Int. J. Urban Manage Energy Sustainability, 4(1): 130-146, 2023

Journal of Urban Management and Energy Sustainability (JUMES)

Homepage: http://www.ijumes.com

ORIGINAL RESEARCH PAPER

Investigation of energy consumption of traditional houses in approach to sustainable architecture (Case Study: Ardebil, Sanandaj, Hamedan and Tabriz cities of Iran)

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ARTICLE INFO

Article History:
Received 2022-10-28
Revised 2023-02-01
Accepted 2023-3-03

Keywords:
Diverse regions
Energy consumption
Iran
traditional houses
urbanization process

DOI: 10.22034/JUMES.2023.1996326.1124

ABSTRACT

The rapid growth of the urbanization process followed by the increase in the population of cities has had various consequences and caused many challenges in energy consumption. Residential construction like houses plays a significant role in resource and energy matters. the native architecture of different regions of Iran talks about the recognition of the environmental characteristics, especially the climate of the diverse regions is related to sustainability subjects. The methodology of research is descriptive-analytical, which has a development purpose. By examining the existing experiences, it extracts physical components that influence the climatic performance of traditional houses in cold climates. In the next step, using the obtained indicators, the study and classification of traditional houses in four cities in the cold climate of northwest Iran will be done based on the available sources and information. In the next step, examples of traditional houses from several cold climate cities will be analyzed by Energy Plus and Open studio software up to the survey data. and results show the main issue in cold climates is to provide thermal comfort in the indoor space in winter, and for this purpose, traditional houses try to use sunlight, avoid adverse wind flow in winter, and reduce heat exchange through the external walls of the building. According to the physical system of traditional cold climate buildings, the use of passive solar methods, especially the thermal mass and the thickness of the walls, is of considerable importance in the design of these buildings.

Running Title: energy consumption of traditional houses in approach to sustainable architecture

NUMBER OF REFERENCES
55

NUMBER OF FIGURES
08

NUMBER OF TABLES
0

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1. Introduction

The rapid growth of the urbanization process followed by the increase in the population of cities has had various consequences. In the meantime, according to estimates, urban areas consume 60 to 80 percent of global energy and release more than 70 percent of greenhouse gases (IEA, 2021). The amount of energy consumption in Iran is about 1.8 times the average world consumption in similar conditions and since about 70% of the buildings have residential use, it seems necessary to check the amount of energy consumption in this sector (Energy Balance Sheet 2016, 2018). Since residential construction accounts for a large percentage of total construction activity, it is obvious that houses play a significant role in resource and energy consumption. Also, the role of the residential sector in the emission of greenhouse gases, as the third contributing factor after the transport and industry sector in Iran, makes the importance of paying attention to the relationship between residential buildings and the climate even more (IEA, 2021). The concept of sustainability is a word that best describes the paths that must be taken in this way. The concept of sustainability concerning architecture and climate forms new concepts such as sustainable architecture and environmental sustainability. Likewise, the contrast between architecture and climate leads to the emergence of an architectural approach compatible with climate. A brief look at the native architecture of different regions of Iran talks about the recognition of environmental characteristics, especially the climate of the diverse regions of Iran. Sustainable architecture is one of the most controversial topics of contemporary architecture. Sustainable architecture, its main concern is related to the environmental issue, it takes advantage of all the previous trends that have paid attention to the issue of reducing the use of materials and energy, with a little study, we find out that many of our traditional buildings are relatively sustainable architecture, because factors Like the culture and authenticity of the climate, the materials of the region and proper functional relationships were influential in these buildings, but these buildings are relatively stable and no building is 100% stable because our needs of architectural spaces change over time, that's why we in every We can have a style of architecture that is relatively sustainable, as long as it is close to the indicators of sustainable architecture (Talar Peshti, 2018). Therefore, a look at the texture of traditional Iranian cities, including their cold regions, is worthy of attention. Contrary to the climatic and environmental conditions, cities in the cold regions of Iran have provided a harsh environment that matches the comfort of the residents and responds to the future and present needs of human life (Alavinejad, 2010). Sustainability is a concept that is mostly used as a measure of the value of a method and is a repeatable process. With this attitude, understanding the principles and repeatable values of native architecture is very valuable. Certainly, traditional architecture responds to the needs of its time and repeats It is pointless.

1.1. Sustainable Architecture

Sustainable architecture is a method in design it deals with reducing the consumption of non-renewable resources and optimizing the consumption of renewable resources and states that what we need for survival can be obtained from the environment. Sustainable development means providing solutions against type patterns is a physical, social, and economic development that can prevent problems such as the destruction of natural resources, the destruction of biological systems, global pollution, climate change, excessive population growth, injustice, and the lowering of the quality of human life (Azerbaijani, 2017). Sustainable architecture is a broad term that describes techniques in architectural design that are in line with environmental attitudes and formed with the idea of respecting nature. This architecture is not a new trend, because, in many ancient civilizations and traditional architectures, including the traditional architecture of Iran, it existed in a fundamental way, which today is due to the negative consequences of the industrial world, such as the increasing pollution of the air and the environment, and the reduction of natural resources. And the energy crisis has become one of the most important concerns of people today (Rastegar, 2010). The traditional architecture of Iran has strong and rich support from various aspects of the sustainability of Iranian art and culture, and it shows a special and valuable contribution from this art and culture. Examining these features can serve to design and popularize the living environment. be placed today Residential needs of people in cities and especially traditional cities today are met independently without identifying its side effects, especially on the environment (Pakzad, 2006). The lack of attention to the stable foundations of traditional Iranian architecture and the various factors affecting it is dilapidated and it has left an unstable urban construction. Undoubtedly, the advancement of technology is a necessity that cannot be ignored, but this factor should not jeopardize our values, especially in the field of environmental sustainability. In this regard, the forgotten solutions in the design of a sustainable residential environment should be identified and by updating them according to the available technologies, they should be used in the design of sustainable buildings (Melotparast, 2018). Some other theoreticians consider sustainable architecture as a kind of popular design, and therefore, in their opinion, the quality of the interior spaces of the building is particularly important. hesitation the desired quality cannot be provided without taking into account the nature of the proper lighting of the spaces and air conditioning, in addition, the stability and longevity must also be considered. Achieving such conditions is done by using efficient management and using the latest technologies. These people consider achieving high-quality standards of security and comfort, which provide human health, as one of the most important goals of sustainable architecture. This point is emphasized that using the experiences of the past in the improvement and quality of architecture will be the way to achieve sustainable design. In other words, according to these theorists, improving the quality of architecture in sustainable design is done in the direction of achieving one goal, and that is comfort. An important point that is taken into consideration in this type of architecture is that all the factors involved in comfort are related to each other and considered as a single system, what is included under comfort in its general sense are peace, security, safety, and Health in general, despite these theorists of sustainable design, shows a kind of attitude towards an architecture that points to several basic points - 1. Quality orientation - 2. Attention to the future - 3. Attention to the environment (Meletparast, 2018).

1.2. Principles of sustainable architecture and climate features

To achieve sustainable development, the following strategies and principles must be followed; Using and sustaining renewable resources (sun and wind), optimizing the use of resources and minimizing the consumption of natural resources to a proportion that is less than their natural growth, minimal production of waste and pollution that can be absorbed in the scale and capacity of the environment It is local to global, meeting the needs of people and society and creating a healthy environment for future generations (Singri, 2016). One of the characteristics of this climate is the extreme heat of the valleys in summer and extreme cold in winter. The amount and intensity of sunlight in this area are high in summer and very low in winter. The heavy snowfall in the north and northwest parts of the country and the great temperature difference between night and day are other features of this climate. In the high areas, the atmosphere is thinner and the water vapor in it is less and its thermal preservation performance is weaker. Due to the extreme coldness of the air in most of the year in these areas, it is essential to make maximum use of radiation, the sun, to take advantage of the daily fluctuations, to maintain the temperature, and to prevent the cold winter wind in residential environments (Shaghaghi, Mofidi Shamrini, 2017).

