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Research Article

Evaluating and Identifying Climatic Design Features in Traditional Iranian Architecture for Energy Saving (Case Study of Residential Architecture in Northwest of Iran)

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In the last decades, researchers have been considering some fundamental issues such as energy saving, global warming, greenhouse emissions, and non-renewable energy to make models of house environmental standards to achieve a suitable consumption pattern for saving energy. In architecture, using natural energy is one of the essential pillars of design because it was one of the criteria of designing, which was considered on climate and geography, and it has been a high performance of climate adaptation in the modeling of traditional houses. In this research, Azerbaijan (located in northwestern Iran) is selected to evaluate the practical features of traditional Iranian houses designed in the cold climate, and criteria for developing sensible solutions to achieve a suitable design model for energy saving are provided. The primary purpose of this paper is to evaluate and identify the features of climate design in traditional houses in a cold climate, which are suitable residential buildings for energy management, and to identify the components affecting energy saving. The data collection method is based on checklists, observation, considering the orientation, density, solar radiation angle in the region, documentary, analysis of maps, and adaptation of the architectural plan of the studied houses with the pattern of solar radiation in the area. This research discusses the design criteria for future structures and their adaptable measures based on the obtained results. Finally, it is declared that the traditional architectural design model follows the region's climatic conditions, and considering the current climate and energies, traditional houses were designed; therefore, the best model for maximum use of available energy is climatic design. As a result, suggestions are made regarding residential architecture design to save energy.

1. Introduction

Increasing fossil fuel consumption and carbon dioxide production levels need no further stress globally, and maximum energy saving is a universal goal. Statistics show that the construction sector is one of the largest energy consumers worldwide [1]. As the number of people living in urban areas is expected to grow to almost 70% by 2050, the energy consumption in cities is likely to follow that trend. Therefore, urban energy efficiency will be critical [2].

Due to the rate of economic development and growing population densities in the world, the majority of these cities are dominated by high-rise apartment buildings [3]. The improvement of building services and comfort level and growth in population has increased energy consumption to the level of transport and industry [4]. The research undertaken by Ref. [5] specified that buildings consume 40% of world energy. The massive magnitude of energy consumption in buildings for cooling and heating by heaters and air-conditioner systems portrays a considerable problem for the system. Available statistics state that the Heat, Ventilation, and Air Conditioning (HVAC) systems in standard buildings account for more than 50% of annual energy consumption globally [6]. This state, coupled with the threat of increasing global temperature and energy cost, induces the need to regulate the temperatures in these buildings [7–10].

In the construction sector of Iran, this issue's importance has been raised, and initial measures in this regard have begun. Currently, according to fuel consumption statistics, energy optimization is vital, especially in the construction sector and in the layout of spaces and the orientation of the building to the natural energies of the sun and wind, etc. The average energy consumption in Iranian buildings per square meter is about 310 kWh per year, which in the same situation in European countries is about 120 kWh per square meter. Therefore, energy consumption in Iranian buildings is about 2.5 times that of European countries. Implementing appropriate methods in designing buildings that coordinate with the place's climate has always been the focus of architects.

The crisis in the relationship between humans and nature, as well as the population density and congestion of information in the current age, is leading to a tense atmosphere in life [11–13].

The various forms existing in our nature have special meanings, which all come from the proper orientation and climate of the area. The region's climate is like the law of nature and the maximum use of natural energy. Considering the four prevailing climates in Iran, a significant amount of energy is consumed to balance cold and hot climates with nature. This research considers the cold climate covering the west to the northwest. Existing buildings in cold climates show significant energy-saving potential, and retrofitting the building stock is essential to targets. Retrofitting measures should reduce energy consumption and improve the indoor climate while being affordable. These can be challenging in cold climates. This paper discusses energy performance requirements and challenges in the retrofitting process. It also presents an overview of the retrofitting status and relevant energy-saving retrofitting measures with their potential for residential buildings [14–17].

One should look at environmental and natural phenomena from a new and different perspective to find these meanings. Hence, for the various climatic regions of Iran, the beautiful and famous form of traditional Iranian houses is suggested, which has been repeated since prehistoric times not only in the internal regions of Iran but also in the regions of the Middle East. Building designers, considering climatology, use the maximum climatic facilities of each region and natural energies to save fossil fuel consumption in buildings, which increases the quality of comfort, tranquility, and physical and mental health of the residents. Therefore, the world is looking to renewable resources, especially solar energy, and to evolve and develop productivity technology, exploiting them is rapidly advancing. The incompatibility of buildings with their bed climate and for getting past experiences have caused damage, including the increase in energy consumption. Moreover, the production of materials and the countless building construction have taken much energy and led to much environmental pollution. Accordingly, it is necessary to orient design strategies in new buildings to reduce energy consumption and environmental pollution.

In addition, some studies in different fields are trying to reduce energy consumption in buildings. Researchers are trying to optimize to reduce energy consumption. Summaries of recent publications on vernacular architectures in the energy-saving field are presented in Table 1.

The design of buildings with maximum usage of renewable energy is proposed to achieve this goal. This research aims to find the relationship between energy-saving and architecture and provide information to achieve logical architectural designs that are in harmony with the desired climate. The purpose of this study is to study and identify cold climatic conditions and explain a suitable model for architectural design with an appropriate climatic approach in modern Iranian architecture.

Among all neglected states, Azerbaijan is one of the most critical states of Iran, is located in the northwest of the county, and shares the same name with the neighboring northern country, Azerbaijan. Despite the distinctive architectural characteristics of the buildings, there is only a little literature published reflecting how the people of this area adapted their buildings to the harsh environment [13, 24–28]. This study aimed to identify the main differences between the architectural characteristics of buildings of Azerbaijan state with those of the central areas of Iran for climatic design issues. The traditional architectural values of this country have been used for centuries and have met the needs of residents in the best way possible.

Therefore, the present research evaluates the spatial features of traditional houses to increase natural energy, then identifies the components affecting the design of contemporary houses, and seeks to answer these questions: which features and models of traditional architecture are effective in designing the architecture for cold climates? what effect does climatic design have on the use of natural energy in the architecture of contemporary houses? how can we achieve solutions to design houses in cold climates? and what are the architectural models to meet these demands? In Figure 1, the overall framework of the current study is illustrated.

2. Methodology

2.1. Definition of the Problem. Azerbaijan could be considered one of the highest geographical places in Iran. The whole state is bounded by other highlands from all sides, which has led to numerous plateaus, e.g., Moghan, Tabriz, Saraband Maragheh. Sahand peak (3722 meters) is the highest place in the state, which is only 50 kilometers far

Table 1: A summary of newly published works with the aim of energy saving in domestic buildings.

