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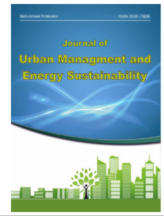

CASE STUDY RESEARCH PAPER

Integrating Vernacular Patterns and Modern Passive Design Strategies for Energy Optimization in Iran's Hot-Arid Climate (Case Study: Qom City)

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ABSTRACT

The building sector is a major consumer of energy, particularly in hot-arid regions where intense summer heat, large diurnal temperature variations, and limited naturally comfortable periods increase dependence on mechanical heating and cooling. The aim of this research was to develop an integrated framework for improving thermal comfort in residential buildings in Qom city by combining the principles of Iranian vernacular architecture with contemporary climatic analysis. The research methodology employed a mixed qualitative–quantitative approach. In the qualitative phase, 34 candidate strategies were identified through a review of peer-reviewed studies, books, specialized reports, and documented examples of vernacular residential architecture in Iran's hot-arid regions. After applying predefined inclusion and exclusion criteria, 20 passive and low-energy design strategies were retained. In the quantitative phase, Qom's climatic conditions were evaluated using Climate Consultant and the ASHRAE Standard 55 thermal comfort model based on a standardized EPW typical meteorological year dataset (1991–2020), with separate analyses for the cold and hot seasons. The results and discussion showed that naturally comfortable conditions occur during only a limited portion of the year. During the hot season, two-stage evaporative cooling achieved the highest applicability, addressing 80.2% of selected hourly conditions. Solar shading, natural ventilation, building and courtyard orientation, vegetation, and high-thermal-mass materials were identified as the most influential passive design strategies. The conclusion indicates that the integrated screening and climatic validation process produced 20 operational strategies, providing an evidence-based framework for reducing mechanical energy demand, improving thermal comfort, and adapting traditional Iranian architectural principles in hot-arid regions.

Running Title: Vernacular and Passive Design Strategies in Qom city

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
37	10	05

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INTRODUCTION

With the advancement of technology, rapid population growth, and the increasing trend of urbanization, the contemporary world is confronted with profound challenges in energy resource consumption challenges that affect not only the macroeconomic level of the global economy, but also various aspects of daily life, human health, and environmental sustainability. Among the most serious and fundamental concerns of the present era is the excessive and accelerating consumption of energy, which has emerged as a major threat to the future of human societies. Within the various energy-consuming sectors, the construction industry occupies a distinctive position. According to global statistics, the building sector accounts for approximately 40% of global energy consumption (Asadpour and Habibi, 2015) and more than 30% of mineral resource use, in addition to contributing to greenhouse gas emissions and waste generation (Asadpour and Asadpour, 2014). This high percentage is also evident in Iran, where the share of this sector in national energy consumption is estimated at around 36%. This reality not only underscores the economic dimensions of the issue, but also indicates that these benchmarks can serve to evaluate the performance and environmental impact of buildings. The increasing energy consumption in this sector translates into higher greenhouse gas emissions, environmental pollution, depletion of non-renewable resources, and, consequently, the intensification of environmental crises. In parallel with technological advancements and changing lifestyle patterns, the need for effective resource management is now more apparent than ever (Mahdinejad and Shirdel, 2024).

In this context, sustainable architecture, as a progressive and modern approach in the field of design and construction, plays a pivotal role in environmental protection and energy optimization. The core principles of this approach include the efficient use of renewable resources, intelligent design, the selection of environmentally friendly materials, and consideration of the cultural and climatic conditions of each region. Such an approach can not only reduce the negative impacts of human activities on ecosystems but also enhance quality of life and human comfort (Reddy et al., 2024).

Evidence from numerous studies indicates that buildings complying with sustainability criteria can consume up to 30% less energy compared to traditional counterparts. Moreover, attention to climate-responsive design, the utilization of advanced technologies, and the increased adoption of clean energy sources such as solar, wind, and hydro power can contribute to reducing operational costs while enhancing occupant comfort (Selvaraj, 2023). This significance is particularly evident in countries such as Iran, which face both wide climatic diversity and challenges in natural resource management. In line with this trend, the implementation of international standards and certifications such as LEED, BREEAM, and Green has been emphasized worldwide to promote climate-conscious design practices and environmental conservation.

Nevertheless, in recent years, contemporary Iranian architecture has not paid sufficient attention to the principles of sustainability and the components of vernacular architecture, the consequences of which are now evident in many aspects. Vernacular and traditional Iranian architecture, however, can serve as suitable models for contemporary construction (Mahdinejad et al., 2020), as it achieved high levels of desirability and acceptance through the use of locally sourced materials, the utilization of natural light, and the creation of spaces harmonious with nature. In this regard, Iranian vernacular architecture is a heritage founded on wisdom and experience, integrating cultural, climatic, economic, and technological capacities, and can be employed as a source of inspiration and guidance for optimizing energy consumption.

To achieve the primary objective, this research seeks to answer the following three interconnected questions, which guide the integration of vernacular strategies into a modern sustainable framework:

1.What are the key architectural and climatic factors that determine the efficiency of natural ventilation in the hot and arid climate of Qom?

2.Which specific historical patterns and courtyard-related strategies in Qom's vernacular architecture are most effective for enhancing thermal comfort?

3.How can these traditional strategies be systematically integrated into a modernized design framework to optimize energy consumption in contemporary residential buildings?

In this regard, the present study employs the Climate Consultant software to analyze the climatic conditions and rank the factors influencing the construction of sustainable buildings in the hot and arid climate of Qom. Furthermore, in line with the reduction and optimization of non-renewable energy consumption, sustainable architectural design strategies have been extracted and presented. Accordingly, the primary objective of this research is to establish an integrated analytical framework that evaluates the influence of central courtyard orientation on natural ventilation efficiency, thereby providing a pathway toward sustainable housing that aligns architectural design with environmental preservation for future generations.

Research background

In recent years, growing attention to environmental issues and the crises associated with pollution and climate change has led to significant shifts in the architectural community's perspective on climate and sustainability. Designers and researchers in this field, recognizing the importance of sustainability, have expanded their focus beyond mere aesthetics and functionality to include the environmental impacts of buildings, thereby prioritizing a sustainable architectural approach (Arab & Farrokhzad, 2017). Sustainable architecture, as an innovative strategy in design and construction, seeks to minimize the negative environmental impacts of building activities while providing models for optimizing the consumption of natural resources. This approach, particularly over recent decades, has gained increasing prominence in parallel with the intensification of climate change and the heightened international concern for environmental preservation (Selvaraj et al., 2023).

The fundamental goal of sustainable architecture is to create a healthy and comfortable environment for people while minimizing damage to nature and the depletion of non-renewable resources (Memarian, 2014). The intensification of environmental degradation has raised global concerns, making the development of sustainable systems and policies one of the key priorities on the agendas of nations, including Iran (Valizadeh Oghani and Movahedi, 2019). Within this framework, issues related to sustainable architecture have gained increased importance, and the adoption of successful models in tandem with modern technologies has been recognized as an effective strategy for combating environmental harm (Molanayi and Soleimani, 2016; Mashhoor, 2020). Passive systems, harmonized with nature such as those providing heating, cooling, and natural lighting (Ghiabaklou, 2016; Rahaei et al.,2026) alongside modern sustainable construction systems, play a pivotal role in advancing architectural sustainability (Ghadiri-Moghadam et al., 2019). Furthermore, energy optimization in buildings now incorporates advanced technologies, intelligent design, and the selection of appropriate materials, which not only reduce energy consumption but also enhance the comfort and convenience of occupants. Previous studies indicate that the implementation of green-building and sustainable-design strategies can substantially reduce operational energy consumption compared with conventional building practices (Afzal et al., 2023).The mission of sustainable architecture is to create buildings that are not only in harmony with nature and environmentally friendly but also safeguard the cultural and historical values of society (Gorji Mehlabani, 2010). In essence, architecture rooted in context and nature is the outcome of a deep understanding of the principles of sustainable development (Rahimi Mehr, 2013).

Traditional Iranian architecture has consistently reflected the climatic conditions of each region, the accumulated experiences of previous generations, and indigenous teachings in its design patterns, making it a valuable source of inspiration for addressing contemporary architectural needs. In every climate, Iranian houses were shaped by a profound understanding of local weather conditions and construction methods. Evidence shows that traditional Iranian architecture not only met the physical and psychological needs of inhabitants but also took into full account the specific climatic characteristics of each region. Climate-centered design not only optimizes energy consumption but also enhances residents' quality of life and reduces costs. Overall, vernacular architecture has always served both people and the environment, with builders striving to create an effective connection between nature and humanity and to revive human-centered spaces with the least possible environmental damage.