1.3. Climatic characteristics of traditional houses

Traditional houses in these areas were built in the form of a central courtyard like in the central areas of Iran. Therefore, the rooms located on the north side of the yard are bigger and wider than the other parts, and the hall or the main living room of the house is located on the same side. be This is due to the use of direct radiation and heat from the sun in the winter, and because the summer season is mostly short and the air temperature is relatively moderate, the south side of the building is used less. Were used. These houses often have a basement with a short roof under the winter area, which is suitable for the inhabitants of the house in the summer due to their relatively cool weather. Since the weather is cold or very cold most of the year, most of the daily activities take place inside the rooms. For this reason, the dimensions of the yards in these areas are smaller than in the central plateau areas of Iran, and the depth of the porches is much less than in the southern areas of the country. Is. In most of the cities of these regions, the floor of the courtyard of the buildings is 1 to 1.5 meters lower than the sidewalk so that the water flowing in the streams and rivers can be carried to the garden in the garden or the cistern located in the basement. It also goes inside the building. Volumes such as cubes and rectangular cubes, which have a small ratio of their outer surface to the volume of the building's interior, are suitable for these areas. In recent years, contrary to the past, when flat roofs were used, the use of gable roofs have become popular, but there are still few roofs in the villages. The buildings, it is flat and covered with wooden beams and thatch, which is mainly due to the financial weakness of the villagers. To keep the cattle in the villages, if the house has two floors, the cattle are usually kept on the lower floor and the second floor is residential. The space of the barn and the residential environment is reduced by the cold outside and the roof between the two floors is heated from both sides, which is useful for both floors. In general, the best building form is the form that loses the least amount of caloric heat in the winter and receives the least amount of heat from the sun and the surrounding environment in the summer, so the square plan is considered the best form because, despite the largest volume, it has the least external surface. Yes, of course, this issue applies to old buildings that usually do not have large windows, and for this reason, the very low penetration of sunlight into them can be ignored. But it is not true for today's buildings that have large glass parts, due to the extreme cold of these areas in winter, open forms or forms whose north-south side is longer than their east-west side are not suitable, and it is better to have a compact building form and a square plan. be Two-story buildings whose form is similar to a cube are the best type of building in terms of indoor air heat control in winter. In general, closed forms with buildings connected back-to-back in the direction of the north-south axis are preferred. In these areas, the buildings should be high (Amidipour, 2012).

1.4. Native features and building form

Using dense and compact plans, minimizing the external surface against the covered volume, buildings with central and introverted courtyards, using materials with good thermal insulation and capacity, low height of rooms, and choosing flat roofs to keep snow on them. In the form of thermal insulation, minimizing the amount of internal air exchange and natural ventilation and thus preventing the formation of heat inside and outside the building, small openings in relatively thick walls, porches, and small yards (Qabadian, 2019) In cold areas, the main goal is to maintain heat inside the building, and the main factor, in this case, is the thermal resistance of the side walls of the building, so in these areas, the side walls of the building must have a suitable thermal resistance to prevent heat loss inside the building. On the other hand, the materials used for traditional construction in mountainous regions, like other climatic regions, are what is available, so the stone is often used for the walls, and wood and straw are used for covering the floors and roofs. If there is enough clay, clay, and brick walls are also built. In today's buildings, using modern technology and mechanical facilities, an attempt has been made to deal with these climatic factors, but in the past, this equipment did not exist, and traditional builders had to use local tools and materials to deal with the unfavorable and erosive factors of nature. And to provide comfortable conditions in urban areas and inside buildings, the use of climate factors has always been a fundamental issue in design and implementation. In general, it can be said that our traditional buildings, contrary to most modern buildings, were not in conflict with natural conditions, but with proper use of these conditions, they were located in a logical coexistence and productivity in the womb of nature. As a general principle, it can be said that the orientation of the buildings is generally facing south, between 15 degrees of the southeast and 10 degrees of the southwest, so that the main spaces are located on the north front, such as the keel and living rooms, facing south. Placed. Only in the house of Haj Sheikh, the main front of the building is located on the west side, which has a suitable orientation (Qabadian, 2010).

2. Materials and Methods

2.1. The most important spaces of Iranian architecture in traditional houses

Ivan is one of the architectural spaces of Iran, which is diverse in terms of form, dimensions, and location and has many functions. The concept of porch and portico throughout the history of Islam has had deep implications. The porch shows the possibilities of determining and writing the space, and it is the transition space between earthly and temporal factors. From the metaphysical point of view, the porch itself can be considered as the soul, which is between the garden or the yard as the soul and the room as the body (Ardalan, 1382) *Sirmi* according to *Diodorus* Siculus, the Greek historian who visited the porch in the 7th century Iranian houses are built around the yard and the porch was also one of the elements of the yard (Sarmi, 2016). In the architecture of traditional houses, three spatial groups, open, closed, and semi-open, are not built separately, but each gives meaning to the other, in the sense that the spaces gradually lose their degree of openness and closure in such a way that one dimension The other becomes This continuity and combination of spaces makes consecutive spaces to be used as an extension of each other, and for example, a porch is an extension of five doors and five doors are an extension of a porch. On the other hand, the interference of the combination of vertical and horizontal layers around the courtyard, sequence, and continuity, and the combination of open, closed, and covered groups have eliminated the spatial blockage, and we are faced with fluidity and buoyancy inside historical houses (Haeri, 2008).

The garden pit is a space surrounded by underground rooms, and such a combination creates cool spaces in the underground rooms and makes it possible to use the airflow correctly and there is no need for artificial cooling devices. and as a result, energy consumption will decrease (Khodabakhshi, 2010). The yard is one of the most valuable places in organizing the design of the houses, thus the enclosed spaces of the central yard houses have the maximum size. In these houses, all the sides around the yard are built to create various internal environments to receive light and heat from the sun. Depending on the amount of sunlight, different sides of the yard can be used in different seasons. Usually, the southern parts are facing the sun. Being and having the maximum heat of the sun in winter. The northern parts are also called summer residents because the residents move to the northern part in the summer. In other words, the residents of this house, their living space in harmony with the regional changes following the use of the place. Seasons change (Rastegar, 2018). Atmospheric factors and temperature fluctuations have very little effect on underground buildings and they continuously protect the building from these changes like a barrier, and the earth's crust as a thick thermal insulator prevents heat from being transferred into the ground (Qabadian, 2010). Among the potential physical benefits of the earth, we can mention its thermal benefits. The use of land has led to the preservation of energy resources and provides the possibility of energy storage. Conditions that can be considered environmental conditions are influenced by different factors such as the intensity of radiation, temperature, humidity, wind, covering the body, stopping its activity... the contract of the range of feeling. Thermal comfort means a condition in which a person can feel comfortable while resting in the open air. Environmental architecture is to focus on the building's ability to combine environmental and atmospheric factors and transform them into spatial qualities, comfort, and form. Environmental sustainability in the examined samples is examined in the field of connection with the nature of the climatic design. From the moment an architectural work is born, from the moment it takes its first steps to become physical, it mixes with the earth, it receives water from the earth, and after changing its appearance and physical-chemical content, it gives it back to a different extent. He turns to the breeze and turns his back to the winds that bother him. In mixing with nature, it is associated with both obeying nature and benefiting from it (Flamaki, 2015). In the seventies, following the increasing global attention to environmental issues and its confrontation with economic issues, discussions on sustainable development were raised, one of which was sustainable architecture. In the meantime, the approach of architecture compatible with the climate, which had long-standing roots in eco-oriented housing, was raised as one of the key topics of sustainable architecture. By using passive strategies such as orientation and building form, vernacular architecture seeks an appropriate response to weather conditions to provide comfort to humans (Forster et al., 2014). Native types of architecture are diverse in design, form, building materials, construction methods, and structural systems; But there is a fundamental similarity in this; In terms of climate and geography, they are more compatible with the main location of their region. (Mitra and Bose, 2017) Today, the necessity of architecture compatible with the climate and its importance is not hidden from anyone. This issue has important results and effects in saving energy consumption and designing in harmony with environmental factors and nature, and it is also a step towards sustainable architecture. The house is the main means to fulfill the needs of comfort, which modifies the natural environment to approach the favorable conditions of livability and must filter, absorb or repel environmental elements according to their useful or undesirable contributions to human comfort. (Olgyay, 1963).