References	Description
Ref. [18]	This work is purposed on the impact of building orientation on energy consumption in a domestic building using emerging BIM
Ref. [19]	In this paper, the climate-responsive solutions in the vernacular architecture of Bushehr city are investigated
Ref. [20]	Studies on sustainable features of vernacular architecture in different regions across the world
Ref. [21]	The simultaneous effects of building orientation and thermal insulation on heating and cooling loads in different climate zones are evaluated
Ref. [22]	This research investigates the relationship between optimum building forms in decreasing the cooling load
Ref. [22]	This paper reviews examples of vernacular architecture and its building elements in Nepal and analyses them in a qualitative manner in which bioclimatic design strategies were applied
Ref. [23]	This paper aims to classify almost all climatic strategies into different levels of space in Iranian vernacular architecture strategies

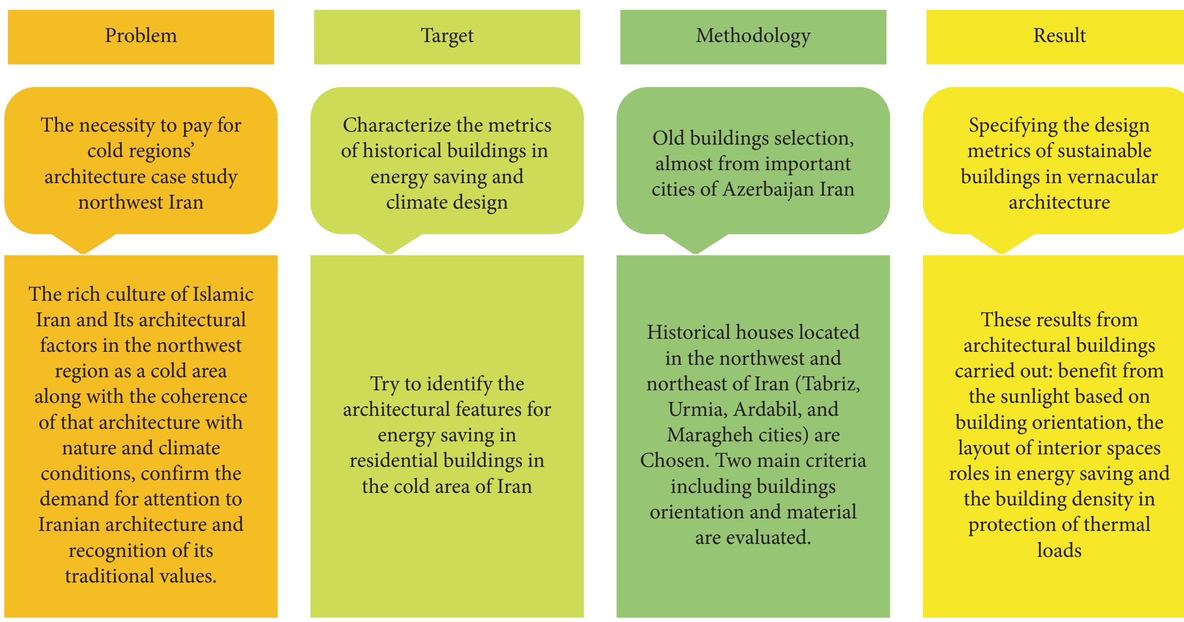


Figure 1: A overall framework of the current study.

from Tabriz, while Urmia Lake (1220 meters) is not more than 100 kilometers far from Tabriz city [29]. Such a geographical position and altitude lead to cold, dry, raining, and snowing weather in certain seasons, with a massive difference between the conditions in the cold and hot seasons. In essence, this part of the country significantly differs from the central arid zones in terms of temperature and weather.

2.2. Main Contributions and Novelties. Reviewing the previous studies confirms that investigating the vernacular buildings of northwest Iran did not observe based on their climate features. Hence, this paper tried to identify the architectural features for energy saving in residential buildings in the cold area of Iran. The study area is Iran's cold climate around West and East Azerbaijan. The current paper focuses on sustainable vernacular buildings according to their orientation and material. Therefore, this matter motivates this paper to investigate the energy in Iranian architectures based on climate design and energy saving, in which thermal comfort in architecture based on cold weather and the optimum use of solar energy without any mechanical systems are evaluated. In addition, the relation between the architecture of the old building in the proposed area and this building's orientation and density are investigated. For exact statistical analysis, the collected data include all buildings in the cold climate that have followed the climatic model and indigenous architecture. Library and field studies and case studies are selected as data collection tools according to the environmental features of the territory. Hence, based on the aim of vernacular architecture, sustainable buildings were built as environmental-friendly buildings, which tried to have a minimum negative effect on the environment. The following novelties are considered to clarify the current paper's advantages:

(i) Selection of 29 old buildings almost from important cities of Azerbaijan and Iran as shown in Table 2.

(ii) The collected data are employed to investigate the climate influence on the orientation of the studied old domestic building.

(iii) The using materials and their effects on energy saving are specified.

Table 2: The studied houses were separately sorted by each city (Source: Author).

Maragheh	Urmia	Tabriz	Ardabil
House of Ashraf Al-Muluk Nabi Vand	Ansari House Urmia)	Sharbat Oghli House	Mobasheri residential complex in the center of the Uch Dokan neighborhood
Nosrati Azar House	Dizaj Siavash House	Heidarzadeh House	Sadeghi House
Shahabian House	General houses	House of Dr. Yahya Zaka (Laleei)	Ershadi House
—	Majidi Afshar House	Ghadaki House	Vakil-or-Roaya House
—	Hadidi House	House of Amir Nezam	Moravej House
—	Moayeri Nia House	Mojtahedi House	Manafzadeh House
—		Behnam House	Marathi House
—	—	Sarraflar House (alavi)	Asef House
—	—	Salmasi House	Mobasheri House

(iv) The specific partitioning of the studied areas is identified.

(v) The zone with the most application is located on the south front, such as the family living room.

3. Main Discussion

3.1. Architectural Climatology. According to the scientific definition of climate, climate is the temporal combination of the physical state of the atmosphere, which is a characteristic of a specific geographical location. Since the weather is the current atmospheric condition of a specific location, we can define climate as the temporal combination of weather conditions [30]. Today, paying attention to climatic conditions in the design and construction of all buildings, especially buildings directly used by humans and living creatures, is vital in two ways. On the one hand, buildings in harmony with climate or with a climatic design have a better quality in terms of human thermal comfort. The environmental conditions of such buildings are better, and the daily and seasonal change and variety, light, heat, and airflow create various and pleasant spaces. On the other hand, the harmony of the building with the climate saves energy consumption required to control the environmental conditions of such buildings. In this building, the interior conditions of buildings in harmony with the climate can be adjusted to human comfort naturally throughout the year without the need for mechanical HVAC systems. To achieve a comfortable condition, using ways to provide comfort in buildings is essential. The following conditions must be observed to continue the fight against the environment in the construction of buildings:

(a) designing a building suitable for the environment;

(b) selecting materials suitable for the environment.