In this context, tools such as climatic simulation software, notably Climate Consultant, have acquired a prominent role in sustainable architecture research. By providing precise data and comprehensive analyses of climatic conditions, this software enables architects to make more informed decisions during the design process and to visually and intelligibly assess the climatic impacts on building energy consumption (Dinku et al., 2022). Its ability to simulate the performance of windows, shading devices, insulation, and other architectural components allows designers to identify and implement the most suitable solutions in accordance with local conditions (Betti et al., 2024).Moreover, the capacity to evaluate the effects of each solution on reducing energy loss and greenhouse gas emissions represents a significant step toward enhancing building sustainability and mitigating environmental impact.The precise and visual data provided by this tool allow decision-makers to easily compare various design options and arrive at scientifically sound choices (Roradeh and Baaghideh, 2024). Given the scientific credibility of this software and its frequent application in numerous studies, its analytical outputs are considered reliable and applicable in sustainable design approaches.

Ultimately, despite the growing importance of sustainability across various societies, the role of climatic factors and environmental requirements has, regrettably, not received adequate attention in the design of contemporary buildings particularly in residential applications. Accordingly, the present study focuses on sustainable residential architecture in the hot and arid climate of Qom and employs climatic analysis using Climate Consultant to propose strategies for optimizing energy consumption and achieving climate-responsive residential design in the region.

MATERIALS AND METHODS

Sustainable Climate-Based Design and Thermal Comfort in Hot and Arid Regions:

Sustainability in architecture has evolved from purely passive traditions toward contemporary approaches that integrate advanced technologies to improve energy efficiency. Current sustainable design prioritizes reducing building energy consumption one of the largest contributors to global energy use through low-energy and net-zero strategies. Performance-based design and the optimization of building envelope, form, and shading help balance aesthetics, functionality, and energy efficiency (Moroni et al., 2024; He et al., 2024; Olfat et al.,2025). Passive design strategies, especially those rooted in vernacular architecture, are essential for achieving low-carbon and long-term sustainability. Their effectiveness increases when combined with environmental simulations, dynamic modeling, and computational optimization (Rouhi et al., 2024; He et al., 2024; Vatankhah et al., 2024). In hot and arid climates, climate-responsive design is a key pillar of sustainable architecture, supported by standards such as ASHRAE 55 and EN

16798 for evaluating thermal comfort and indoor environmental quality (Naghipour et al., 2025). Both traditional and modern climate-responsive strategies aim to provide thermal comfort while minimizing reliance on mechanical systems. These include windcatchers, central courtyards, shading devices, and phase change materials for thermal storage (El Azhary et al., 2021; Salameh and Touqan, 2022). Contemporary design adapts these principles through climatic simulations and parametric optimization to meet current needs, ensuring comfort with lower energy demand (Vatankhah et al., 2024). Studies consistently show that passive techniques such as optimal orientation, efficient massing, and natural ventilation reduce heat gain and enhance indoor environmental quality (El Azhary et al., 2021; Salameh and Touqan, 2022).

Vernacular Architecture of Iran and Contemporary Innovations

Iranian vernacular architecture in cities such as Qom, Yazd, and Kashan demonstrates effective adaptation to hot-arid climatic conditions through the integrated use of central courtyards, high-thermal-mass walls and materials, windcatchers, compact morphology, shading elements, earth-contact spaces, and natural ventilation. These strategies help moderate indoor temperature fluctuations, enhance airflow, reduce solar heat gain, and improve thermal comfort, thereby providing valuable references for sustainable contemporary architectural design (El Azhary et al., 2021; Salameh & Touqan, 2022; Chohan & Awad, 2022; He et al., 2024; Vatankhah et al., 2024) (Table 1).Recent research increasingly explores the integration of this vernacular knowledge with modern technologies, including building-integrated photovoltaics, intelligent environmental control systems, and bioclimatic or biomimetic design approaches (Gutiérrez, 2023; He et al., 2024). Such hybrid strategies seek to enhance energy efficiency while preserving cultural identity and meeting contemporary lifestyle demands (Gutiérrez, 2023). Studies from 2020 to 2025 show that vernacular buildings often outperform modern ones in thermal comfort and energy efficiency when passive strategies are well adapted to local climates (El Azhary et al., 2021; Sharma, 2024). However, challenges remain, particularly the lack of clear frameworks for systematically integrating vernacular principles with advanced active systems such as intelligent HVAC (He et al., 2024; Abdeldjaouad et al.,2025). To address this gap, the framework proposed in this study promotes a hybrid approach that combines environmentally responsive vernacular principles with contemporary technologies, aiming to achieve energy-efficient, sustainable architecture that respects cultural heritage and current societal needs (He et al., 2024; Gutiérrez, 2023). (Tab. 1)

Table 1: Strategies and Key Outcomes in Sustainable and Vernacular Architecture

Strategy and Elements	Impact on Energy and Comfort	Example of Modern Integration	References
Courtyard, Thick Walls, Windcatcher	Reduction of Heat Transfer, Improvement of Comfort	BIPV, Smart Controls, Phase Change Materials (PCM)	El Azhary et al. (2021); Salameh and Touqan (2022); He et al. (2024)
Passive Solar Orientation	Reduction of Cooling/Heating Demand	Parametric Optimization	(Vatankhah et al., 2024; El Azhary et al., 2021)
Shading Devices, Natural Ventilation	Improvement of Thermal Comfort, Reduction in HVAC Usage	Simulation Tools, AI Based Optimization	(Salameh and Touqan, 2022; Li et al., 2020)

The aim of the present study is to identify, analyze, and redefine effective strategies for optimizing energy consumption in residential buildings located in Iran's hot-arid climate, with particular emphasis on the city of Qom city.

To fulfill the primary objective of this research, a multi-stage methodological framework is adopted to systematically identify and analyze climate-responsive strategies and to redefine the role of courtyard orientation in enhancing passive cooling performance. Given the multi-dimensional nature of the research problem, a mixed-methods design combining qualitative and quantitative evidence was adopted to provide a comprehensive interpretation of the climatic and architectural findings (Creswell & Plano Clark, 2018). The climatic analysis was based on long-term meteorological data covering the period 1991–2020 for the city of Qom, representing its hot and arid climatic conditions.The climatic analysis is based on long term meteorological data covering a 30 year period for the city of Qom, representing its hot and arid climatic conditions. These data were obtained from standardized and validated meteorological databases derived from local weather station records and formatted for use in Climate Consultant software. The dataset includes key climatic variables such as dry bulb temperature, relative humidity, solar radiation, and wind characteristics. Climate Consultant was employed to process, organize, and statistically analyze the long term climatic data, generating climate summaries, bioclimatic charts, and climate based design strategy recommendations. This approach ensures methodological transparency, reproducibility, and consistency with established climate responsive design frameworks. The climatic analysis was based on a standardized EPW typical meteorological year dataset derived from long-term meteorological records for Qom. The dataset represents the city's hot-arid climatic conditions and includes dry-bulb temperature, relative humidity, solar radiation, wind speed, wind direction, and other relevant climatic variables. Climate Consultant was used to process the dataset and generate climate summaries, bioclimatic charts, and climate-responsive design recommendations.

Step One – Qualitative Descriptive Analytical Method:

In the first step, a qualitative descriptive analytical method was applied. This stage involved the use of library resources, including books, peer reviewed articles, specialized reports, and reputable national and international studies, to gather and analyze data related to vernacular architecture, climate responsive design, and the principles of sustainable architecture. Acting as the foundation for the development of the study's theoretical framework, this phase facilitated the clarification of key concepts, the identification of effective traditional strategies, and the establishment of their connection to contemporary sustainable architecture objectives. This analytical approach enabled the extraction of functional patterns from Iran's vernacular architecture particularly in the cities of Yazd, Kashan, and Qom leading to a structured understanding of how traditional spatial configurations have adapted to the hot and arid climatic conditions (El Azhary et al., 2021; Salameh & Touqan, 2022; He et al., 2024). An initial pool of 34 candidate strategies was compiled, including 17 vernacular architectural strategies identified from peer-reviewed studies, books, and documented examples of residential architecture in Iran's hot-arid regions, as well as 16 climate-responsive strategy categories derived from the Climate Consultant outputs. A strategy was retained when it: (1) was applicable to residential buildings in hot-arid climates; (2) had a clear relationship with thermal comfort, solar control, natural ventilation, thermal storage, or energy-demand reduction; (3) was supported by at least two independent sources or was consistent with the climatic outputs generated by Climate Consultant; and (4) could be translated into an applicable contemporary design recommendation. Duplicated or overlapping strategies, features with no clearly demonstrated climatic function, measures unrelated to the residential scale, and strategies unsupported by either the literature or the climatic analysis were excluded. Following the screening, comparison, and consolidation process, 20 passive and low-energy design strategies were retained and presented in Tab. 5. No interviews, surveys, expert panels, practitioner consultations, or other forms of human-subject input were used in the identification, screening, or validation of the strategies. The selection process was based exclusively on published literature, documented vernacular examples, and the climatic outputs generated by Climate Consultant.