"The main goal of climate design is to provide comfortable living conditions with minimal and significant artificial energy input" (Gut & Ackerknecht, 1993). "Our ancestors recognized that regional compatibility is a basic principle in architecture". In a cold and mountainous climate, dealing with the cold is one of the most important design concerns, which should prevent the entry of cold into the living area as much as possible and maximize the use of the sun's thermal energy. Climate-compatible buildings must respond to both summer and winter climates. For overall annual optimization through architectural design, both heating and cooling should be considered. The heating load of a building in a cold climate is minimized in the first stage by increasing heat gain from the sun and reducing heat loss in cold periods. The cooling load is minimized by controlling solar energy through window shades and using natural cooling techniques such as blind air and evaporative cooling. Buildings for residential purposes are usually occupied during the day and night. Therefore, they should be designed for optimization for the whole period and special attention should be paid to their sleeping place and night conditions because the body is more sensitive to thermal comfort when resting (Gut & Ackerknecht, 1993).

2.2. Thermal comfort in buildings in cold climates

Considering the share of energy consumption in residential buildings and the need for the climatic design of buildings, determining and explaining the concept of comfort conditions is very important. One of the main functions of buildings is to protect the inhabitants from outdoor weather conditions, which are often harsh and annoying. The building must provide an environment that does not harm the health of the residents and also provide suitable conditions for living and working. The temperature inside a building, even when it is not mechanically heated or cooled, is usually different from the temperature outside. The real relationship between inside and outside depends to a large extent on the architectural and structural design of the building, and with proper design of the building, the internal conditions can be controlled to meet human comfort needs (Givoni, 1998). Man strives to reach the point where the minimum expenditure of energy is required to adjust himself to his surroundings. The conditions that he succeeds in doing can be defined as the "comfort zone" in which most of his energy is released for productivity (Olgyay, 1963). Mentally, intellectually and physically are in comfortable conditions. Many researchers believe that thermal neutrality is a more accurate interpretation than thermal comfort, in such an environment, a person does not feel cold, hot, or local discomfort caused by Air drafts and cold rooms, and heterogeneous clothes (Qabadian and Faiz Mahdavi, 2019). Thermal comfort conditions can change based on different people and in terms of individual characteristics as well as environmental and geographical conditions. As it is known, people who live in cold climates have more resistance to cold than people who live in hot climates. For example, if the indoor temperature of buildings in hot areas is supposed to be 25 degrees Celsius in winter, 20 degrees is enough in cold areas, considering that each degree change in heating or cooling systems can save about 7% in consumption. becomes energy (Heidari and Ghafari Jabari, 2010) the need to form a new approach to redefine the thermal comfort temperature for cold climate regions has arisen. This approach leads to a reduction in the base temperature, and the number of winter heating temperatures in the required days, and helps to properly design and size space heating systems, thus reducing the initial costs of passive solar features. Thermal comfort is an important aspect of residential buildings because it affects the health and well-being of the occupants (Mahavi & Kumar, 1996). In the past, research has focused on non-residential buildings (Gou, Lau & Shen, 2012; Khoshbakht et al., 2018; Sun et al., 2018), and the thermal perception and comfort of occupants in residential buildings have largely been overlooked. had been taken. The importance of the influence of climate on architecture became the basis for conducting comprehensive studies and research in this field. Lukeward (1833) pioneered research in the field of mutual influence of architecture and climate in London. He is known as the first person who paid attention to the impact of urban areas on the local climate. Olgi (1984) and Oke (1987) were the first people who investigated the relationship between buildings and climate by emphasizing the interaction between buildings and microclimate.

Thompson and Perry (1997) introduced climate as one of the most important decision-making components in the process of architecture and urban planning in the activities related to residential use (Thompson & Perry, 1997). Oktay (2002) has stated the requirements of the sustainability of design according to the climate as one of the most important criteria and showed that every country has a style and structure of design called “native architecture” in such a way that this native architecture can be found in every region. It is completely different from other regions (Oktay, 2002). In Hong Kong, Sam and Chung (1997) conducted a study on the use of climatic elements in architectural design and building energy and proposed the use of climatic conditions of the design area as a potential tool to optimize energy consumption (Sam & Chung,1997). Among other studies, we can refer to the research of Prucal and Ogunsote (2002) in Nigeria, who investigated the effective climatic factors in the design of this region (Prucnal & Ogunsote, 2002). Toy et al. also studied the bioclimatic comfort conditions in each of them by dividing the climate of Erzurum city in Turkey into three rural, urban, and forest urban areas (Toy et al., 2007). Among the studies that have been conducted around cold climate architecture at the global level, we can refer to the research of Martin et al. (Martins et al., 2012). Johnson (2011) investigated the passive solar arrangements in the vernacular architecture of Northeast India concerning the variables related to the construction form and the orientation and design of the masses and offered suggestions in the field of providing optimal thermal comfort in residential spaces for different areas. (Jahansson, 2011). Oikonomouna and Bougiatiotib (2011) studied the typology of 40 houses in the city of Florina with a cold continental climate in Greece and investigated the climatic parameters inside and outside the building (Oikonomouna & Bougiatiotib, 2011).

2.3. Energy

The topic of energy is considered one of the most important and fundamental discussions in the sustainable development approach. About 70% of the existing buildings in the cities are residential, constantly facing the challenges of energy supply and controlling the consequences of its consumption, hence attention and revision in the process of production, consumption, and solutions to deal with the energy crisis and pay attention to Climate in cities is unavoidable. Since energy provides power and movement for modern life, energy conservation (less energy consumption) and energy efficiency (reduction of energy waste) can expand energy supply sources and promote economic development. Therefore, energy efficiency and the use of renewable energies are the two main pillars of sustainable energy (Daniels & Daniels, 2003). The residential sector is one of the main factors in energy consumption and greenhouse gas emissions (Green House Gases), representing 25% of the total electricity consumption in OECD countries in 2012 (Iwafune and Yagita, 2016). According to the Energy Information Administration, in the United States, most of the energy located in housing is used for space heating and electrical appliances. In Iran, the share of the household sector in energy consumption was about 31% in 2018, which has increased by about 180% from 2000 to 2018, and the amount of carbon dioxide gas produced in the household sector has increased by 1.6 times during this period. Found. Also, according to the energy balance sheet of 2016, Iran's final energy consumption per capita in agriculture, household, commercial and general sectors, transportation and industry is 3.3, 2.2, 1.5 and 1.5 times the world average, respectively. (Energy balance sheet, 2018). About 37% of the country's electrical energy consumption is used in residential buildings, of which about 60% is the building's heating and cooling sector, which is 22% of the country's total energy consumption (IEA, 2021). With rapid economic development and urbanization in the past few decades, the total urban population is expected to reach 66% of the global population by 2050, leading to greater energy demand (UN, 2014). In addition, increasing household income and improving living standards will be a serious threat to efforts to respond to climate change. The two main and basic strategies that are effective in achieving energy sustainability can be considered the use of renewable energy sources (technological dimension) and the second is optimizing the consumption of non-renewable energy (environmental dimension). Effective use of non-renewable energy refers to a set of actions and activities that lead to a reduction in dependence on and consumption of fossil energy.