3.1.1. Energy in Architecture. Each city and region consumes different energy based on the types of existing buildings. In residential buildings, space heating, water heating, lighting, and cooking shape energy consumption. Among the mentioned activities, energy consumption for heating the house's interior accounts for about 60% of the total energy consumption in these buildings and has the most significant proportion [31]. In architecture, energy is divided into two components: light energy and thermal energy. A) Light energy is for sighting, seeing, studying, walking, and living. This type of energy is controllable and adjustable, but it is wasted without planning. B) Thermal energy is to make the environment favorable for work and life by heating or cooling inside the house, work environment, and other spaces for a better life. Such energies, like other energies, can be wasted. One of the most important parameters in architecture is the use of light, especially natural light such as the sun. In ancient times, the use of light and thermal energy in architecture was common, including inhibition of heating by thick walls and cooling production by proper orientation of the building. Necessary and sufficient light can turn the environment of the created architectural space into an artistic, familiar, livable and useable environment [32]. Regarding the temperature inside the complex and its usability and usefulness, like the optimal use of outside temperature, it is necessary to make the necessary controls in the design regarding the optimal use of thermal energy. In summer, thermal energy is radiated by the sun on the building's body and makes inside the building warmer. In this case, architects must control this case by thinking together and seeking the opinion of experts (engineers and installation experts) [33].

In summer, thermal energy is transferred from outside to inside. In winter, thermal energy is transferred from inside to outside; this change and exchange of energy cause architects and designers to consider the necessary design arrangements.To achieve the above goals to control and use energy optimally, according to current knowledge, experts have developed guidelines and criteria for the optimal use of energy in the design of buildings known as Article [34]. Therefore, the world should focus on how to save energy in their operations and environmental impacts and improve resource efficiency [35].

3.1.2. Climatic Design and Energy Saving. The degradability and limitation of energy resources, especially fossil fuel sources, have led countries to research and study other energy sources, especially renewable energy such as solar, wind, geothermal, and sea and ocean waves, and on the other hand, to put the optimal, appropriate, and correct use of fossil fuels on the agenda.

Governments have committed themselves to various climate change agreements and policies. Trends are highlighted, and motivations for specific trends are explored and investigated, distinguishing between the world's developed and developing economies. Despite the efforts and resolutions of many countries, the cursory penetration of energy efficiency and the adoption of environmentally sustainable energy sources highlight the fundamental challenge of the need for a solution that will entrench a culture of energy efficiency and sustainable energy in our way of life [36–41].

Throughout the history of architecture and construction, designers have always sought to respond to climatic conditions; so-called traditional architects' climatic design has had an accurate and orderly expression. In this method of climatic design, no mechanical and installation means are used. In other words, this method has no cost, and the building receives and maintains this energy with its elements and components. Only knowledge and awareness about buildings of climatic design are needed. Whether in the form of the direction of buildings located in mountainous cities that are protected from the wind and facing south or in the form of traditional central courtyard house plans designed to maintain the cold of night in hot and dry climates. For example, the design of the buildings (Pavilion) is based on the ancient architecture of Iran using renewable energy such as solar and wind energy [16, 17, 34, 42].

Indigenous buildings and local styles, climate, and weather were considered the primary basis of human life and activities, ultimately leading to a beautiful form. This method is called building climatic design, and climate design is a method to reduce the energy of a building. The building design is the first line of defense against external climatic factors. In all climates, buildings built according to design principles minimize the need for mechanical heating and cooling and instead use the natural energy around the building. The climatic design causes the buildings to have the best comfort conditions. Instead of putting much pressure on the heating and cooling systems, the building provides comfortable conditions without equipment and devices. The use of central generating devices reduces the environmental effects and the consumption of fossil fuels, which we see in this model of climatic design in the architectural design of traditional houses. Factors such as heat, humidity, wind, etc., are effective in the type and style of buildings in a city [43] (Figure 2).

3.1.3. Typology of Architecture and Climate. Designing is the attempt to see beyond. It is an attempt to control a space's quality and make it appropriate for humans. We have the perception that in many cases, the visual quality was the main element considered by architects. However—at the same time—the missing control of "other" qualities in the building was precise. The result was an unbalanced feeling of pleasant and unpleasantness that is difficult to decode and understand [34].

The function of the building envelope is to physically separate the interior of the building from the exterior environment. Therefore, it serves as external protection to the indoor environment while facilitating climate control at the same time [43–45]. Environmental control installations must be considered with the external conditions [43]. Because building envelopes separate indoor and outdoor environments, they are exposed to temperature fluctuations, humidity, air movement, rain, solar radiation, and other natural factors [46]. The climatic thermal design of the building envelope affects thermal performance, which also affects energy consumption [47].

There are five methods of heat and mass transfer in the buildings: conduction through opaque elements, including external walls, ceilings, floor slabs, roofs, and partitions; solar radiation and conduction through window glazing; infiltration of outdoor air and air from adjacent rooms; and heat and moisture dissipation from the room's lighting, equipment, occupants, and other materials. The HVAC system provides heating or cooling and humidification or dehumidification [48]. A study by Ref. [49] shows that the building envelope contributes 73% of the total heat/gain loss. The choice of construction materials is dependent on thermal, moisture, and sound considerations. Walls, doors, windows, ventilators, roofs, etc., are components that are directly exposed to the sun.

3.2. Building Density. Building density is one of (Figure 3) the most critical factors affecting the amount of energy consumption in the building. The higher the building density, the lower the covered area of the land and the better the area's climate will become. It should be noted that in case of an excessive increase in building density in the city, the height of buildings will increase. Then, it will cause wind draft around the building and thus reduce the temperature. Therefore, more energy is spent on heating the house space in the building [50].

3.2.1. Plan and Layout of the Building. The layout form of residential buildings is referred to how they are placed, which has various types. Such as attached and separate, linear, central courtyard, and high-rise blocks. Each of them has its characteristics and changes the amount of energy consumption of the building considering the difference between each point of view of access to sunlight and exposure to wind. For example, suppose residential buildings are attached. In that case, the free surface of the buildings is reduced. As a result, the heat exchange of the building with the surrounding environment is reduced. Less energy is needed to heat the building [50].