Step Two – Quantitative Analytical Phase:
In the second stage, the research progressed to the quantitative analytical phase. The city of Qom was selected as the case study because it represents Iran's hot-arid climatic conditions and possesses a rich heritage of vernacular architecture that has evolved in response to local environmental constraints. A standardized EPW typical meteorological year dataset for Qom, derived from long-term meteorological records covering the period 1991–2020, was analyzed using Climate Consultant. As a reliable and widely used tool in climate-responsive design and building energy optimization, Climate Consultant enables both visual and numerical analysis of climatic parameters, including dry-bulb and wet-bulb temperatures, relative humidity, solar radiation, wind speed and direction, and cloud cover (Dinku et al., 2022; Roradeh and Baaghideh, 2024) see (Fig. 1).

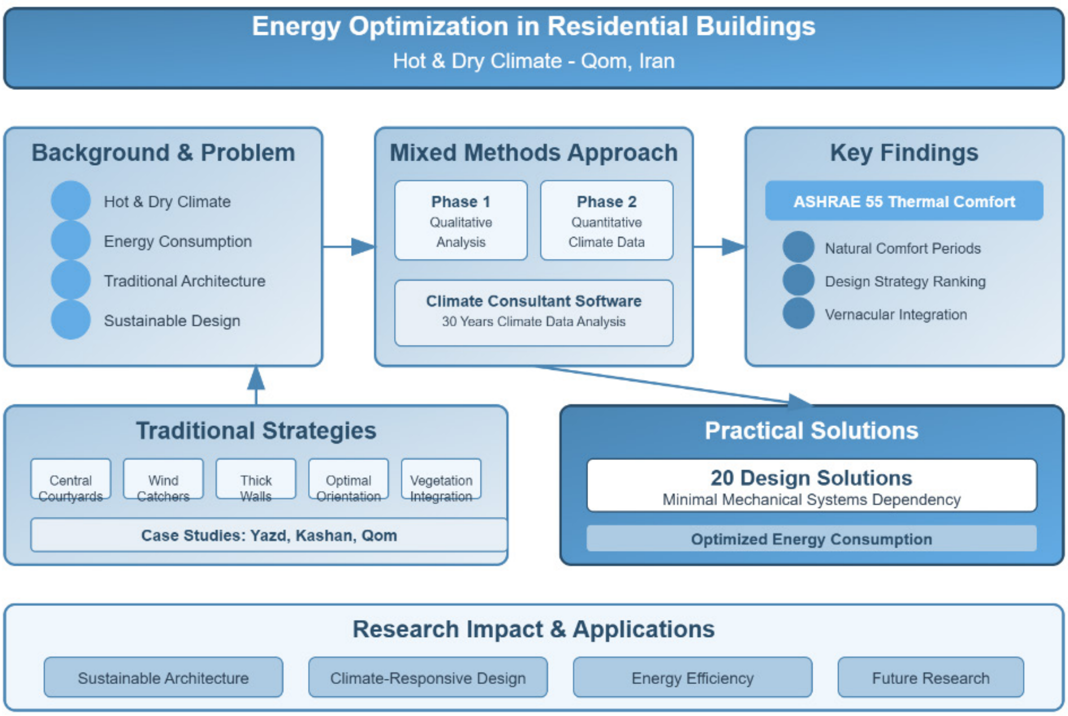


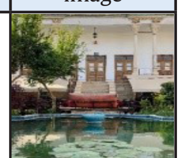
Figure 1 : Overview of the research framework for energy optimization in residential buildings located in hot and arid climates.

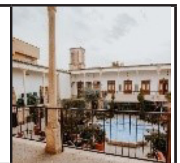
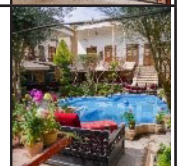
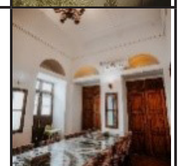
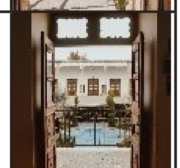
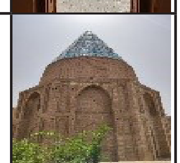
The analyses performed in Climate Consultant particularly the thermal comfort charts derived from ASHRAE Standard 55 enabled the accurate identification of specific periods throughout the year during which natural comfort conditions are achieved. Furthermore, by utilizing factor ranking tools to assess the relative impact of thermal comfort determinants in both hot and cold seasons, it was possible to prioritize climate responsive design strategies appropriate to local conditions. These systematic evaluations provided a scientifically sound and reliable basis for formulating actionable design recommendations.Ultimately, the qualitative and quantitative results were analyzed and interpreted in an integrated manner. In this stage, strategies derived from vernacular architecture such as central courtyards, windcatchers, thick masonry walls, optimal building orientation, and the incorporation of vegetation were compared and cross validated against the outcomes of the climatic analysis. This synthesis enabled the re definition and adaptation of these measures within the framework of contemporary architecture, aligned with present day functional and environmental requirements.As a result, a set of 20 operational design strategies was formulated, aimed at achieving thermal comfort with minimal reliance on mechanical systems, thereby optimizing energy consumption in hot and arid climates.This research method by integrating vernacular knowledge with scientific climatic analysis follows a recognized approach in sustainable architecture studies, wherein vernacular architecture is regarded as a repository of tested experiential knowledge (He et al., 2024; Gutiérrez, 2023). Moreover, the use of Climate Consultant as a standard and widely acknowledged tool for climate analysis strengthens the scientific validity and reliability of the findings (Vatankhah et al.,2024; Betti et al., 2024).

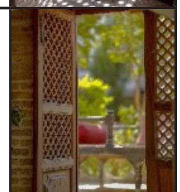
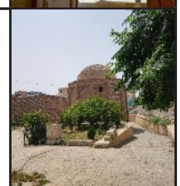
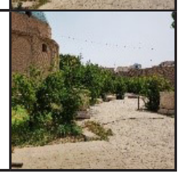
FINDINGS AND DISCUSSION

In advancing the goals of sustainable development and reducing the negative environmental impacts of human activities, sustainable architecture has emerged as an essential and strategic approach in design and construction. This study, aimed at identifying effective strategies for optimizing energy consumption and enhancing thermal comfort in Iran's hot and dry climate with a focus on the city of Qom, conducted an integrated analysis of vernacular knowledge and high resolution climatic data. The findings indicate that Iranian vernacular architecture particularly in cities such as Qom, Yazd, and Kashan embodies operational, empirically tested knowledge for adapting to severe climatic conditions. Elements such as the central courtyard, windcatchers, thick masonry walls, appropriate orientation, vegetation, and the use of local materials have proven not only functionally effective but also valuable models for contemporary sustainable design. To obtain the results presented in (Tab. 2), a hybrid research approach was employed. In the first phase, a qualitative review and analysis of vernacular knowledge in Iran's hot arid cities identified traditional strategies; in the second phase, these findings were verified and refined through quantitative analysis of Qom's climatic data using Climate Consultant.

Table 2: Strategies Employed in Buildings of Iran's Hot Arid Climate for Energy Optimization. (Source: Authors).

NO.	Strategy	Description	image
1	Optimal building orientation	In hot-arid climates, NE-SW orientation minimizes solar/wind exposure while optimizing natural ventilation. (He et al., 2024; Salameh and Touqan, 2022)	
2	Central courtyard	In hot arid houses, the central courtyard offers cooling, shade, improved ventilation, and a private outdoor space. Salameh and Touqan (2022); He et al. (2024)	
3	Construction materials	In hot arid regions, locally available materials with high thermal mass and light colors help stabilize indoor temperatures and reduce energy demand. (El Azhary et al., 2021; Sharma, 2024)	

4	Sunken garden	In hot arid climates, sunken courtyard houses reduce heat exchange, reuse excavated soil, support irrigation, and improve structural stability. He et al. (2024); El Azhary et al. (2021)	
5	Landscape vegetation	Courtyard trees and vegetation provide shade, promote evapotranspiration, and moderate the local microclimate, thereby improving outdoor and indoor thermal comfort (Salameh and Touqan, 2022)	
6	Windcatcher	Windcatchers capture prevailing winds, direct cooler air into interior spaces, and remove warm air through pressure differences and stack ventilation, thereby reducing dependence on mechanical cooling (Chohan & Awad, 2022; Salameh & Touqan, 2022).	
7	Specific morphology	Compact and inward-oriented building morphology reduces the external surface area exposed to solar radiation, increases self-shading, protects interior spaces from hot winds, and improves thermal performance in hot-arid climates (Salameh & Touqan, 2022; He et al., 2024).	
8	Seasonal division of spaces	Seasonal spatial organization allows occupants to use different parts of the building according to variations in solar exposure, shading, daylight, and natural ventilation throughout the year. (He et al., 2024; Salameh and Touqan, 2022; El Azhary et al., 2021)	
9	iwan and shading elements	Wide iwans, overhangs, and other shading elements reduce direct solar gain and improve indoor and outdoor thermal comfort. (Vatankhah et al., 2024 Moroni et al., 2024)	
10	Limited and small openings	Limited and appropriately positioned openings reduce direct solar heat gain and the entry of hot outdoor air while helping retain cooler indoor conditions (El Azhary et al., 2021; Salameh & Touqan, 2022).	
11	Thickened walls	Thick earthen, brick, or masonry walls provide high thermal inertia, delay heat transfer, and moderate indoor temperature fluctuations between day and night (El Azhary et al., 2021).	
12	Use of pools and water features	Courtyard pools and other water features improve the local microclimate through evaporative cooling and, when combined with shading and airflow, contribute to improved outdoor and indoor thermal comfort (Salameh & Touqan, 2022; He et al., 2024).	

