in Kashan is supplied from mountains and is reached to building by aqueducts it would be essential to protect the water from likely pollution on the way, for this matter, using proper pipes is useful remedy.	
	



Due to the hot-arid weather of Kashan, there are expectancy of water vaporization. So, make use of profound pool and protect the water by covering its surface during the sunny days, and also use numbers of trees around the pool to make a shadow upon the water.	
Be using vegetation as a small croft to refine environmental by inspiration of designing and planning of Iranian garden (chahar bagh), according to sustainable architecture thinking, it is worth nothing this space was built in central plateau of Iran which is called “Sardabestan”.	

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