3.3. Orientation of Traditional Houses in the Cold Climate of Azerbaijan. The orientation of buildings (particularly houses) is one of the most influencing factors in determining the characteristics of Iranian architecture and urban

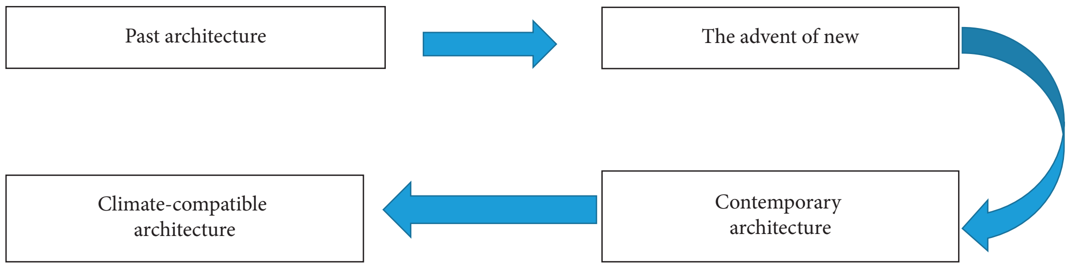


Figure 2: The trend of climatic design from the past to the present [30].

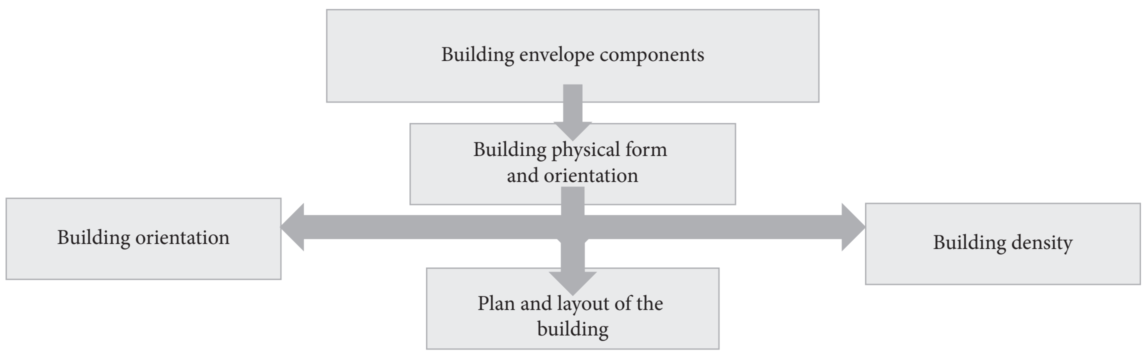


Figure 3: Effective characteristics in climatic design (Source: Author).

structures. The term "Ron" was the dominant traditional term that Iranian architects used to orient buildings. In terms of the classification of the building based on their orientation, Iranian vernacular architectures have three Rons: Raster Ron, Isfahani Ron, and Kermani or Shirazi Ron. Pirnia (1995) asserted that vernacularly in Iran, climate, ground conditions, topography, and slope significantly contribute to the formation of these Rons. Based on their tacit knowledge, traditional Iranian architects were aware of the direction of the prevailing winds, and they knew that giving enough credit to this factor could significantly affect environmental comfort. For instance, although the plateau of Tabriz, which is located among high mountains, naturally has various strong winds throughout the year, some prevailing winds strongly affect the direction of houses in this region, e.g., the East wind throughout the year and the North-East wind, which is very strong in winters [51]. As such, the vernacular houses of Tabriz mainly face south (varying from 15 degrees towards East to 10 degrees towards West), and all main spaces, including Tanabe (reception), study rooms, and lounge area are located at this site [18]. Mosques are also not excluded from this rule. Unlike those in the central parts of Iran, most mosques in Tabriz have multiple openings. This Ron order is the only Iranian Ron that coincides with the Kiblah direction as the direction for the prayer of Muslims, hence the natural.

The religious beliefs further lead to the orientation of buildings in the Azerbaijan area. In traditional complexes, using natural resources and energies is one of the principles of their construction and spatial organization. The direction of the house followed the angle of sunlight and the Kiblah. In the vast majority of traditional houses, the main axis of the buildings was the north-south axis. They had the best position to receive sunlight, so they could have shade on hot summer days and warm sun in winter. The main living spaces were built on the north and south sides, and the less important spaces, especially the service spaces, were built on the east and west sides. Considering the difficult climate and environmental and natural elements, the traditional architect has paid attention to the suitable climatic direction. The direction of buildings in villages and cities with cold climates is generally on the foothills' southern slopes (positive slopes). With this type of placement and extension of buildings in the east and west axis, the lowest surface is exposed to adverse winds, which often blow from the west. In addition, the construction of buildings on negative slopes (behind the sun) should be avoided, and positive slopes (slopes facing south and up to +60 degrees of deviation to the east and west) should be selected for the location of buildings [52].

3.3.1. Building Materials in the Cold Climate. What should be examined more carefully in this climate are the materials used in the body of walls and the body of buildings. In most areas and climates, using vernacular materials favorably meets the climatic needs of the region. For example, clay and mud are obtained from the region's clay in hot and dry climates. In temperate and humid climates, wood, found in abundance in temperate and humid areas, meets the climatic demands of the regions. However, in cold climates, such as mountainous areas, the body and walls are often made of stone, which due to the high heat transfer property of the stone causes the heat exchange of the indoor and outdoor spaces to increase. The cold outside enters the interior spaces in the cold areas, and the inside heat is transferred to the outside environment. Therefore, it is recommended to use materials with low density and high heat capacity in cold climates. In ancient times, a Cobb covering was used on the stone wall to prevent this heat exchange. However, the appropriate materials for this climate and materials with low thermal conductivity should be used due to the great variety of building materials in all climates and, most notably, in cold and mountainous climates. This climate has high energy consumption, and in fact, a lot of heat energy is required to heat different parts of a building and stabilize the temperature of various interior spaces. Considering this issue, materials with low heat capacity (porous and lightweight concrete) are among the suitable materials that can be very practical and useful in this climate. However, it should be noted that these materials are more desirable to be used in parts of the building that are used for insulation and are not suitable in parts of the building that require dense materials (such as Trombe walls on the south). In the other parts of the building, where thermal insulation is important, mineral wool (glass wool and rock wool with thermal conductivity of 0.039–0.047 and expanded polystyrene plastics with thermal conductivity of 0.047–0.057) can be used. The proper use of materials such as thermal insulation (felt layers and soft coatings impregnated with bitumen as well as rubbles at the foot of the walls) is another critical factor in removing moisture around the building. The proper use of these materials is a good solution for preventing the infiltration of rising dampness into the walls of the building [53].

3.3.2. Evaluation of Energy-Saving Criteria in Residential Architecture in the Cold Climate. As we know, the number of residential buildings in a city is much higher than office-commercial; in this article, the main emphasis is on residential buildings and their energy consumption. Based on the reviewed sources, factors such as orientation, the layout of the building plan (using the direction of sunlight), and building density are introduced as physical features of the building, which affect energy consumption and are affected by the traditional design model of residential houses [54–56]. Qualitative criteria in case research samples are evaluated using the tools that in this research are energy management indicators in the design of residential architecture in cold climates. Two groups of data are obtained in this study, which is related to the indicators obtained from the two main factors of the research. The first group is the parameters derived from the indicators about the first factor—the characteristics and needs of users—in traditional houses, the information provided by various methods of library studies, document reviews, and interviews with experts. The second group is the parameters obtained about the second factor—the characteristics and needs of the residential environment—in each of these houses, the information obtained by the literature review, interviews with experts, observation, analysis of maps, and investigations of spatial features. In this way, the necessary background for recognizing the criteria related to each indicator, developing a model for each of them, and then evaluating the priority of the indicators in defining the climatic design of traditional houses is provided.

