Analysis and Review of the Impact of Iran's Climatic Conditions on the Design of Nearly Zero Energy Buildings According to the Köppen-Geiger Method

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Abstract:

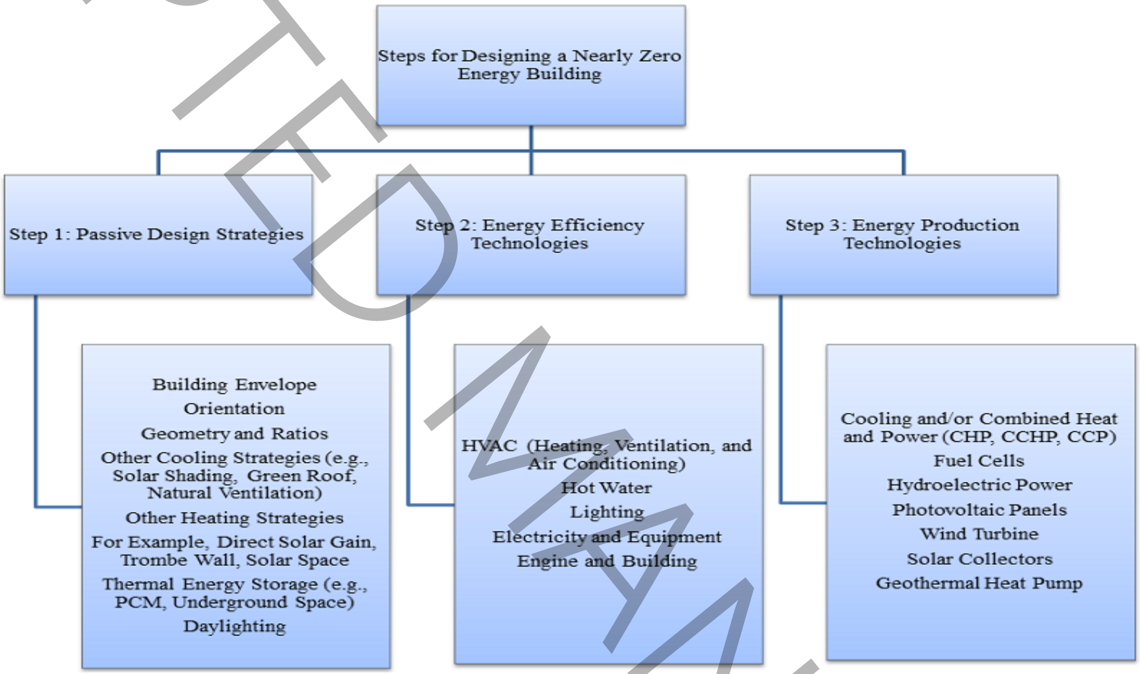
The architectural blueprint and the selection of climate-adaptive building elements are primarily governed by environmental factors such as solar exposure, thermal variations, moisture, and airflow. This research explores customized design strategies and thermal comfort standards necessary for developing nearly zero-energy buildings (NZEBs) within the diverse Iranian landscape, utilizing the Köppen-Geiger classification and passive engineering methods. Iran’s territory is segmented into nine distinct climatic regions under this framework. We evaluated how regional climate profiles dictate NZEB design requirements by modeling representative cities using Climate Consultant software and the PMV comfort index (ASHRAE Standard 55). By processing localized weather data, the study derived critical metrics for natural ventilation, active thermal loads, and comfort durations. The analysis also prioritized passive features, including optimized window shading and internal heat recovery systems. Our findings reveal a wide disparity in comfort potential: the BWh zone (Yazd) achieved the highest natural comfort at 19.7%, while the CFa zone (Anzali) reached only 3.6%. Data indicates that in arid regions like Yazd, a synergy of evaporative cooling (25.8%) and internal heat gains (22.5%) is essential for NZEB performance.

Keywords:

Climatic conditions, nearly zero-energy buildings, Köppen-Geiger, passive methods.