13	Light colored exterior façades	Light-colored exterior surfaces reflect a greater proportion of incident solar radiation, reduce solar absorption and surface temperatures, and consequently limit heat transfer into the building (Salameh & Touqan, 2022).	
14	Openings and rooflights	Rooflights and high-level openings provide controlled daylight and support stack-driven ventilation by allowing accumulated warm air to escape from interior spaces. (Vatankhah et al., 2024; He et al., 2024; Gutiérrez, 2023)	
15	Utilization of underground and cellars	Underground spaces and cellars benefit from the relatively stable temperature of the ground and limited exposure to solar radiation, providing cooler conditions and reducing cooling demand during hot periods (Arab & Farokhzad, 2017; Salameh & Touqan, 2022).	
16	Design of entrance filters and transitional vestibules	Entrance filters, bent entrances, and transitional vestibules function as thermal buffers between outdoor and indoor environments, limiting the direct entry of hot air, dust, and solar radiation into occupied spaces.	
17	Creation of perimeter fences and high perimeter walls	High perimeter walls increase courtyard shading and protect interior spaces from hot, dusty, and undesirable winds. Salameh and Touqan (2022)	

Subsequently this section examines and interprets the charts generated by Climate Consultant software to understand the climate of Qom and develop appropriate design strategies. According to (Fig. 2) (temperature chart), thermal comfort conditions in Qom occur during mid-spring and early autumn. Low temperatures in early winter and late autumn deviate significantly from the comfort range (20–26 °C), as illustrated in the chart. The data indicate that the minimum temperature in winter is approximately −2 °C, while the maximum summer temperature reaches around 44 °C. Considering the substantial thermal amplitude between hot and cold periods in this city, there is a high demand for both cooling and heating systems, which can be mitigated through sustainable architectural patterns aimed at optimizing energy consumption.

According to (Fig. 3 and 4) (dry-bulb and wet-bulb temperature charts), in Qom, approximately 1% of the days in a year experience temperatures below 0 °C, about 50% of the days record temperatures between 0 and 21 °C, around 17% of the days fall within the range of 21 to 27 °C, and approximately 5% of the days exceed 38 °C. It is noteworthy that from early spring to early autumn, the city experiences the greatest difference between dry-bulb and wet-bulb temperatures.

According to (Fig. 5), the annual illumination conditions in Qom were evaluated using the Climate Consultant illumination-range chart. The approximate annual average direct normal illumination was 52,000 lux, while the global horizontal illumination was approximately 48,000 lux. Monthly variations indicate higher daylight availability during the warmer and sunnier months and lower illumination levels during late autumn and winter.

According to (Fig. 6) (cloud cover levels), the highest cloud cover in Qom occurs in March, at approximately 35%, while the lowest occurs in September, at about 3%. On an annual basis, average cloud cover is around 20%. Furthermore, analysis of (Fig. 7) (wind speed chart) shows that the highest wind speed is recorded in July, at approximately 4 m/s, characterized by warm winds, whereas the lowest wind speeds occur in December and January, at about 2 m/s. The annual mean wind speed in Qom is approximately 2.5 m/s.

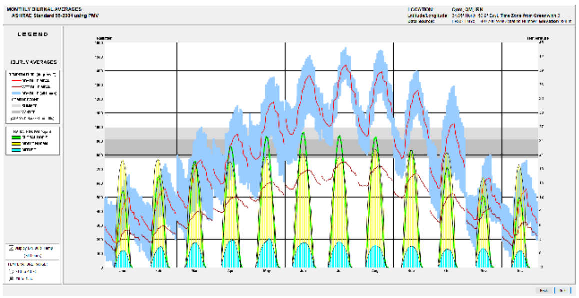


Figure 2: Temperature Chart

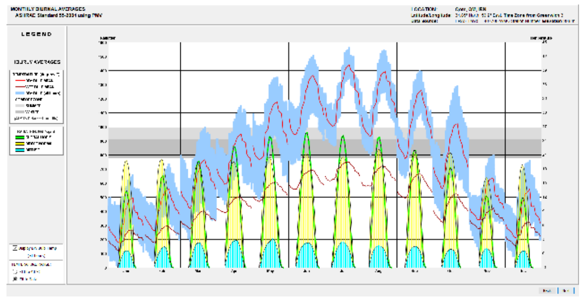


Figure 3: Wet-Bulb and Dry-Bulb Temperature Chart

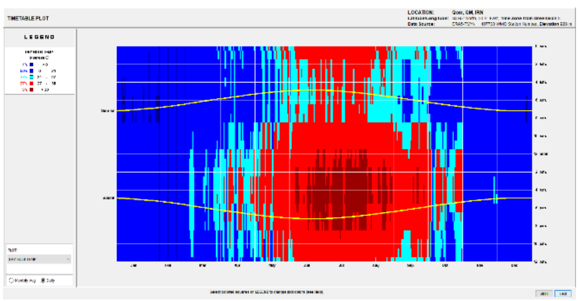


Figure 4: Wet-Bulb and Dry-Bulb Temperature Chart

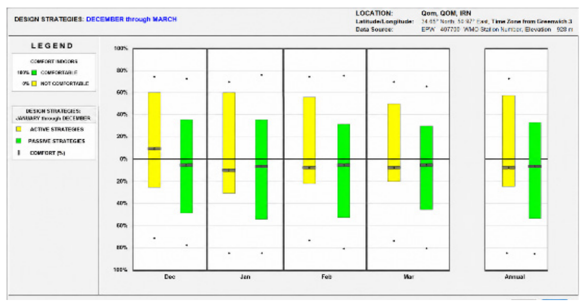


Figure 5: Monthly and Annual Illumination Range in Qom

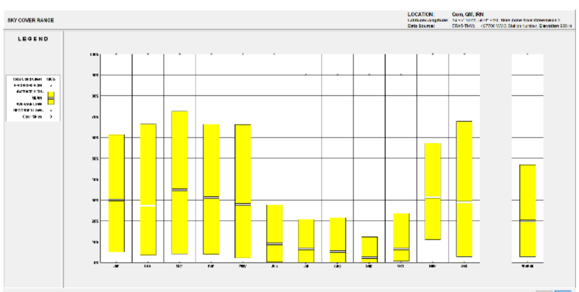


Figure 6: Cloud Cover Chart

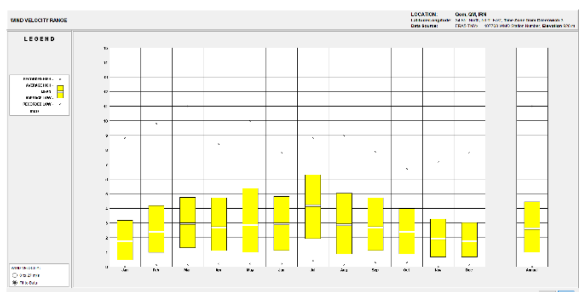


Figure 7: Wind Speed Chart

Based on the data presented in Fig. 8 (relative humidity and dry-bulb temperature charts) for Qom, the most humid months are December, January, February, and November, with relative humidity reaching approximately 80%. The driest months are June, July, and August, with humidity levels dropping to around 38%. Additionally, in September, October, April, and May, temperature and relative humidity conditions are closer to the comfort range (20–26 °C). (Fig. 8)

In the following section the results of ranking the factors influencing the improvement of thermal comfort in Qom are examined. (Fig. 9) evaluates and ranks the factors affecting the creation of thermal comfort conditions during the four cold months of the year (December, January, February, and March). Based on analyses conducted using the Climate Consultant software and applying the ASHRAE 55 thermal comfort model, the chart quantitatively illustrates which design and operational strategies can most effectively reduce the number of hours outside the comfort range, thereby bringing the building's interior environment closer to optimal conditions. Figure 9 presents the results of the Climate Consultant analysis for the four cold months of December, January, February, and March. The analysis was rerun using the correct month selection, and the strategy labels, applicable hours, and percentages were transferred directly from the verified software output. The cold-season results were also checked independently against the June–August analysis to ensure that the data presented in Figures 9 and 10 were not cross-assigned.