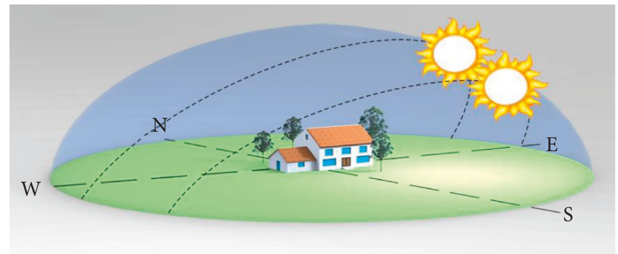


Figure 4: Positions of solar radiation at latitude 37° north in summer and winter seasons [53].

4. Findings and Analysis of the Research

The architecture requires special design measures that, in addition to saving energy consumption, provide very favorable conditions for residents in terms of cooling and heating in a cold and dry climate.

Concerning issues, with the proper design of residential buildings and considering the critical factors suitable for the climatic conditions of this region, efforts are made to create a favorable condition for the comfort of residents in this region. In the history of modern architecture, the achievements of environmental adjustment have significantly affected the visual appearance of many architectural masterpieces. Moreover, the climatic design is an obvious reaction to the visible and hidden forces. In traditional architectural design, instead of relying on HVAC equipment and energy consumption, efforts are made to use the form and orientation of a building so that the necessary comfort is provided by using natural energy flows. Thermal comfort is a state that includes both physical and mental comfort, and designers are obliged to create weather conditions.

Revitalization in this approach: The effort is to minimize the intervention with the structure, and the emphasis is on application change to eliminate functional exhaustion. The primary purpose is to keep the main structure of the old structure and framework unchanged while introducing positive social and economic functions to it.

Now, given the cold weather in this climate in winter, it is tried to create solar space in the building to heat and balance the temperature of the building at night by storing heat during the day. In fact, by the maximum use of thermal energy in winter and creating a temperature draft in summer, it is possible to provide an ideal condition without the intervention of any electrical system. Used sunlight is directly related to the geographical direction of the opening and the building skin relative to the south. At the design stage, only the volumetric orientation of the building in the face of wind and radiation is usually considered, and the composition of the spaces based on the solar cycle is marginalized. We reach the following results by determining the peak hours of receiving solar energy and the position and

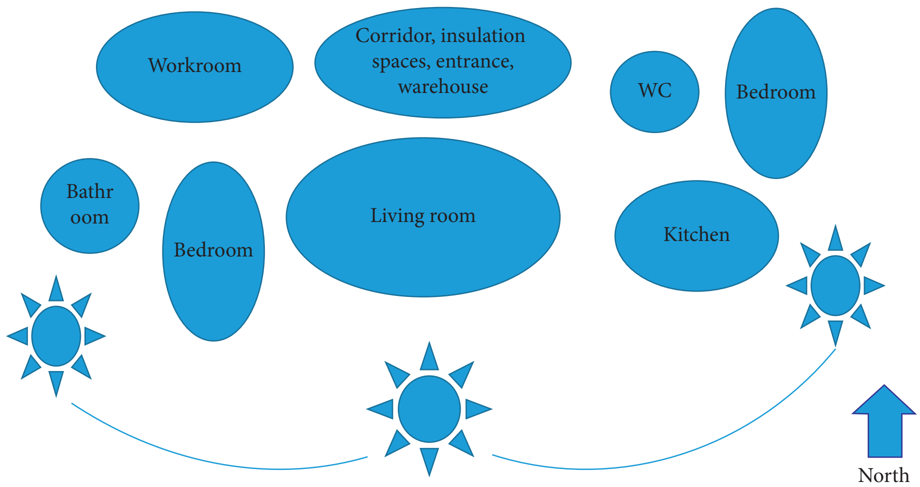


Figure 5: Dominant building partitioning of northwest Iran [57].

angles of solar radiation at latitude 37 degrees north. Since the position of the sun and its radiation is known, the spaces can be designed and laid out to make the most of the beneficial heat of the sun.

The main goal is to find a solution for a more outstanding balance between natural and artificial to achieve a higher level of quality of life and energy storage in residential architecture.

4.1. Solar Altitude Angle. Due to the cold climate in northwest Iran, the main goal of traditional architecture is utilizing solar energy and temperature fluctuations and avoiding cold winter wind to provide thermal comfort. In these areas, extreme cold is the main factor in forming urban and village contexts. The compact cities with central courtyards, flat roofs, low heights of rooms, the good-sized windows facing to the south, and thick walls are the features of northwest buildings. Generally, traditional architecture tries to minimize the building surface's connection with the cold outside in cold areas. As above-mentioned, the northwest of Iran is located about 37° north latitude, so the position of buildings in the purposed area and solar radiation angels in the winter and summer seasons is shown in Figure 4. As can be seen from Figure 4, the buildings are south facing to get the maximum solar energy in winter; the old architects funded it. In addition, building partitioning in the intended area is discussed in the next section.

In the design based on the sun circulation, the space occupancy model by residents during the day and night is the most important factor in the layout of zones (Figure 5).

According to the above figure, the warm and daily used spaces are placed on the south face of the building, the spaces used in the morning are placed on the east section, the spaces used at night are placed on the north section, and the warm spaces are placed on the west front of the building. The cold and dry climate where the spaces are arranged next to each other is dense to store more energy and prevent energy loss. The neighborhoods should be east-westward, and the lighting should be provided from the south-north.

The results of studies conducted for four sample cities and residential buildings in the cold weather context are investigated to achieve the optimal orientation for the location of buildings in cold climates. In the present research, historical houses located in the northwest and northeast of Iran (Tabriz, Urmia, Ardabil, and Maragheh cities) are evaluated, which are located in cold climates. After studies, it was found that the construction of buildings was based on the region's climatic conditions and the direction of sunlight and light. The following table and results are obtained from the review of 29 samples.

Table 3 shows the plan of selected residential buildings. Based on the plan analysis and considering the solar energy role in the cold climates, the following reasons can be derived:

(i) The family living room is located on the south front, and the rooms use southwest light.