2.4. Forms of energy consumption

To achieve the goal of reducing energy consumption in the city, the factors that consume energy in the city must first be identified and introduced. Steemers considers the three main pillars of energy consumption to be industry, construction and transportation (Steemers, 2003). In another definition, based on the forms of energy consumption, there are three types of energy consumption in the city, which are; Latent energy: It consists of all the energy inputs needed in the production of primary housing materials, as well as the energy used in production devices and transportation of natural resources and final goods (construction, materials, maintenance). Operational energy: operational energy for any building (residential and non-residential) includes the energy used for cooling, heating, lighting and household electrical appliances. Transportation energy: energy used through public and private vehicles (Emmauel, 1995). Every year, buildings consume approximately 48% of global energy in construction, operation, maintenance and renovation (Baum, 2007; Dixit, 2016). Energy is directly consumed in buildings as energy sources such as electricity and natural gas, while buildings also use energy sources indirectly through the use of building materials. Every building material used in a building consumes primary energy (e.g., coal) and produces energy (e.g., petrol) in its production and transportation to a construction site.

The total primary energy consumed in the construction of a building through the use of building materials, products and processes, along with transportation, administration and related services is collectively known as latent energy (Stephan & Stephan, 2016). Although operational energy appears to be greater than the total latent energy of a building's life cycle, recent research has evidence of an increasing proportion of latent energy in total life cycle energy, especially with the increasing emergence of energy-efficient buildings (Plank, 2008; Davies et al. al, 2014; Copiello, 2016). For example, Sartori and Hestens (2007) concluded that latent energy can account for 2–38% of the total life cycle energy of a typical building, while this range can be 9–46% for a low-energy building. (Sartori & Hestnes, 2007). Thormark (2007) also found that the latent energy in a low-energy house can account for almost half of the total life cycle energy (Thormark, 2007). He argued that a low-energy building consumes more materials and less energy (more electricity) than a normal building. Recently, Shadram et al. (2016) found that the contribution of latent energy can be up to 60% of the total energy consumption of the building (Shadram et al., 2016). However, most researchers are of the opinion that the ratio of latent and operational energy cannot be generalized because it depends on various factors such as location, weather and fuel source (Wen et al., 2015; Nebel et al., 2008; Karimpour et al., 2014).

2.5. Methodology

At first, this research reviews the existing literature in the three fields of study of energy, climate and traditional architecture of Iran, and by examining the existing experiences, it extracts the factors and physical components that influence the climatic performance of traditional houses in cold climates. In the next step, using the obtained indicators, the study and classification of traditional houses in four cities of the cold climate of northwest Iran (Ardebil, Tabriz, Sanandaj, and Hamedan) will be done based on the available sources and information. Finally, according to the results obtained from the review of the literature and the evaluations, solutions are presented for sustainable architecture in contemporary houses in the cold climate of Iran to optimize energy consumption. In terms of purpose, this research is applied and in terms of its nature, it is considered mixed research that uses a combination of qualitative and quantitative methods. In the first part, using qualitative research methods, and in the second part, using quantitative tools and simulation software, the characteristics of traditional houses are examined.

Data collection for zero energy houses in North America in terms of physical design, placement of spaces, type of materials and method of insulation, type, and method of using new technologies will be done in the field and the library. Also, unstructured and long-term interviews with experts will be conducted in person and online in Iran and abroad. Data collection tools are notebooks, cameras, audio recorders, and questionnaires. In the next step, examples of traditional houses from several cold-climate cities will be analyzed. Then, by collecting climate data and using energy simulation, the mentioned and contemporary houses will be compared and evaluated. In this research, the characteristics of the cold climate of northwestern Iran are considered independent variables, and the building design and energy consumption are considered dependent variables. This study is based on a series of simulations that will be done by simulation software Energy Plus version 4.9, OpenStudio version 1.3 and Radiance version 5.2 to calculate the amount of energy consumption and lighting of historic buildings in cold climate cities. It should be noted that the energy codes used in the ASHRAE 90.2 standard of 2018 for the residential part of the urban bed are taken. The purpose of these analyzes is to find architectural elements that affect energy performance in traditional Iranian and zero-energy houses in America and to provide solutions in contemporary houses in Iran's cold climate to minimize energy consumption.

3. Findings and Discussion

For the geometrical definition of the walls of the building, the outermost surface of the walls of the building was selected for thermal zoning in the simulation software (according to the change in the thickness of the walls, the average thickness was applied in the software), then the effective volume for cooling and heating of the space was seen for the significant area of the walls of the building. Also, the physical properties of the materials have been determined in the software according to the 2019 edition of the 19th topic of the National Building Regulations. For example, to define the walls of the house, brick walls with a heat transfer coefficient of 0.88 W/m-K are considered, or around the definition of the openings of the building, they are defined as single-paned glass with a wooden frame, and its heat transfer coefficient is assumed to be 5.70 W/m-K. It should be noted that except for the communication spaces, the rest of the building spaces are ventilated. Despite the constant use of spaces with the direction of the different presence of people in the space, thermal zones are defined in multiple ways. Also, to investigate the effect of the physical variables of the architecture, the seasonal shading of plants in the outer yard has been omitted, but the shadow side on the building has been calculated by the software in the geometry part of the building by defining it as a substrate. The simulation results stated in this part show the amount of energy required to establish thermal comfort conditions along with the assumption of constant equipment consumption loads in all spaces of the building. In these analyses, the investigation of passive solutions based on the user (people present in the building) which has been traditionally used, such as regional heating or moving the living space during the day, has been omitted to make a comparative comparison with contemporary buildings.

3.1. Historical houses

3.1.1. Ebrahimi House – Ardabil

In the analysis of the simulation results of Ebrahimi House, we see the annual need of 110 kWh/sqm in the cooling section, which is mainly due to the high thermal capacity of the building shell and sunlight. On the other hand, in the heating sector, the annual requirement of 228 kWh/sqm is expected, this requirement is mainly related to heat loss in the form of convection flow from building walls and unwanted air infiltration into the building. According to the opening surface of the building, artificial lighting consumption for this building is estimated to be equal to 17 kWh/sqm annually. Also, home equipment consumption is estimated at 38 kWh/sqm and hot water consumption at 45 kWh/sqm. The amount of equivalent carbon consumption in the case of default operation is expected to be 164 kg/sqm annually. The optimal ratio of surface to volume and the placement of a single building in the north