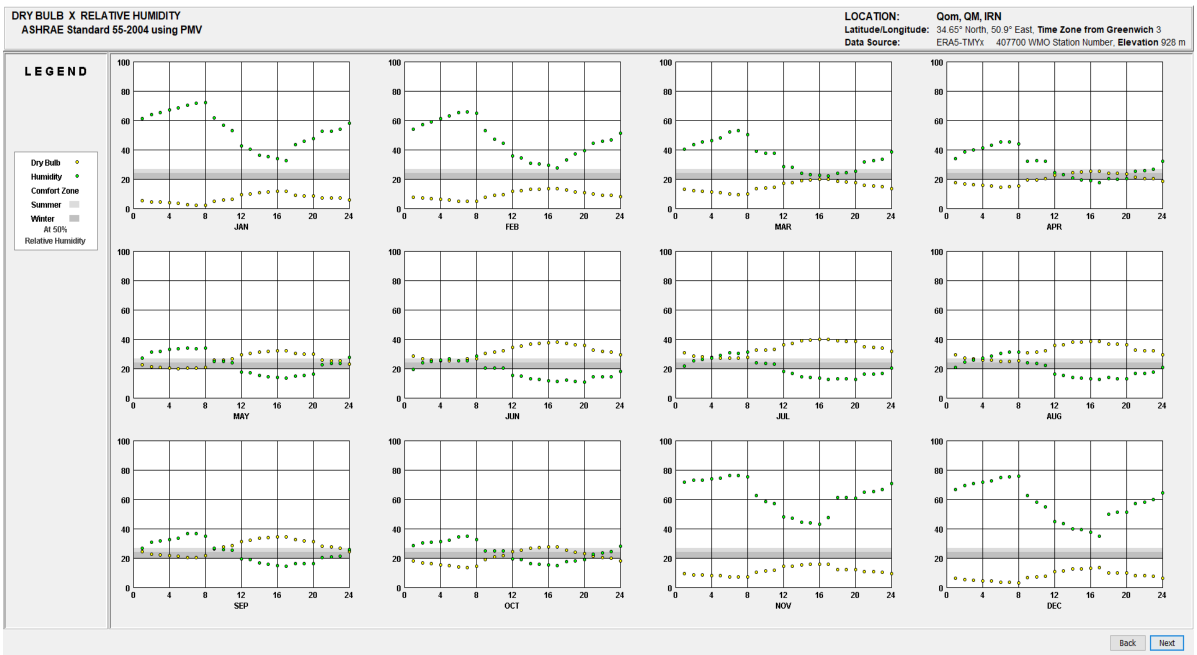


Figure 8: Comparative Charts of Relative Humidity and Dry-Bulb Temperature

The analysis of the December–March period indicated that two-stage evaporative cooling had the highest reported applicability, accounting for 35.3% of the selected hourly conditions. This result should not be interpreted as indicating that evaporative cooling is the principal cold-season strategy. Rather, it suggests that a proportion of the hourly conditions within the selected period exhibited warm and dry conditions for which evaporative cooling could contribute to thermal comfort. Internal heat gain and comfort under normal conditions were each associated with 22.1% of the selected conditions, while window shading, high-mass passive solar gain, and heating with humidification accounted for 21.5%, 15.6%, and 13.7%, respectively. The strategy labels and percentages were checked to prevent cross-assignment between the cold-season and hot-season analyses. (Fig. 9)

Furthermore, (Tab. 3) presents a more structured and comprehensive classification of the factors influencing the improvement of thermal comfort during the cold seasons in Qom.

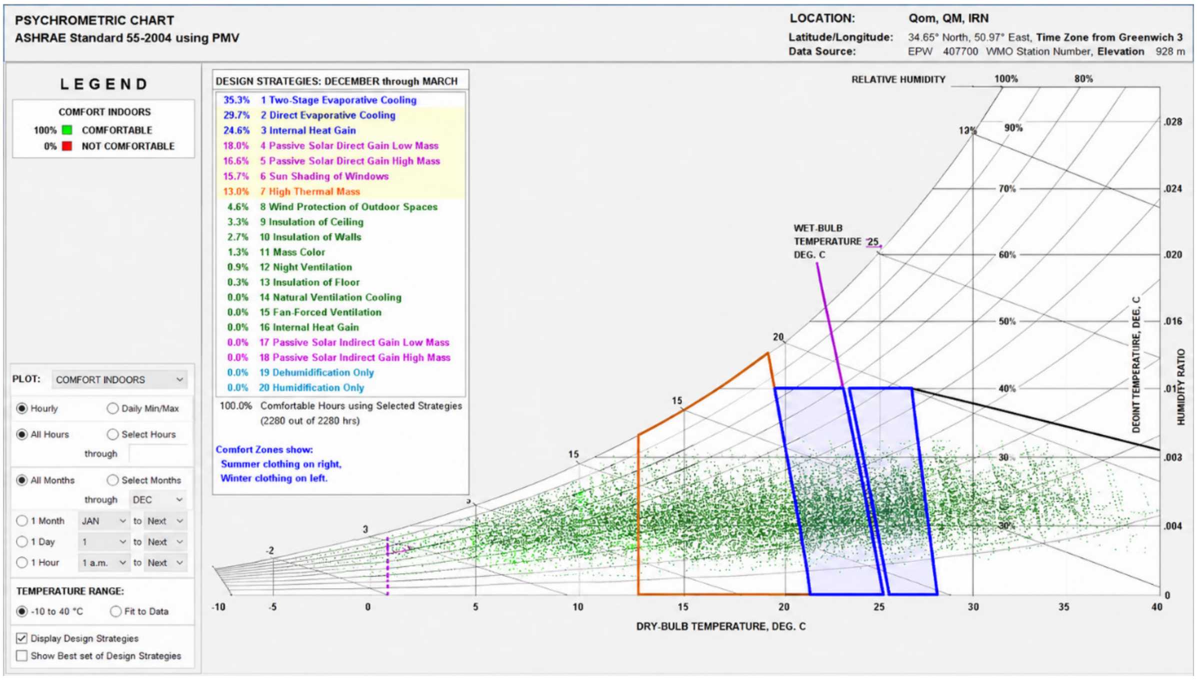


Figure 9: Psychrometric Analysis and Applicable Design Strategies for the Cold-Season Period in Qom (December–March)

Table 3: Classification of Design Strategies Affecting Thermal Comfort During the Cold-Season Period in Qom (December–March)

No,	Factors Affecting the Creation of Thermal Comfort Conditions	Impact Percentage	No.	Factors Affecting the Creation of Thermal Comfort Conditions	Impact Percentage
1	Comfort Under Normal Conditions	22.1%	9	Internal Heat Gain	22.1%
2	Use of Window Shading Devices	21.5%	10	Use of Low-Thermal-Mass Passive Solar Systems	---
3	High Thermal-Mass Materials	---	11	Use of High Thermal Mass Passive Solar Systems	15.6%
4	High thermal-mass materials that release the energy absorbed during the day at night	---	12	Wind Protection	---
5	Direct Evaporative Cooling	---	13	Humidity Generation Using a Mechanical Device	---
6	Use of Two Stage Evaporative Cooling	35.3%	14	Dehumidification	---
7	Provision of Natural Ventilation	---	15	Cooling with Dehumidification	---
8	Mechanical Ventilation	---	16	Heating with Humidification	13.7%

All percentages reported in Table 3 were transcribed directly from the Climate Consultant output generated for December through March. Strategies with zero applicable hours are reported as 0.0%, and the cold-season dataset was verified separately from the June–August dataset presented in (Tab. 4. Fig. 10) presents a chart illustrating the ranked results of factors influencing the improvement of thermal comfort during the three hottest months of the year June, July, and August in the city of Qom. This chart was generated through analysis of the city's climatic data using the specialized Climate Consultant software, applying the ASHRAE 55 thermal comfort model. The primary aim of this figure is to provide a quantitative and reliable framework for prioritizing design strategies under extreme summer climatic conditions. The key findings indicate that the most significant factor in enhancing comfort during hot seasons is the use of two stage evaporative cooling, with an impact score of 80.2%. This quantitatively confirms the high efficiency of low energy passive cooling systems in arid climates and aligns closely with the performance of traditional Iranian architectural solutions such as badgirs (windcatchers) and central pools (howz). The second most influential factor is the use of window shading devices, with an impact score of 40.7%, underscoring the critical role of solar radiation control particularly on south and west facing façades in reducing unwanted indoor heat gain and thereby lowering the need for mechanical cooling systems. Together, these two measures clearly form the main pillars of design strategies for Qom's hot dry climate.In addition, ceiling fans are highlighted as a low energy solution capable of improving perceived comfort by creating internal air movement potentially enhancing thermal tolerance by up to 2.8 °C and thus reducing reliance on air conditioning. This chart directly guides architects and designers in focusing on the most effective strategies, enabling them to optimize designs that not only ensure occupant comfort but also markedly decrease energy consumption and dependence on mechanical systems. (Fig. 10)