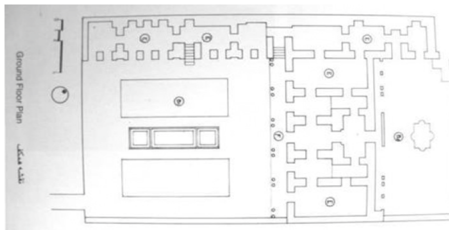
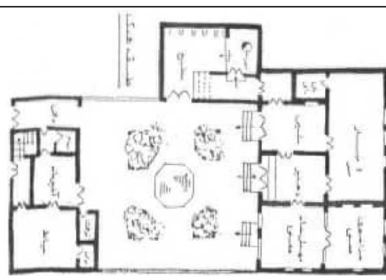
(ii) Retaining spaces such as stairs and entrance warehouses should be located between the main zone and the undesirable front.

(iii) The kitchen is located on the east side of the building to enjoy the morning sun.

4.2. Interpretation of Results. Table 3 shows the results of the analysis of 29 case studies that discussed and studied the plans of historical buildings using solar plans. Based on the 29 samples studied, four models of buildings are given in Table 3. According to this study, it is found that historical buildings received the maximum natural energy by following the orientation of sunlight in all months of the year and other climatic factors.

In Figure 6, 19% of the buildings were constructed in the north, 17% of the buildings were constructed in the northeast, 16% of the buildings were constructed in the northwest of the land (52% in the north in total), 6.7% of the buildings were constructed in the south, 12% of the buildings were constructed in the southeast, 12% of the buildings were constructed in the southwest (30.7% in the

Table 3: Evaluation of the studied architectural plan (Source: Author).

	Plan		Explanation
Tabriz (Sharbat Oghli House)		The lighting direction of north and east	Complies with the solar plan
Urmia (Ansari House)		The lighting direction of north, east, and south	Complies with the solar plan
Mobasheri House		The lighting direction of north and east	Complies with the solar plan
Maragheh (Shahabian House)		The lighting direction of north and east, west	Complies with the solar plan

south in total), 6.7% of the buildings were constructed in the east, and 10.6% of the buildings were constructed in the west.

In Figure 7, the density of the studied buildings was analyzed. 3 units had a density of up to 50%, 22 units had a density of up to 100%, 3 units had a density of up to 150%, one unit had a density of more than 150%, and the percentages are 20% to 50%, 68% to 100%, 9% to 150%, and 2% more than 150%.

The general plan forms in various periods and their changes; most of the plans followed the module of room and atrium, and now all the plans are affected by the region's cold climate. As mentioned, all plans are dense and the close connection of heat-creating spaces such as the kitchen with the living area, the relatively proper use of solar energy, double-glazed windows, and the small size of doors and windows that minimize the connection with the outside space and thick walls can be considered as reasons for the effect of climate on the architecture of this region.

4.3. Limits of the Research. Because this research is a kind of historical study with all case studies aligned accordingly, it is evident that neither time nor limited resource access allowed the deep ancient archeological study to obtain new data. As a result, the best practice was to go through as many available books and documents as possible. Furthermore, due to a lack of sufficient observations or information, studying the shreds of evidence belonging to specific eras became inevitable. In addition, any literature similar to the present study did not do previously to validate this work.

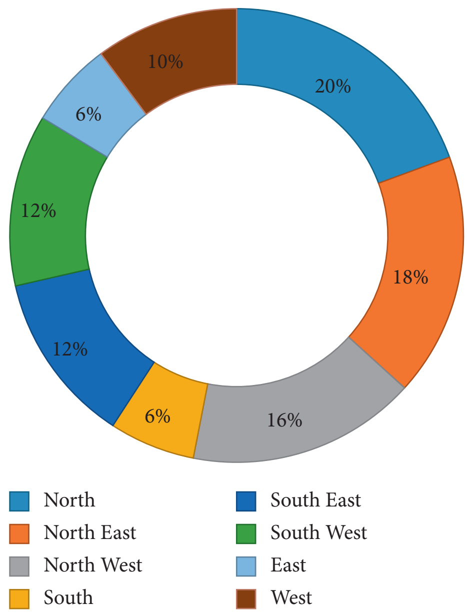


Figure 6: Orientation of the studied buildings (Source: authors based on the research findings).

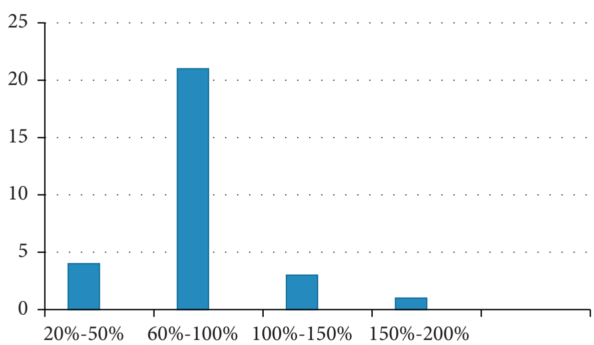


Figure 7: The density of studied buildings (Source: authors based on the research findings).

5. Conclusion

Today, reduction in the consumption of non-renewable energy and maximum use of sustainable and green energy, including solar thermal energy, is considered by architects and building designers. Hence, paying attention to each region's climate and climatic conditions and designing based on climatic conditions, especially in cold and dry climates, is very important. Due to Iran's geographical and climatic location can reach the energy-saving model in contemporary houses by considering other factors such as economy, independence, using natural (non-fossil) energy such as the sun and wind for energy saving, using past experiences, and the help of traditional architectural methods. Therefore, harmonizing the environment with the prevailing climatic conditions is the first step to using natural energy. In other words, the necessary condition for using natural conditions is the coordination and adaptation of buildings to climatic conditions. The optimal orientation of a building has a significant effect on reducing energy demand. Hence, in cold weather, the orientation of a building plays a vital role in its energy demand. Consequently, it is more important to pay attention to the orientation in cold weather conditions. Optimal orientation always reduces the total annual energy consumption. Buildings with optimal orientation need less insulation than those built with other orientations. It can be inferred that orientation plays a more prominent role.

On the other hand, architecture often ignores sufficient attention to the building orientation, which can be important for urban planners and decision-makers. The above analysis and comparison of the structure and unique features of the space in traditional Iranian houses in cold climates and case studies is the main objective of the present research, and various results can be yielded. These results in the similar buildings studied are as follows: In the historical buildings in the cold climate, to reduce the thermal load of the houses, the points necessary to benefit from the sunlight are taken into account. In addition to the orientation of buildings, the layout of interior spaces is very effective in the amount of thermal load of the buildings. By modeling traditional buildings in cold climates, it can be seen that these buildings significantly decrease the thermal load of the building and thus the energy consumption of houses. For architecture to be able to orient toward energy-saving goals and the construction industry to minimize environmental pollution, it is necessary to observe two principles in it: First, the architecture should be flexible, compatible, and adaptable to the environmental conditions and needs of the residents of that region, and measures should be taken so that it can accept future developments at any time and can be updated. Second, the plan should be designed using the surrounding environment and climate in the area, and the materials used in it should be vernacular and returnable to the environmental cycle. Thus, it can be inferred that the designer of such a structure should also be its main planner.