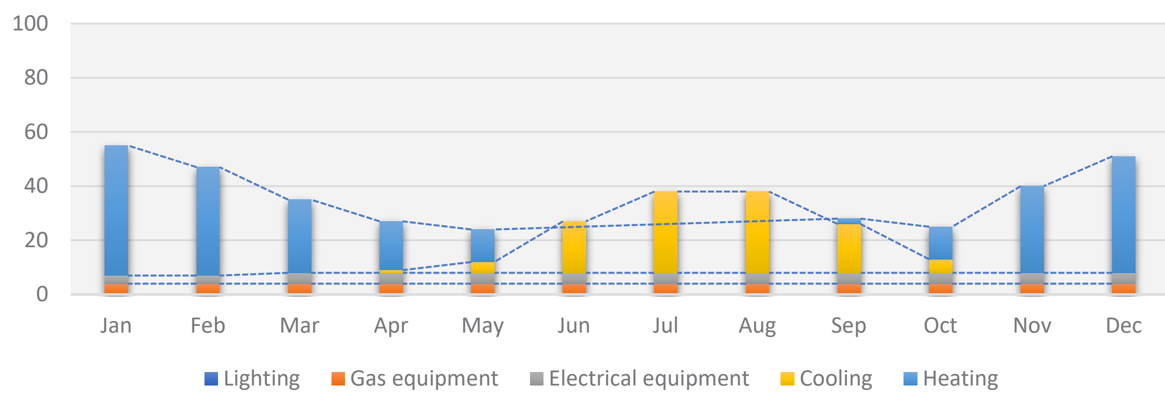

Figure 1: Monthly energy consumption chart of Khaneh Ebrahimi - Ardabil

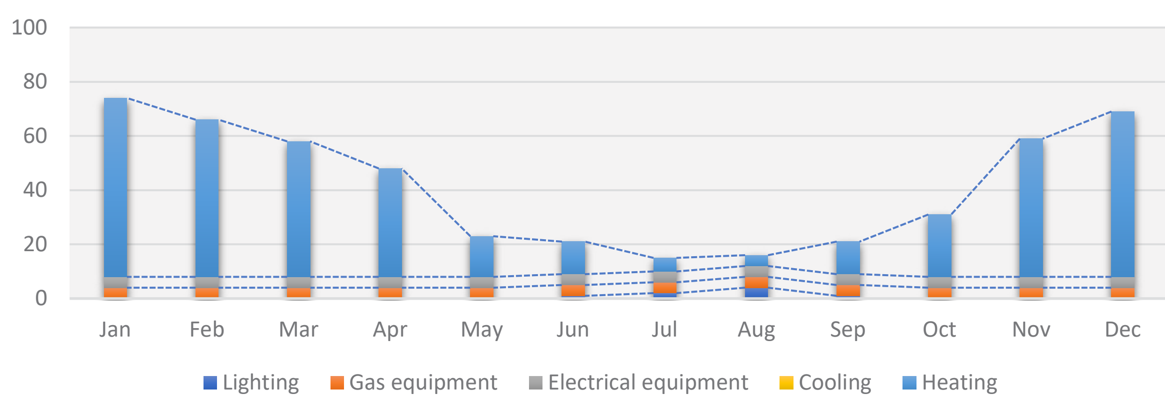

Figure 2: Monthly energy consumption chart of Rezazadeh house - Ardabil

and the porch of this building are among the most important features of the Ebrahimi house.

3.1.2. Rezazadeh House – Ardabil

In the analysis of the simulation results of Rezazadeh house, we see an annual requirement of 109 kWh/sqm in the cooling section, which is mainly due to the high thermal capacity of the building shell and sunlight. On the other hand, in the heating sector, the annual requirement of 244 kWh/sqm is expected, this requirement is mainly related to heat loss in the form of convection currents from building walls and unwanted air infiltration into the building. According to the opening surface of the building, the consumption of artificial lighting for this building is estimated to be equal to 16 kWh/sqm annually. Also, home equipment consumption is estimated at 38 kWh/sqm and hot water consumption at 45 kWh/sqm. The amount of equivalent carbon consumption in case of default operation is predicted to be 167 kg/sqm annually. The optimal ratio of surface to volume and the placement of a single building in the northern part are the most important features of Rezazadeh house.

3.1.3. Behnam House – Tabriz

In reviewing the simulation results of Behnam's house, we see an annual requirement of 82 kWh/sqm in the cooling section, which is mainly due to the high thermal capacity of the building shell and sunlight. On the other hand, in the heating sector, the annual requirement of 289 kWh/sqm is predicted, this requirement is mainly related

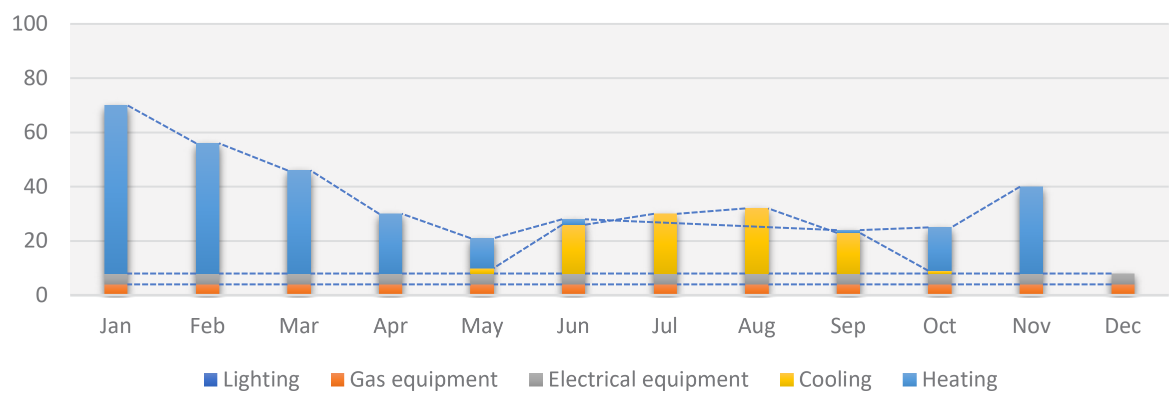

Figure 3: Monthly energy consumption chart of Behnam House - Tabriz

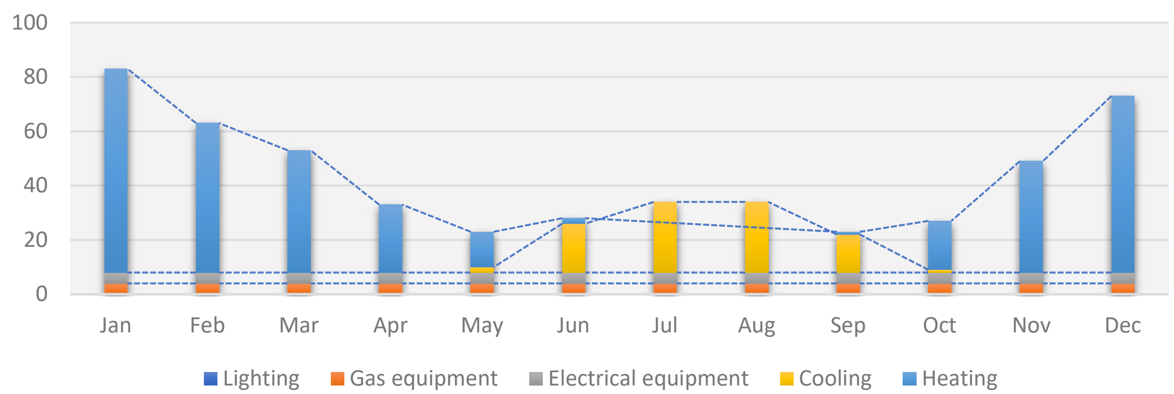

Figure 4: Monthly graph of energy consumption of Khadaki House - Tabriz

to heat loss in the form of convection flow from building walls and unwanted air infiltration into the building. According to the opening surface of the building, artificial lighting consumption for this building is estimated to be equal to 12 kWh/sqm annually. Also, home equipment consumption is estimated at 38 kWh/sqm and hot water consumption at 45 kWh/sqm. In total, the energy consumption of Behnam House is estimated to be 428 kWh/sqm in case of operation under contemporary structures. It should be noted that a large part of this requirement is related to the roped space. The amount of equivalent carbon consumption in the case of default operation is expected to be 158 kg/sqm annually. One of the most important influencing factors in the energy consumption of Behnam house is the compactness of the building on the north side and the ratio of the surface to its optimal volume.

3.1.4. Gadaki House - Tabriz

In the reviews of the simulation results of Qadaki house, we see the annual need of 85 kWh/sqm in the cooling section, which is mainly due to the high thermal capacity of the building shell and sunlight. On the other hand, in the heating sector, the annual requirement of 338 kWh/sqm is expected, this requirement is mainly related to heat loss in the form of convection flow from the building walls and unwanted air infiltration into the building. According to the opening surface of the building, the consumption of artificial lighting for this building is estimated to be equal to 18 kWh/sqm annually. Also, home equipment consumption is estimated at 38 kWh/sqm and hot water consumption at 45 kWh/sqm. The amount of equivalent carbon consumption in the case of default operation is expected to be 175 kg/sqm annually. It should be mentioned that the western and western walls of the building are improperly oriented to receive solar energy, causing serious changes in the energy needs of this building.