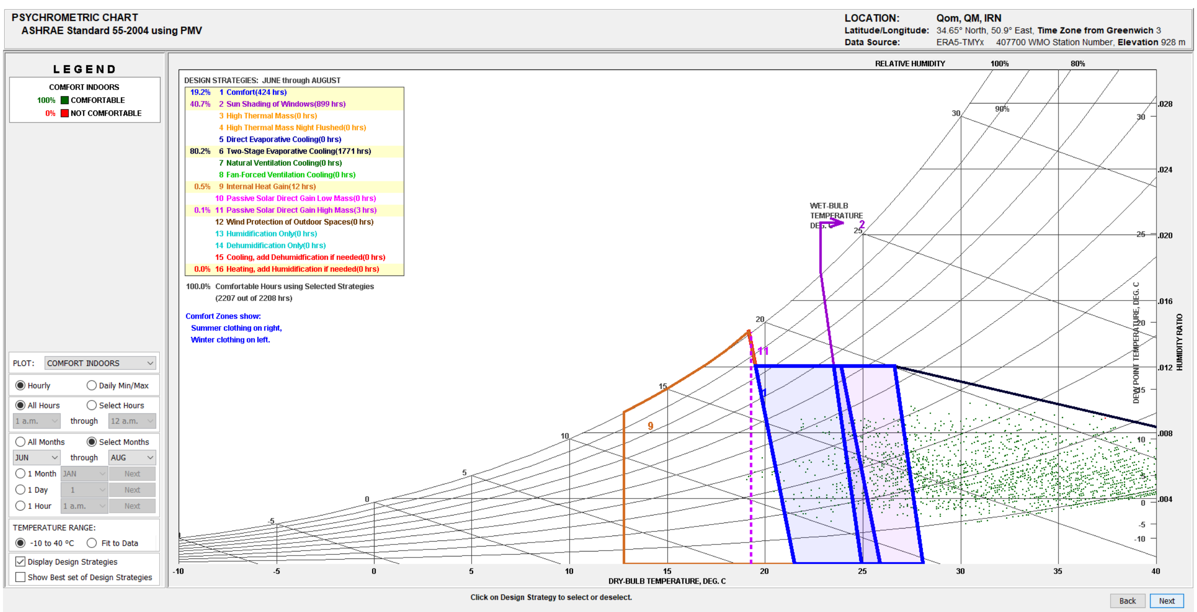


Figure 10: Analysis of Factors Affecting the Creation of Thermal Comfort Conditions During the Three Hottest Months of the Year (June, July, and August)

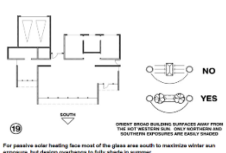
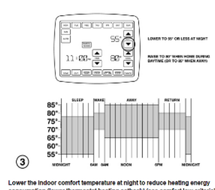
Furthermore, Table 4 presents a more structured and comprehensive classification of the factors influencing the improvement of thermal comfort during the hot seasons in the city of Qom city. (Tab. 4)

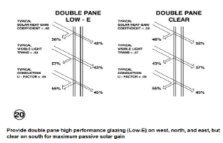
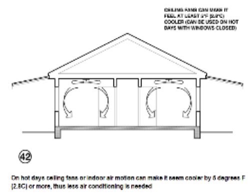
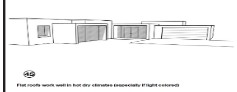
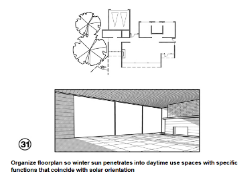
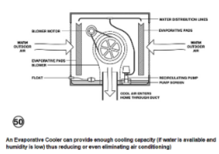
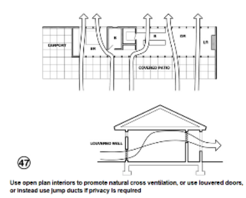
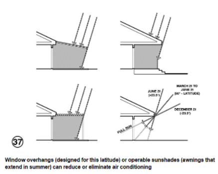
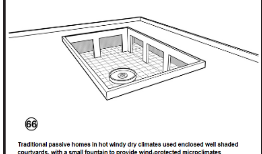
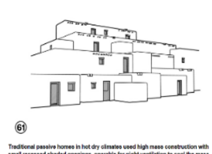
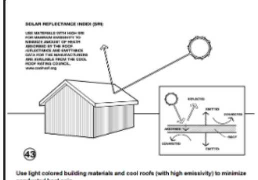
Table 4: Classification of Factors Affecting the Creation of Thermal Comfort Conditions During the Three Hottest Months of the Year (June, July, and August)

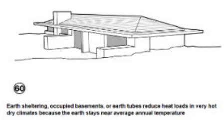
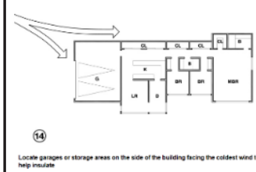
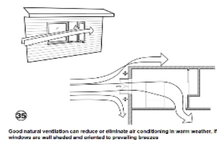
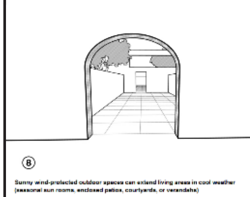
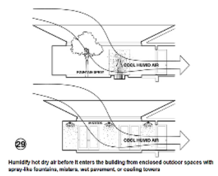
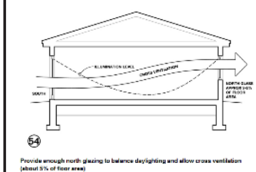
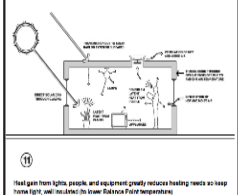
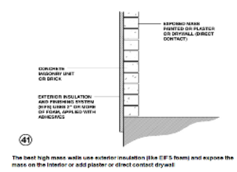
No	Factors Affecting the Creation of Thermal Comfort Conditions	Impact Percentage	No	Factors Affecting the Creation of Thermal Comfort Conditions	Impact Percentage
1	Comfort Under Normal Conditions	19.2%	9	Internal Heat Gain	0.5%
2	Use of Window Shading Devices	40.7%	10	Use of Low-Thermal-Mass Passive Solar Systems	---
3	High Thermal-Mass Materials	---	11	Use of High Thermal Mass Passive Solar Systems	0.1%
4	High thermal-mass materials that release the energy absorbed during the day at night	---	12	Wind Protection	---
5	Direct Evaporative Cooling	---	13	Humidity Generation Using a Mechanical Device	---
6	Use of Two Stage Evaporative Cooling	80.2%	14	Dehumidification	---
7	Provision of Natural Ventilation	---	15	Cooling with Dehumidification	---
8	Mechanical Ventilation	---	16	Heating with Humidification	0.0%

In the next stage, the Extraction and Prioritization of Effective Design Strategies are presented. The climatic analysis conducted using the Climate Consultant software has gone beyond merely identifying periods of natural comfort; it has also enabled the prioritization and extraction of operational design strategies. Based on the software's output data ranking the factors that influence the improvement of thermal comfort a set of effective strategies was identified. These strategies were categorized and ranked according to their relative impact on achieving the thermal comfort range and reducing dependence on mechanical systems. As demonstrated in earlier analyses, the use of two stage evaporative cooling (80.2% impact) during the hot months, and nighttime temperature reduction (13.7% impact) during the cold months, constitute two of the most significant factors (see Tab. 4). These findings provide a scientifically robust and reliable foundation for deriving operational solutions (Vatankhah et al.,2024). Subsequently, Table 5 presents a summary of the top 20 design strategies, derived from integrating the software's quantitative data with indigenous knowledge. These strategies are divided into two categories Passive and Low Energy and can serve as an actionable guide for architects and designers working in Iran's hot arid climate zones. (Tab. 5)

Table 5: presents the final 20 strategies retained after literature screening, removal of duplicates, evaluation of climatic relevance, and comparison with the Climate Consultant findings ,compiled by the

No.	Figure Description	Design Strategies	No.	Figure Description	Design Strategies
1		For passive solar heating, orient the majority of glazing toward the south to maximize winter solar gain, while ensuring that appropriately designed overhangs provide complete shading during the summer.	11		Lower the indoor comfort temperature at night to reduce space heating energy consumption (setback of the thermostat) (refer to low comfort criteria).

2		On the west, north, and east façades, use high performance low emissivity (Low E) double glazing; however, on the south façade, employ clear glazing to maximize passive solar energy gain.	12		On hot days, ceiling fans or enhanced indoor air movement can produce a perceived cooling effect of 2.8°C or more, thereby reducing reliance on mechanical air conditioning.
3		Flat roofs perform well in hot and arid climates, particularly when finished in light colors.	13		Organize the floor plan so that winter sunlight penetrates regularly occupied daytime spaces, and locate functions that align with solar orientation accordingly.
4		An evaporative cooler can provide sufficient cooling capacity (given water availability and low humidity), thereby reducing or even eliminating the need for air conditioning.	14		Use open plan interiors to enable cross ventilation, employ louvered doors where appropriate, or, when privacy is required, provide dedicated ventilation ducts.
5		Window overhangs (designed for this latitude) or adjustable sunshades (awnings that extend during summer) can reduce or completely eliminate the need for air conditioning.	15		Traditional passive houses in hot, arid, and windy climates employed covered, shaded courtyards with a small fountain to establish wind protected microclimates.
6		Traditional passive houses in hot and arid climates employed massive structures with small, recessed, and shaded openings, which facilitated nighttime ventilation and cooling of the building's thermal mass.	16		Use light colored building materials and cool roofs (with high emissivity) to minimize heat gains transmitted by conduction.