Moreover, as it turned out from the historical documents and traditional houses, the designer must design the building entirely, aware of the environment's information. In other words, the design should be local and indigenous. Finally, it can be concluded that in contemporary houses, according to the climatic conditions of the region, using renewable energy in the main aspect of the building, proper orientation, the layout of spaces next to each other, and choosing the suitable form and volume for the building and building components should be considered.

All of the above solutions seek to make the most of the available and appropriate renewable energy in the region and greater coordination and consistency with the environment and climate of the region. Since this study depends on climatic factors, the same can be repeated in any climatic condition. Further analysis of the results showed that the type of building in the cold climate of Azerbaijan to confirm whether it is compatible with the climate, and further research is needed. Orientation is the best choice for all types of buildings.

Data Availability

There are no available data for this paper.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] B. M. Ziapour, M. Saadat, V. Palideh, and S Afzal, "Power generation enhancement in a salinity-gradient solar pond power plant using thermoelectric generator," *Energy Conversion and Management*, vol. 136, pp. 283–293, 2017.

[2] Y. C. Aydin, P. A. Mirzaei, and S. Akhavannasab, "On the relationship between building energy efficiency, aesthetic features, and marketability: toward a novel policy for energy demand reduction," *Energy Policy*, vol. 128, pp. 593–606, 2019.

[3] C. Cheung, R. Fuller, and M. Luther, "Energy-efficient envelope design for high-rise apartments," *Energy and Buildings*, vol. 37, no. 1, pp. 37–48, 2005.

[4] L. Pérez-Lombard, J. Ortiz, and C. Pout, "A review of building's energy consumption information," *Energy and Buildings*, vol. 40, no. 3, pp. 394–398, 2008.

[5] C. C. Siew, A. Che-Ani, N. Tawil, N. Abdullah, and M. Mohd-Tahir, "Classification of natural ventilation strategies in optimizing energy consumption in Malaysian Office buildings," *Procedia Engineering*, vol. 20, no. 0, pp. 363–371, 2011.

[6] A. Bastide, P. Lauret, F. Garde, and H. Boyer, "Building energy efficiency and thermal comfort in tropical climates: presentation of a numerical approach for predicting the percentage of well-ventilated living spaces in buildings using natural ventilation," *Energy and Buildings*, vol. 38, no. 9, pp. 1093–1103, 2006.

[7] R. V. Ralegaonkar and R. Gupta, "Review of intelligent building construction: a passive solar architecture approach," *Renewable and Sustainable Energy Reviews*, vol. 14, no. 8, pp. 2238–2242, 2010.

[8] C. Zhang, A. A. Mousavi, S. F. Masri, G. Gholipour, K. Yan, and X. Li, "Vibration feature extraction using signal processing techniques for structural health monitoring: a review," *Mechanical Systems and Signal Processing*, vol. 177, Article ID 109175, 2022.

[9] X. Chen, Q. Quan, K. Zhang, and J. Wei, "Spatiotemporal characteristics and attribution of dry/wet conditions in the Weihe River Basin within a typical monsoon transition zone of East Asia over the recent 547 years," *Environmental Modelling & Software*, vol. 143, Article ID 105116, 2021.

[10] C. Guo, C. Ye, Y. Ding, and P. Wang, "A multi-state model for transmission system resilience enhancement against short-circuit faults caused by extreme weather events," *IEEE Transactions on Power Delivery*, vol. 36, no. 4, pp. 2374–2385, 2021.

[11] B. Bathaei, *Process Analysis of environmental perception of Persian garden based on psychological theory of environment*, Vol. 124, EDITURA UNIVERSITAR, ION MINCU, 2016.

[12] L. Qiu, L. He, H. Lu, and D. Liang, "Systematic potential analysis on renewable energy centralized co-development at high altitude: a case study in Qinghai-Tibet plateau," *Energy Conversion and Management*, vol. 267, Article ID 115879, 2022.

[13] S. Kadaei, *Human Presence in the Architectural Environment (From a Phenomenological Perspective)*, p. 144, Bid Publishing, Tehran, 2020.

[14] L. C. Felius, F. Dessen, and B. D. Hrynyszyn, "Retrofitting towards energy-efficient homes in European cold climates: a review," *Energy Efficiency*, vol. 13, no. 1, pp. 101–125, 2020.

[15] Y. Shan, J. Zhao, H. Tong, J. Yuan, D. Lei, and Y. Li, "Effects of activated carbon on liquefaction resistance of calcareous sand treated with microbially induced calcium carbonate precipitation," *Soil Dynamics and Earthquake Engineering*, vol. 161, Article ID 107419, 2022.

[16] O. Hossein Eskandani, S. Yılmaz, and P. Doraj, "Role of nature in the formation of organik architecture," *International Journal of Social Humanities Sciences Research (JSHSR)*, vol. 8, no. 69, pp. 1114–1122, 2021.

[17] B. Bathaei and M. Abdel-Raheem, "Assessment of the relative importance of the main parameters used in the selection of the urban heat island mitigation strategies," *Construction Research Congress*, pp. 627–636, 2022.

[18] F. H. Abanda and L. Byers, "An investigation of the impact of building orientation on energy consumption in a domestic buildiqng using emerging BIM (Building Information Modelling)," *Energy*, vol. 97, pp. 517–527, 2016.

[19] P. Motealleh, M. Zolfaghari, and M. Parsaee, "Investigating climate responsive solutions in vernacular architecture of Bushehr city," *HBRC journal*, vol. 14, no. 2, pp. 215–223, 2018.

[20] M. E. Kohansal, H. R. Akaf, J. Gholami, and S. Moshari, "Investigating the simultaneous effects of building orientation and thermal insulation on heating and cooling loads in different climate zones," *Architectural Engineering and Design Management*, vol. 18, no. 4, pp. 410–433, 2021.

[21] W. S. S. W. Rashdi and M. R. Embi, "Analysing optimum building form in relation to lower cooling load," *Procedia-Social and Behavioral Sciences*, vol. 222, pp. 782–790, 2016.

[22] S. Bodach, W. Lang, and J. Hamhaber, "Climate responsive building design strategies of vernacular architecture in Nepal," *Energy and Buildings*, vol. 81, pp. 227–242, 2014.

[23] S. Saljoughinejad and S. Rashidi Sharifabad, "Classification of climatic strategies, used in Iranian vernacular residences based on spatial constituent elements," *Building and Environment*, vol. 92, pp. 475–493, 2015.

[24] M. A. Keynejad and M. R. Shirazi, *Historical houses of Tabriz*, Vol. 1, Tabriz Islamic Art University Press, Tabriz, Iran, 2010.