3.1.5. Saifi House – Hamedan

In the analysis of the simulation results of Sifi house, we see the annual need of 86 kWh/sqm in the cooling sector, which is mainly due to the high thermal capacity of the building shell and sunlight. On the other hand, in the heating sector, the annual requirement of 294 kWh/sqm is predicted, this requirement is mainly related to heat loss in the form of convection flow from building walls and unwanted air infiltration into the building. According to the opening surface of the building, artificial lighting consumption for this building is estimated to be equal to 17 kWh/sqm annually. Also, home equipment consumption is estimated at 38 kWh/sqm and hot water consumption at 45 kWh/sqm. The amount of equivalent carbon consumption in case of default operation is predicted to be 167 kg/sqm annually. The southwest orientation of this building is one of the most important factors in its annual energy needs.

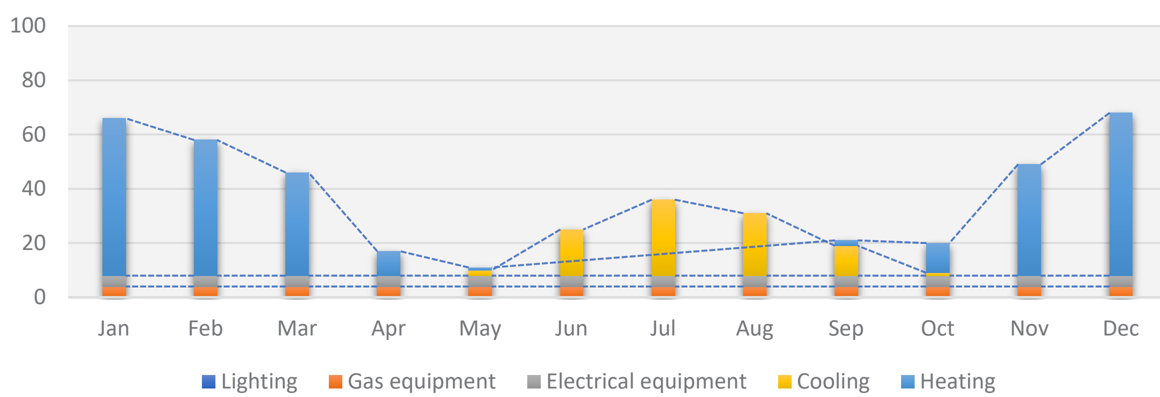

Figure 5: The monthly energy consumption chart of Saifi House - Hamedan

3.1.6. Samadian House – Hamedan

In the analysis of the simulation results of Samadian House, we see an annual requirement of 91 kWh/sqm in the cooling section, which is mainly due to the high thermal capacity of the building shell and sunlight. On the other hand, in the heating sector, the annual requirement of 385 kWh/sqm is expected, this requirement is mainly related to heat loss in the form of convection flow from the building walls and unwanted air infiltration into the building. According to the opening surface of the building, the consumption of artificial lighting for this building is estimated to be equal to 20 kWh/sqm annually. Also, home equipment consumption is estimated at 38 kWh/sqm and hot water consumption at 45 kWh/sqm. The amount of equivalent carbon consumption in the case of default operation is expected to be 191 kg/sqm annually. The existence of an independent building on the south side of this building is one of the most important reasons for the significant heating needs of this building.

3.1.7. Asif Mansion – Sanandaj

In the analysis of the simulation results of Asif mansion, we see the annual need of 111 kWh/sqm in the cooling section, which is mainly due to the high thermal capacity of the building shell and sunlight. On the other hand, in the heating sector, the annual requirement of 284 kWh/sqm