7		Earth-sheltered structures, residential basements, or earth tubes reduce thermal loads in extremely hot and arid climates, as the ground remains close to the mean annual temperature.	17		Locate garages or storage rooms on the windward side of the building facing the coldest prevailing winds to serve as thermal buffers and improve overall insulation.
8		Effective natural ventilation in warm climates can reduce or eliminate the need for mechanical air conditioning, provided windows are well shaded and oriented to the prevailing breeze.	18		Sunny, wind-exposed outdoor spaces can extend living areas in cold weather (seasonal sunrooms, enclosed patios, courtyards, or porches).
9		Cool hot, arid air before it enters the building by passing it through enclosed outdoor buffers equipped with spray fountains, misters, cooled asphalt surfaces, or evaporative cooling towers.	19		Provide sufficient north-facing glazing to balance daylight and enable cross-ventilation (approximately 5% of the floor area).
10		Internal gains from lighting, occupants, and equipment significantly reduce space-heating demand; consequently, airtightness and controlled ventilation become critical for maintaining thermal comfort and conserving energy.	20		Optimal high mass walls use external insulation while exposing thermal mass on the interior, or add gypsum/plaster directly bonded to the mass.

RESULTS AND CONCLUSION

The findings of the present study, derived from climatic analysis of the city of Qom using Climate Consultant software, indicate that passive and low energy design strategies play a central role in achieving thermal comfort and reducing energy consumption in a hot dry climate. These findings substantially align with the empirical knowledge of indigenous Iranian architecture and with results from contemporary research in sustainable architecture. The high effectiveness of two-stage evaporative cooling (80.2%) during the warm season is consistent with previous studies demonstrating that courtyard-based passive design, shading, natural ventilation, and evaporative mechanisms can improve thermal conditions and reduce cooling demand in hot-arid climates (El Azhary et al., 2021; Salameh & Touqan, 2022; Chohan & Awad, 2022; He et al., 2024). In traditional Iranian architecture, the combined use of wind-driven airflow, shaded courtyards, vegetation, and water features creates a cooler microclimate through air movement, shading, and evaporation. The results of the present climatic analysis provide quantitative support for adapting these vernacular principles through contemporary low-energy cooling systems. Accordingly, the findings reinforce the value of vernacular architecture as a climate-responsive design approach for reducing dependence on mechanical air-conditioning in hot-arid regions. Additionally, the significant effect of shading devices and north facing windows (40.7%) in reducing excessive solar heat gain is consistent with the findings of Salameh and Touqan (2022) in the United Arab Emirates and in the eastern Mediterranean. These studies likewise emphasize the necessity of controlling solar radiation particularly on south and west façades and the use of parametric shading devices. This is clearly reflected in Table 5 by strategies no. 2, 5, and 19. The recommendation to use ceiling fans as a low-energy cooling strategy is supported by research on elevated indoor air movement. Ho et al. (2009) reported that fan-generated airflow could compensate for an indoor temperature increase of approximately 2.8–3.3°C while producing estimated cooling-energy savings of 15–18%. Similarly, a critical review by Omrani et al. (2021) concluded that ceiling fans can improve thermal comfort and reduce cooling demand with substantially lower energy consumption than conventional air-conditioning systems. Miller et al. (2021) further reported that modern ceiling fans produced an approximate cooling effect of 2–4°C and, when coordinated with air-conditioning operation, achieved 36% measured cooling-season compressor energy savings. Collectively, these findings support Strategy No. 12 in Table 5 and demonstrate that low-energy air-movement technologies can extend acceptable comfort conditions while reducing dependence on compressor-based mechanical cooling. Furthermore, the recommendation to use high-thermal-mass materials, presented as Strategies Nos. 3 and 20 in Table 5, is consistent with experimental and numerical evidence indicating that materials with high thermal inertia can moderate indoor temperature fluctuations, delay heat transfer through the building envelope, and reduce cooling demand in hot-arid climates (El Azhary et al., 2021).Although the findings generally align with the existing literature, a notable apparent contradiction exists. While Table 3 indicates that nighttime lowering of comfort temperature (13.7%) is an influential factor in cold seasons, this measure implies increased heating energy use and may superficially conflict with energy reduction objectives. This contradiction can be explained by the concept of adaptive thermal comfort and ASHRAE 55 both emphasize that occupants in warm climates tolerate lower nighttime comfort temperatures especially following hot daytime conditions. Therefore, this strategy (No. 11 in Table 5) does not merely increase heating demand; it represents an intelligent behavioral strategy that aligns with occupant habits and can prevent excessive use of heating systems. Another point is the negligible impact of increasing humidity during the warm seasons. This finding is consistent with studies emphasizing dehumidification but serves as a caution that in dry climates raising humidity is not only unnecessary but may cause discomfort (skin stickiness). It underscores the importance of precise climatic analysis and indicates that broad regional measures cannot be applied without local adaptation.

In advancing sustainable development goals and reducing the adverse impacts of human activities on the environment, sustainable architecture emerges as a necessary and strategic approach in design and construction. This study, aiming to identify effective strategies for optimizing energy use and enhancing thermal comfort in Iran's hot dry climates with a focus on the city of Qom, conducted an integrated analysis of vernacular knowledge and precise climatic data. The findings indicate that Iranian vernacular architecture particularly in cities such as Qom city, Yazd, and Kashan embodies operational, proven knowledge for adapting to severe climatic conditions. Elements such as the central courtyard, windcatcher, thick walls, appropriate orientation, vegetation cover, and the use of local materials have been not only functionally effective but also serve as valuable models for contemporary sustainable design. Climate analysis of Qom city using Climate Consultant and the ASHRAE 55 thermal comfort model indicates that naturally comfortable conditions occur only for a limited part of the year (notably from early spring to early autumn); summer peak temperatures near 44°C and winter lows around −2°C, combined with large diurnal swings, substantially increase the need for mechanical heating and cooling systems, and therefore passive, low energy design strategies play a central role in reducing dependence on non renewable energy sources.

This study answered three core questions: the first concerned integrating vernacular architectural principles with rigorous climatic analysis to produce operational strategies, and the answer is evident in the successful combination of qualitative and quantitative approaches qualitatively identifying vernacular patterns in Qom city and similar cities (central courtyards, windcatchers, thick walls, seasonal space zoning), and quantitatively validating these patterns with Climate Consultant outputs (for example, the high effectiveness of two stage evaporative cooling at 80.2% during warm seasons aligns with traditional systems like windcatchers and pools), thereby providing data driven, evidence based solutions beyond intuition and experience.

The second question concerned energy optimization measures in vernacular architecture of hot dry regions; the study's findings, clearly summarized in Table 2, show that Iranian vernacular architecture systematically combines strategies of demand reduction (through appropriate orientation, shading, and limited openings), passive supply (via natural ventilation, windcatchers, pools, and subterranean spaces), and thermal storage (using thick walls and high thermal mass materials), forming a comprehensive, time tested design system adapted to local environmental conditions. The third question addressed contemporary measures to improve energy performance in Qom, and Table 5 presents twenty practical, passive and low energy strategies that merge vernacular patterns with modern technologies for example, modernizing traditional windcatchers with evaporative coolers (strategy 4) and shaded natural ventilation (strategy 8), updating thick wall concepts to high thermal mass walls with external insulation (strategy 20) and cool roofs (strategy 16), and proposing innovations like ceiling fans (strategy 12) and nighttime comfort temperature reduction (strategy 11) derived from climatic data as low energy, behaviorally smart measures.

This study has several limitations. First, its spatial scope is confined to Qom, which may limit the generalizability of the findings to other hot-arid regions of Iran because differences in humidity, wind speed, diurnal temperature range, and local morphology may alter the priority of design strategies. Second, although Climate Consultant was used to identify climate-responsive design recommendations, building energy simulation tools such as EnergyPlus or DesignBuilder were not employed to quantify the energy-saving potential of individual or combined strategies. Third, the economic dimensions of the proposed measures, including initial costs, life-cycle costs, and payback periods, were not assessed. Similarly, social factors such as occupant acceptance, behavioral adaptation, and the practical operation of passive systems were not investigated. Finally, the analysis relied on historical climatic data and did not incorporate future climate-change scenarios, including projected increases in mean temperature and the frequency of extreme heat events.

REFERENCES

Abdeldjaouad, M., Attoui, R., Belghar, N., Driss, Z., & Boufahja, F. (2025). Computational Fluid Dynamics Simulation and Experimental Study of the Airflow in a Traditional Courtyard House. CFD LETTERS, 17(6), 134-150.

Afzal, M., Li, R. Y. M., Ayyub, M. F., Shoaib, M., & Bilal, M. (2023). Towards BIM-based sustainable structural design optimization: a systematic review and industry perspective. Sustainability, 15(20), 15117.