[25] S. Kheyri, *Architecture and Decoration of Wooden Verandas in Safavid Ear in Azerbaijan*, vol. 1, Mahdi Azadi's Publications, Tabriz, Iran, 2006.

[26] L. Guo, C. Ye, Y. Ding, and P. Wang, "Allocation of centrally switched fault current limiters enabled by 5G in transmission system," *IEEE Transactions on Power Delivery*, vol. 36, no. 5, pp. 3231–3241, 2021.

[27] X. Xu and M. Nieto-Vesperinas, "Azimuthal imaginary poynting momentum density," *Physical Review Letters*, vol. 123, no. 23, Article ID 233902, 2019.

[28] S. Huang, M. Huang, and Y. Lyu, "Seismic performance analysis of a wind turbine with a monopile foundation affected by sea ice based on a simple numerical method," *Engineering applications of computational fluid mechanics*, vol. 15, no. 1, pp. 1113–1133, 2021.

[29] R. Shaterian, *Climate and Architecture*, Simaye Danesh Publications, Tehran, Iran, 2009.

[30] E. Iranmanesh, N. Darya, M. D. Maryam, and H. Marzieh, "Provide local housing design patterns with emphasis on design elements climatology; case: Kerman," *Urban Management*, vol. 14, no. 38, pp. 347–370, 2015.

[31] K. Steemers, "Energy and the city: density, buildings, and transport," *Energy and Buildings*, vol. 35, no. 1, pp. 3–14, 2003.

[32] R. Gurabi and Bahman, "The relationship between sustainable development of environmental architecture and climate design in mountainous areas Case study," *Geographical*

Quarterly Journal of Environmental Management, vol. 4, no. 14, pp. 21–38, 2011.

[33] A. Heidari, A. Qasemian Asl, and M. Kiai, "Analysis of spatial structure of traditional Iranian homes using spatial method case study: comparison of yazd, kashan, and isfahan houses," *Iranian Islamic City Quarterly*, vol. 7, no. 28, pp. 21–33, 2017.

[34] B. Bathaei, "Achieving sustainable city by the concept of Persian garden," *Acta Technica Napocensis: Civil Engineering & Architecture*, vol. 61, no. 3, 2018.

[35] M. Nhleko and L. Professor Freddie, "Inambao, energy audit on primary municipal facilities: reflection of municipality's energy consumption as a direct consumer of the energy utility (eskom)," *International Journal of Engineering Research and Technology*, vol. 13, no. 12, pp. 4033–4047, 2020.

[36] J. Jerusha and F. L. Inambao, "Trends: energy efficiency and energy security," *International Journal of Engineering Research and Technology*, vol. 13, no. 12, pp. 4084–4117, 2020.

[37] C. Lu, H. Zhou, L. Li et al., "Split-core magnetoelectric current sensor and wireless current measurement application," *Measurement*, vol. 188, Article ID 110527, 2022.

[38] S. Liu, C. Liu, Z. Song, Z. Dong, and Y. Huang, "Candidate modulation patterns solution for five-phase PMSM drive system," *IEEE transactions on transportation electrification*, vol. 8, pp. 1194–1208, 2022.

[39] H. Tian, J. Pei, J. Huang et al., "Garlic and winter wheat identification based on active and passive satellite imagery and the google earth engine in northern China," *Remote Sensing*, vol. 12, no. 21, p. 3539, 2020.

[40] P. Doraj, M. Baran, and O. Hossein Eskandani, "Using thermal potential of the earth to optimize energy consumption in architectural structures," *Natural Volatiles & Essentional Oils (NVEO) Journal*, vol. 9, no. 1, pp. 7–20, 2022.

[41] J. Yuan, D. Lei, Y. Shan, H. Tong, X. Fang, and J. Zhao, "Direct shear creep characteristics of sand treated with microbial-induced calcite precipitation," *International Journal of Civil Engineering*, vol. 20, no. 7, pp. 763–777, 2022.

[42] L. Qiu, L. He, H. Lu, and D. Liang, "Pumped hydropower storage potential and its contribution to hybrid renewable energy co-development: a case study in the Qinghai-Tibet Plateau," *Journal of Energy Storage*, vol. 51, Article ID 104447, 2022.

[43] M. Shams and M. Khodakarami, "Study of traditional architecture in harmony with the cold climate," *Geographical Preparation of the Quarterly*, vol. 3, no. 10, pp. 91–114.

[44] A. Rogora, "Simplified methods and tools for the representation of energy in the project of architecture," in *Bioclimatic Approaches in Urban and Building Design*, G. Chiesa, Ed., PoliTO Springer Series. Springer, Cham, 2021.

[45] G. K. Oral, A. K. Yener, and N. T. Bayazit, "Building envelope design with the objective to ensure thermal, visual, and acoustic comfort conditions," *Building and Environment*, vol. 39, no. 3, pp. 281–287, 2004.

[46] S. B. Sadineni, S. Madala, and R. F. Boehm, "Passive building energy savings: a review of building envelope components," *Renewable and Sustainable Energy Reviews*, vol. 15, no. 8, pp. 3617–3631, 2011.

[47] S. Al-Saadi and I. Budaiwi, "Performance-based envelope design for residential buildings in hot climates," in *Proceedings of Building Simulation*, Beijing city, January 2007.

[48] S. Sabouri, *Optimization of Architectural Properties of a Tropical Bungalow House with Respect to Energy Consumption*, Universiti Kebagnsaan Malaysia, Malaysia, 2012.

[49] U. DoE, *Buildings Energy Databook*, Energy Efficiency & Renewable Energy Department, 2011.

[50] M. Biddulph, *Introduction to Residential Layout*, Elsevier, Oxford, 2007.

[51] Department of Housing and Urban Development, *An Experience for Documentation of Iranian Bazaars, Iran's Bazaar*, Jahad Daneshgahi Press, Tehran, Iran, 2010.

[52] C. Binggeli, *Building Systems for interior Designers*, John Wiley & Sons, 2003.

[53] T. Iran, *The 19th Issue of Iran National Building Regulations, Deputy of Housing and Building*, Tehran, Iran, 2010.

[54] V. Ghobadian, *Traditional Buildings*, Tehran University Press, Tehran, 2015.

[55] Khalil and Allah, "Energy Efficiency Strategies in Urban Planning of Cites," in *Proceedings of the 7th International Energy Conversion Engineering Conference*, Reston, US, August 2009.

[56] B. Bathaei, "Persian enclosed garden: recognition & recreation of the Persian garden," *Revista Şcolii Doctorale de Urbanism*, vol. 1, no. 1, pp. 53–56, 2016.

[57] S. Kadaei, M. Majidi, Q. Asaee, and H. H. Mehr, "Hotel construction management considering sustainability architecture and environmental issues," *Shock and Vibration*, vol. 2021, Article ID 6363571, 13 pages, 2021.