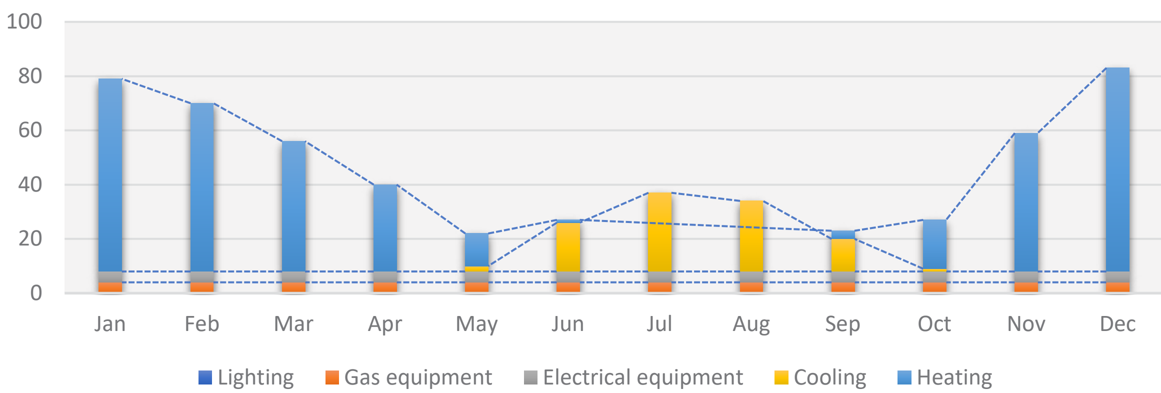

Figure 6: Monthly graph of energy consumption of Samadian House-Hamadan

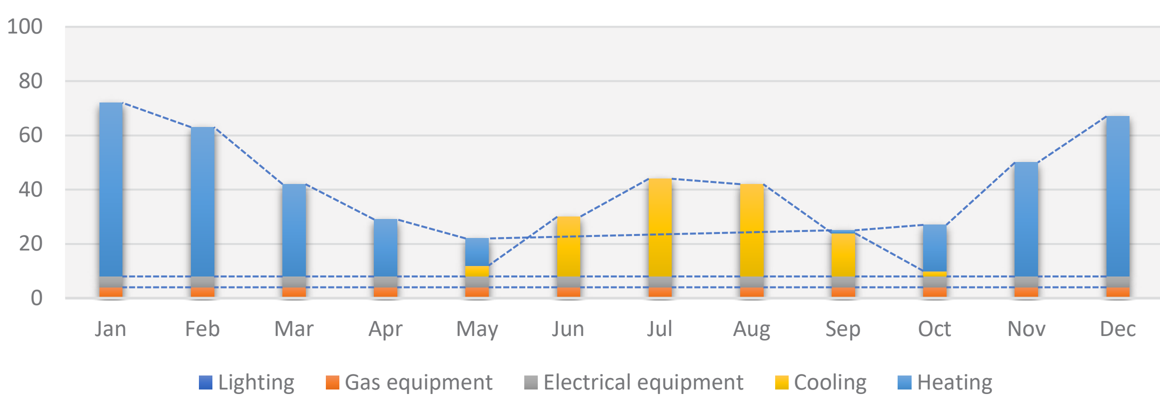

Figure 7: Monthly diagram of energy consumption of Asif Mansion – Sanandaj

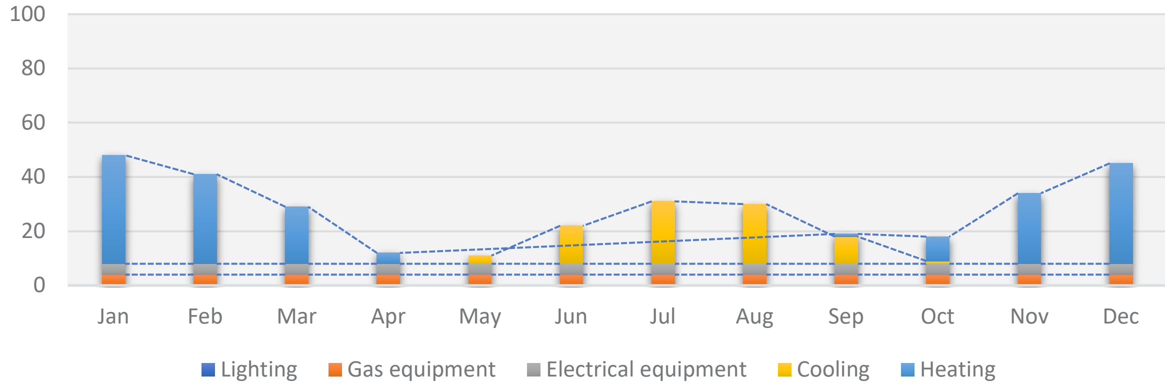

Figure 8: Monthly graph of energy consumption of Moshir Divan Mansion - Sanandaj

is predicted, this requirement is mainly related to heat loss in the form of convection flow from the building walls and unwanted air infiltration into the building. According to the opening surface of the building, the consumption of artificial lighting for this building is estimated to be equal to 20 kWh/sqm annually. Also, home equipment consumption is estimated at 38 kWh/sqm, and hot water consumption at 45 kWh/sqm. The amount of equivalent carbon consumption in the case of default operation is expected to be 179 kg/sqm annually. The way of organizing the space in Asif Mansion and the location of a significant part of the building in the western part next to the height system which has led to the increase of the surface-to-volume ratio, especially on the second floor, is one of the most important features of Asif Mansion, which has been effective in its annual energy needs.

3.1.8. Moshir Divan Mansion - Sanandaj

In the analysis of the simulation results of the Moshir Divan mansion, we see the annual need of 108 kWh/sqm in the cooling section, which is mainly due to the high thermal capacity of the building shell and sunlight. On the other hand, in the heating sector, the annual requirement of 243 kWh/sqm is expected, this requirement is mainly related to heat loss in the form of convection flow from building walls and unwanted air infiltration into the building. According to the opening surface of the building, the consumption of artificial lighting for this building is estimated to be 21 kWh/sqm annually. Also, home equipment consumption is estimated at 38 kWh/sqm, and hot water consumption at 45 kWh/sqm. The amount of equivalent carbon consumption in case of default operation is predicted to be 171 kg/sqm annually. The way of spatial organization in Moshir Divan and the location of a significant part of the building in the western part next to the height system that has led to the expansion of the shell, especially in the roof, is one of the most important features of the Moshir Divan mansion, which has been effective in its annual energy needs.

4. Result and Conclusion

As stated, in general, the main issue in cold climates is to provide thermal comfort in the indoor space in winter, and for this purpose, traditional houses try to use sunlight, avoid adverse wind flow in winter, and reduce heat exchange through the external walls of the building. Have had. In the study of the spatial system of traditional cold climate buildings, since these buildings are affected by the urban structure, the issue of the ratio of surface to volume and neighborhood, along with the orientation of the building, has been considered. Regarding the surface-to-volume ratio, if we examine traditional buildings without taking into account the urban context to try to use sunlight, we see significant surface areas, especially on the northern front, compared to the volume of buildings. At the same time, the design of spaces for the formation of local micro-climates and compact urban contexts expresses the importance of investigating the concept of urban density in the investigation of traditional climate houses in the historical context. It should be noted that the attention of the contemporary urban planning system to the car and the linear structure of the neighborhoods in the vicinity of the roads limits the possibility of using the spatial system of traditional buildings.

In the investigation of the geometrical system of the traditional buildings of the cold climate of the northern front, due to the climatic issues of proper lighting and the use of sunlight in the cold seasons of the year, all the houses of the cold climate, it has been considered. In this front, the main living spaces, such as tanabis and kelehs, are located. Also, in some cases, an all-round veranda is placed on this front, which prevents the sun from penetrating in the summer. In most of the houses, the main spaces are located along the main axis of the building, for example, the ropes of the south and north porches, the pond and the central staircase are formed in this direction. The western front is of secondary importance due to the fact that it faces the unfavorable western sun, so in the case of multiple fronts, the western front house has priority. This front is mostly for spaces such as cellars and warehouses, which are less used. Among other things, in the investigation of the geometrical system, the situation of the openings of traditional buildings is that due to the priority of receiving radiation and providing lighting using daylight, we see a different percentage of openings compared to contemporary residential structures. On the other hand, in the national standards (issue 19, edition 99) compiled for the design of residential buildings in Iran, we see instructions such as reducing the number of surfaces and the opening surface to less than 40%, despite the use of low-emissivity (Low-E) and double-glazed glass. This makes it difficult to exploit the geometric structure of traditional buildings even at the level of national standards.

According to the physical system of traditional cold climate buildings, the use of passive solar methods, especially the thermal mass and the thickness of the walls, is of considerable importance in the design of these buildings. In the use of thermal mass, when exposed to heat, the materials can store more heat than other materials and transfer it to an internal space when needed. The use of thermal mass is unattainable due to the importance of building weight and structural performance, and the use of thermal insulation in contemporary buildings is more important to designers. The simulation results of the energy requirement also confirm the more effective use of thermal insulation. In the national standards of Iran, the minimum thermal resistance considered for building shells is equal to 0.5 m2. K/W; Achieving this amount of resistance for the external wall by using only thermal mass leads to the thickness and weight of unusual walls.

Due to the potential of heating and air conditioning equipment to provide thermal comfort conditions, the residents of contemporary houses have a bio-balanced model in their buildings. While the pattern of living in traditional houses is not uniform and living in different spaces is done according to the time conditions. This case is of great importance due to the change of habitation patterns in contemporary architecture, so that if traditional buildings are inhabited according to the requirements of contemporary conditions, they no longer have the appropriate climatic performance of their past. It should be noted that the way of life was not only related to the habitation pattern, and issues such as the adaptive action of space users to provide thermal comfort and adapt more to thermal stress in the use of traditional houses in contemporary structures are not considered by users.

References

Alvinejad, M. Mojahdieh, the study of urban sustainability factors in the old context of Nayin, Hamadan, the second sustainable architecture conference 2010

Ardalan, N. Bakhtiar, L., Hess Vahdat, Tehran Khak Publishing House 2002

Azarbaijani, M., sustainable architecture and its indicators, collection of articles of the third conference on fuel consumption optimization in buildings 1988

Baum M. (2007). Green building research funding: an assessment of current activity in the United States. US Green Building Council: Washington, DC.

Cheng, B., Fu, Y., Khoshbakht, M., Duan, L., Zhang, J., & Rashidian, S. (2018). Characteristics of Thermal Comfort

Conditions in Cold Rural Areas of China: A Case study of Stone Dwellings in a Tibetan Village. Buildings, 8. https://doi.org/10.3390/buildings8040049

Copiello S. (2016). Economic implications of the energy issue: evidence for a positive non- linear relation between embodied energy and construction cost. Energy Build,123:59-70. https://doi.org/10.1016/j.enbuild.2016.04.054

Daniels, T, Daniels K. (2003). environmental planning handbook: for sustainable communities and regions, american planning association.

Davies PJ, Emmitt S, Firth SK. (2014). Challenges for capturing and assessing initial embodied energy: a contractor's perspective. Constr Manag Econ,32(3):290-308. https://doi.org/10.1080/01446193.2014.884280

Dixit, MK. (2016). An Input-Output-based Hybrid Recurrent Embodied Energy Calculation Model for Commercial Facilities, in: CIB World Building Congress, May 31- June-3, Tampere: Finland.

Dixit, MK. (2016). Embodied energy and cost of building materials: correlation analysis. Build Res Inf:1-16.

Emmanuel, Rohinton. (1995). Energy Efficient Urban Design Guidelines for Warm-Humid Cities: Strategies for Colombo, Sri Lanka, Journal of Architectural and Planning Research,12:1 spring, p.p 58-79.

Energy balance sheet of 2016 (2018). Vice President of Electricity and Energy Affairs, Bureau of Planning and Macroeconomics of Electricity and Energy, http://www.ifco.ir/index.php/

Flamaki problematization of architecture in the experiences of Iran and the West, published by Fza Tehran 2005

Forster, Wayne, Amanda Heal, and Caroline Paradise. (2014). Lesson from Vernacular Architecture. Taylor & Francis: England.