Arab, Maryam; Farokhzād, Mohammad (2017). "Design of Earth sheltered Buildings Based on Principles of Sustainable Architecture to Reduce Building Energy Consumption in a Hot Dry Climate: Case Study of Shahrud." Quarterly Journal of Energy Policy and Planning Research, Vol. 3, No. 8, pp. 147–173.

Asadpour, F., Asadpour. A. (2014). Optimization of Energy Consumption Using Solar Bath in the Hot and Dry Climate of Iran. European Online Journal of Natural and Social Sciences: Proceedings, 3(3s), 40-49.

Asadpour, F., Habibi, A. (2015). Strategies for climatic design for sustainable urban housing development (case study of Nur City, mazandaran, Iran). Cumhuriyet Science Journal, 36(6), 653-664.

Betti, G., Tartarini, F., Nguyen, C., & Schiavon, S. (2024). CBE Clima Tool: A free and open-source web application for climate analysis tailored to sustainable building design. In Building Simulation (Vol. 17, No. 3, pp. 493-508). Beijing: Tsinghua University Press.

Chohan, A. H., & Awad, J. (2022). Wind catchers: An element of passive ventilation in hot, arid and humid regions, a comparative analysis of their design and function. Sustainability, 14(17), 11088. https://doi.org/10.3390/su141711088

Creswell, J. W., & Plano Clark, V. L. (2018). Designing and Conducting Mixed Methods Research (3rd ed.). SAGE Publications.

Dinku, T., Faniriantsoa, R., Islam, S., Nsengiyumva, G., & Grossi, A. (2022). The climate data tool: enhancing climate services across Africa. Frontiers in Climate, 3, 787519.

El Azhary, K., Ouakarrouch, M., Laaroussi, N., & Garoum, M. (2021). Energy efficiency of a vernacular building design and materials in hot arid climate: Experimental and numerical approach. International Journal of Renewable Energy Development, 10(3), 481–494. https://doi.org/10.14710/ijred.2021.35310

Ghadiri Moghaddam et al. (2019). "Evaluation of the Performance of Passive Energy Systems (Trombe Wall and Greenhouse Effect) on Building Energy Consumption in a Cold Climate." Scientific Journal of Architecture and Urbanism of Iran, Vol. 10, No. 17, Spring–Summer 2019, pp. 25–36.

Gorji Mehlabani, Yousef (2010). "Sustainable Architecture and Its Critique in the Field of Environment." Scientific Journal of Architecture and Urbanism of Iran, No. 1, pp. 91–101.

Gutiérrez, C. (2023). Vernacular architecture and modern design: Towards a new aesthetics and functionality. Land and Architecture, 1(1), 1–15.

He, M., Li, L., & Tao, S. (2024). Sustainable design methods translated from the thermodynamic theory of vernacular architecture: Atrium prototypes. Buildings, 14(10), 3142. https://doi.org/10.3390/buildings14103142

Ho, S. H., Rosario, L., & Rahman, M. M. (2009). Thermal comfort enhancement by using a ceiling fan. Applied Thermal Engineering, 29(8–9), 1648–1656. doi: 10.1016/j.applthermaleng.2008.07.015.

Mahdinejad, J. D., & Shirdel, A. H. (2024). Analysis And Ranking of Factors Affecting The Design of Sustainable Housing in the Cold and Dry Climate of Sabzevar Based on Energy Consumption Optimization.

Mahdinejad, J., Sharghi, A., Asadpour, F. (2020). Investigating the Effective Indicators on the Desirable Quality of Open and Semi-Open Spaces of Contemporary Housing. Int. J. Architect. Eng. Urban Plan, 30(1),119-135.

Mashhoor, Zeynab (2020). "A Study of Optimization Strategies for Passive Heating Systems in Achieving Sustainable Architecture." Shabak Scientific Journal, Vol. 6, No. 4, pp. 11–20.

Memarian, Gholamhossein (2014). A Survey of Theoretical Foundations of Architecture. Tehran: Soroush e Danesh, 9th ed.

Miller, D., Raftery, P., Nakajima, M., Salo, S., Graham, L. T., Peffer, T., Delgado, M., Zhang, H., Brager, G., Douglass-Jaimes, D., Paliaga, G., Cohn, S., Greene, M., & Brooks, A. (2021). Cooling energy savings and occupant feedback in a two-year retrofit evaluation of 99 automated ceiling fans staged with air conditioning. Energy and Buildings, 251, 111319. https://doi.org/10.1016/j.

enbuild.2021.111319

Moroni, G., Forcael, E., & Berrios, C. (2024). Variables and objectives in multi-objective optimization for the integration of architecture, structure, and environmental impact: a literature review. Architectural Science Review, 1-17.

Moulānāʾi, Salah al Din; Soleymāni, Sara (2016). "Architecturally Valuable Elements of the Vernacular Architecture of the Sistan Region Based on Climatic Components of Sustainable Architecture." Bāgh e Nazar Journal, Vol. 13, No. 41 (Mehr–Aban 1395), pp. 57–66.

Naghipour, P., Naghipour, A., Shirdel, A. H., Behzadi, S. Z., Rahaei, O., & Salamati, S. (2025). Sustainability in Historical Islamic Architecture: Lessons from Sheikh Lotfollah Mosque's Construction Techniques. Journal of Islamic Architecture, 8(3), 585-603.

Olfat,M. , Asadpour,F. and Shirdel,A. H. (2025). Scientometric Analysis of Research Trends in Smart and Sustainable Architecture in Educational Environments: With an Emphasis on Green Schools and Campuses. (e4909). Scientometrics Research Journal, ( ), e4909 doi: 10.22070/rsci.2025.20848.1844

Omrani, S., Matour, S., Bamdad, K., & Izadyar, N. (2021). Ceiling fans as ventilation assisting devices in buildings: A critical review. Building and Environment, 201, 108010. https://doi.org/10.1016/j.buildenv.2021.108010

Qiyabkloo, Zahra (2016). Building Physics 2 (Environmental Conditioning), 13th ed., Jihad Daneshgahi Publishing, Amirkabir Industrial Unit.

Rahaee, O., Salehi, S. S., & Shirdel, A. (2024). Improving the quality of natural ventilation in Masjedsoleiman's Schools' classrooms based on the openings' position and the outdoor shading blades with CFD Method. Journal of Sustainable Architecture and Urban Design, 12(1).

Rahaei, O., Shirdel, A. H., Asadpour, F., & Omidi, M. (2026). Explaining the pattern of natural ventilation in central courtyards of traditional houses based on orientation. Sustainable Cities and Society: Advances, 2(1), 100025. doi: 10.1016/j.scsadv.2026.100025.

Rahimi Mehr, Vahideh (2013). "A Look at Sustainable Development in Earth sheltered Architecture." Proceedings of the First National Conference on Architecture, Conservation, Urbanism and Sustainable Environment, Hamedan. Hegmataneh Environmental Assessors Association.

Reddy, V. J., Hariram, N. P., Ghazali, M. F., & Kumarasamy, S. (2024). Pathway to sustainability: An overview of renewable energy integration in building systems. Sustainability, 16(2), 638.

Roradeh, H., & Baaghideh, M. (2024). The Application of the Climate Consultant Tool in the Design of Architecture Compatible with the Climate (Case Study: Shiraz City). Urban Structure and Function Studies, 11(41), 167-196.

Rouhi, S., Valibeig, N., Khodayari Mafi, M., & Shirdel, A. H. (2024). Retrieve Khaju Bridge Architecture and Surrounding Landscape and Environment based on Visual and Descriptive Documents. Journal of Revitalization School, 2(3), 36-47.

Salameh, M., & Touqan, B. (2022). Traditional passive design solutions as a key factor for sustainable modern urban designs in the hot, arid climate of the United Arab Emirates. Buildings, 12(11), 1811. https://doi.org/10.3390/buildings12111811

Selvaraj, R., Kuthadi, V. M., & Baskar, S. (2023). Smart building energy management and monitoring system based on artificial intelligence in smart city. Sustainable Energy Technologies and Assessments, 56, 103090.

Sharma, V. (2024). Understanding Thermal Performance of Vernacular Houses for Propagating Sustainable Energy Techniques in Design and Planning. 2024 International Conference on Computer, Electronics, Electrical Engineering & their Applications (IC2E3), 1-6.

Valizadeh Oghani, Mohammadbāqer; Moḥaddedi Nāser (2019). "Use of Passive and Inactive Solar Systems to Create Thermal Comfort in the Architectural Design of Traditional Houses of Tabriz." Renewable and New Energies Quarterly, Vol. 6, No. 1 (Summer), pp. 26–37.

Vatankhah, M., Vakilinezhad, R., Zakeri, S. M. H., & Fattahi, K. (2024). Optimizing energy and daylight performance of vernacular dwellings for contemporary architecture: A parametric analysis. Architectural Engineering and Design Management, 20(6), 1795–1814. https://doi.org/10.1080/17452007.2023.2274876

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