Givoni, B. (1969). Man, climate and architecture, Elsevier: Amsterdam.

Givoni, B. (1998). Climate considerations in building and urban design, Van Nostrand Reinhold: New York.

Gou, Z., Lau, S.S.-Y., Chen, F. (2012). Subjective and objective evaluation of the thermal environment in a three-star green office building in China. Indoor Built Environ. 21, 412-422. https://doi.org/10.1177/1420326X11419311

Gut, P. and Ackerknecht, D. (1993). Climate responsive building, Appropriate Building Construction in Tropical and Subtropical Regions, St Gallen, Switzerland: SKAT, Swiss Centre for Development Cooperation in Technology and Management.

Haeri, M., research on the application of architectural principles of traditional historical houses in modern housing design, housing and urban development, Tehran 1999

Heydari, Sh., and Ghaffari Jabari, Sh. (1389). Determining the time range of thermal comfort for the city of Tabriz. Madras Mechanical Engineering, 10(4), 37-44. https://www.sid.ir/fa/journal/ViewPaper.aspx?id=121539.

IEA. World Energy Statistics and Balances (Database). (2019). Available online: www.iea.org/statistics

Iran energy balance sheet 1396. (2019). Ministry of Energy.

Iwafune, Y., Yagita, Y. (2016). High-resolution determinant analysis of Japanese residential electricity consumption using home energy management system data. Energy Build. 116, 274e284. https://doi.org/10.1016/j.enbuild.2016.01.017

Jahansson, E. (2011). Influences of urban geometry on outdoor thermal comfort in a hot dry climate, A Study in Fez, Morocco, Building and Environment, vol 41. https://doi.org/10.1016/j.buildenv.2005.05.022

Karimpour M, Belusko M, Xing K, Bruno F. (2014). Minimising the life cycle energy of buildings: review and analysis. Build Environ,73:106-14. https://doi.org/10.1016/j.buildenv.2013.11.019

Khodabakhshi, S. Mofidim sustainable construction in connection with the traditional architecture of Iran, the third national energy conference of Iran, 2008.

Mahdavi, A., Kumar, S. (1996). Implications of indoor climate control for comfort, energy and environment. Energy Build, 24, 167-177. https://doi.org/10.1016/S0378-7788(96)00975-9

Mahri Talar Patshi S. Sustainable architecture and its indicators, Hamedan, the first sustainable architecture conference, 2008.

Melatparast, sustainable architecture in the desert cities of Iran, Armanshahr 2008.

Mitra, Sanmarga, and Shivashish Bose. (2017). Sustainable Performance of Diverse Regional Vernacular Architecture of India-Case Study of I.G.R.M.S. Bhopal, INDIA. Journal of Procedia Environmental Sciences -(37): 495-513. https://doi.org/10.1016/j.proenv.2017.03.023

Nebel B, Alcorn A, Wittstock B. (2008). Life cycle assessment: adopting and adapting overseas LCA data and methodologies for building materials in New Zealand. New Zealand: Ministry of Agriculture and Forestry, 2008.

Ogunsote, OO., Prucnal-Ogunsote, B. (2002). Defining climatic zones for architectural design in Nigeria: a systematic delineation. J Environ Technol 1(2):1-14.

Oikonomoua, A., F. Bougiatiotib. (2011). Architectural structure and environmental performance of the traditional buildings in Florina. NW Greece, Building and Environment. Issue 3 (46): 669-689. https://doi.org/10.1016/j.buildenv.2010.09.012

Oktay, D. (2002). Design with the climate in housing environments: an analysis in Northern Cyprus. Building and Environment, 37(10), 1003-1012. https://doi.org/10.1016/S0360-1323(01)00086-5

Olgyay, V., & Olgyay, A. (1963). Design with Climate, Bioclimatic approach to architectural regional- ism, Princeton, New Jersey: Princeton University Press.

Omidpour, S. Native architecture of East Azarbaijan province, a case study of houses in Tabriz), 1351

Pakzad J. Vaheh, Neighboring articles on the concepts of architecture and urban design, Shahidi Publications, Tehran 2006.

Plank R. (2008). The principles of sustainable construction. IES J Part A: Civil Struct Eng ,1(4):3017. https://doi.org/10.1080/19373260802404482

Qobadian, and, Climatic survey of traditional buildings, Tehran University, Tehran, 2013

Rostgar, N., Investigating the role of the central courtyard in

the environmental sustainability of traditional tourism houses and environmental arts, 2013
Sam.C.M., Chung, K.P. (1997). Climatic data for building energy design in Hong Kong and mainland China, In proc, of the CIBSE National Conference 1997, London.
Sarmi, A., Radmard, T. Sustainable values in Iranian architecture, Cultural Heritage Organization Publications, Tehran 1997
Sartori, I., Hestnes, AG. (2007). Energy use in the life cycle of conventional and low-energy buildings: a review article. Energy Build, 39(3):249-57. https://doi.org/10.1016/j.enbuild.2006.07.001
Shadram F, Johansson TD, Lu W, Schade J, Olofsson T. (2016). An integrated BIM-based framework for minimizing embodied energy during building design. Energy Build,128:592-604. https://doi.org/10.1016/j.enbuild.2016.07.007
Shaghaghi, S. Mofidi Shemirani, M., The relationship between sustainable development and climatic design of buildings in cold and dry regions, Azad University of Tabriz 2007
Singari M. Explaining the structure of sustainable architecture and presenting its practical solutions in the city of Tabriz, Tabriz Islamic Azad University Research Unit, 2006
Steemers, K. (2003). Energy and the city: density, buildings and transport, Energy Build.35 (1) , 3-14. https://doi.org/10.1016/S0378-7788(02)00075-0
Stephan A, Stephan, L A. (2016). Life cycle energy and cost analysis of embodied, operational and user-transport energy reduction measures for residential build- ings. Appl Energy,161:445-64. https://doi.org/10.1016/j.apenergy.2015.10.023
Sun, X., Gou, Z., Lau, S.S.-Y. (2018). Cost-effectiveness of active and passive design strategies in existing building retrofits in tropical climate: Case study of a zero-energy building. J. Clean. Prod., 183, 35-45. https://doi.org/10.1016/j.jclepro.2018.02.137
Thompson, R.D. and Perry, A. (1997). Applied Climatology, Principles and Practice, Rutledge.
Thormark C. (2007). Energy and resources, material choice and recycling potential in low energy buildings, in: CIB Conference, SB 07 Sustainable Construction Materials & Practices, Lisbon: Portugal.
Toy, S., Yilmaz, S., Yilmaz, h. (2007). Determination of bioclimatic comfort in three different land uses in the city of Erzurum, Turkey, Building and Environment, Vol. 42. https://doi.org/10.1016/j.buildenv.2005.10.031
UN. (2014). World Urbanization Prospects, the 2011 Revision. United Nations: Department of Economic and Social Affairs, Population: New York.
Watson, D. and Lab, K. (1993). Climate design (translated by Qabadian, V. and Faiz Mahdavi, M.). Tehran: Tehran University Press.
Wen, TJ., Siong, HC., Noor, ZZ. (2015). Assessment of embodied energy and global warming potential of building construction using life cycle analysis approach: case studies of residential buildings in Iskandar Malaysia. Energy Build,93:295-302. https://doi.org/10.1016/j.enbuild.2014.12.002

HOW TO CITE THIS ARTICLE

Hajali Zadeh, G. (2023). Investigation of energy consumption of traditional houses in approach to sustainable architecture (Case Study: Ardebil, Sanandaj, Hamedan and Tabriz cities of Iran). J Urban Manage Energy Sustainability, 5(1): 130-146.

DOI: 10.22034/JUMES.2023.1996326.1124