1. Introduction

On a global scale, the construction sector is a major energy consumer, accounting for nearly 40% of total demand, which necessitates a rapid shift toward high-efficiency building standards. Nearly zero-energy buildings (NZEBs) have emerged as a critical solution, bridging the gap between minimal energy consumption and on-site renewable energy production. International regulations are tightening; for instance, the EU mandated NZEB standards for new residential builds in 2020, while the US targets carbon-neutral commercial zones by 2050 [1]. The threat posed by climate change in the 21st century is multifaceted, carrying profound risks for global economies, public health, and environmental stability. Data from the last decade reveals an alarming increase in extreme thermal events, with summer temperatures frequently surpassing the 35°C threshold [2]. Climate change significantly alters environmental indicators such as solar radiation, humidity, and wind patterns, causing long-term shifts in global meteorological cycles. Driven by anthropogenic factors and fossil fuel combustion, this crisis poses substantial risks to ecological and social stability. According to the IEA, the building and construction sectors are central to this issue, accounting for 36% of energy use and 40% of total emissions; thus, evaluating HVAC systems is critical for reducing energy demand. Ultimately, a cyclical interdependence exists where building energy footprints exacerbate climate change, while these shifting conditions simultaneously increase the energy required to maintain indoor comfort [2]. Extensive scholarly work has been conducted to evaluate how shifting climatic patterns influence the cumulative energy efficiency of the built environment [25]. Researchers have determined that while climate change widens the gap between heating and cooling demands, the magnitude of this variance is highly contingent upon specific geographical coordinates and regional climate classifications [24]. Within the Iranian energy context, the building sector is a major source of ecological impact, contributing to 25% of greenhouse gas emissions through the consumption of natural gas and petroleum-based products. Furthermore, this sector accounts for 36.25% of national energy utilization—an amount equivalent to 432.4 million barrels of oil—with approximately 85% of these needs met by electricity and natural gas [7]. Given these figures, implementing strategies to secure alternative energy supplies and conserve finite resources is of paramount importance. Consequently, zero-energy buildings (ZEBs) and sustainable architecture have become focal points for governmental policy [3]. However, establishing a standardized and universally accepted definition for nearly zero-energy buildings is a necessary prerequisite for any technical discussion on the subject [22]. A nearly zero-energy building (NZEB) generates 30% or more of its required energy through the use of lighting [22]. Figure 1 illustrates the three main stages for achieving NZEB goals: utilizing passive design strategies (such as building envelope, orientation, and geometry/proportions), energy efficiency technologies (such as HVAC, water heating, lighting, appliances, and equipment), and energy generation technologies (such as combined cooling and/or heating and electricity generation, fuel cells, hydropower, photovoltaic panels, and wind turbines [5]).



F.1. Three main stages for achieving NZEB goals [5].

Over the last ten years, NZEB research has centered on establishing definitions, advancing energy-efficient technologies, optimizing system design and control, and enhancing life-cycle performance [6]. Although the academic exploration of NZEBs dates back to the early 2000s, extensive numerical and analytical investigations continue to shape the future of zero-energy architecture [6]. For instance, Sharifzadeh et al. (2024) modeled an NZEB villa in Kerman’s arid climate by combining passive design with wind energy [7]. By evaluating parameters such as window-to-wall ratios (WWR), glazing types, and insulation materials, their study concluded that a 40% WWR, polyurethane insulation, and argon-filled triple-pane glazing constitute the optimal passive configuration for minimizing energy demand in hot, dry regions [7]. This combination results in a significant reduction in annual energy consumption (Sharifzadeh et al., 2024). Miralahi et al. (2020) conducted a study on climate change for a four-story building in Tehran using DesignBuilder software to minimize cooling and heating loads and capital investment costs [8].

The study results indicated a 14.65% reduction in energy consumption. Additionally, by using photovoltaic (PV) panels, the building could achieve nearly zero energy status, supplying approximately 90% of its required energy (Miralahi et al., 2020, pp. 65-74). Entazari et al. (2020) introduced the implementation of a zero-energy building (ZEB) design for a hot and dry climate region in Yazd and compared it with a typical house in the same climate [9]. Energy and economic analyses were conducted using EnergyPlus software. The results showed a 5.5-year payback period for the ZEB and a reduction in carbon dioxide pollution compared to conventional buildings (Entazari et al., 2020, pp. 223-240). Kasemayi and Varmaghani (2021) studied factors influencing energy reduction in high-rise buildings in Tehran. Using energy simulation software, they optimized the effects of seven key indicators on energy consumption reduction, including building form, window-to-wall ratio, shading angle, canopy depth, type and thickness of thermal insulation, and glazing type in different scenarios [10] (Kasemayi and Varmaghani, 2021, pp. 67-100).

Previous studies primarily focused on individual cities or, at most, one climate region. However, in this article, for the first time, we employ the Köppen-Geiger climate classification to analyze the climatic conditions across all nine climatic zones of Iran using the Climate Consultant software (CCS). The standard ASHRAE 55 method, in conjunction with the PMV (Predicted Mean Vote) model, was utilized in this software. By applying the PMV mathematical model, we consider the combined effects of variables such as temperature, mean radiant temperature, wind speed, clothing thermal resistance, and humidity levels. This comfort index, initially introduced by Fanger in 1970 [11-13], is one of the most important physiological temperature indices widely used in urban planning and climate studies. It evaluates human thermal comfort levels in outdoor climatic conditions or the environment under investigation. The innovation of this article is that by studying thermal comfort, engineering design can be guided to use passive methods (thermal comfort, window shading, evaporative cooling, etc.) and also minimal use of active methods to create comfort in residential buildings in the nine climates of Iran.

2. Methodology

Meteorological datasets are integrated into the Climate Consultant Software (CCS) to generate and evaluate climatic diagrams. The thermal comfort assessment within CCS is governed by ASHRAE Standard 55 and the PMV (Predicted Mean Vote) model, which incorporates variables such as dry-bulb temperature, air velocity, humidity, mean radiant temperature (MRT), and occupant-related factors like metabolic rate and clothing insulation. In residential settings, occupants typically adjust their attire seasonally and tolerate higher air speeds, resulting in a broader comfort envelope compared to climate-controlled environments [14, 15, 28]. Table 1 outlines the specific meteorological station data for the representative cities categorized under the Köppen-Geiger system, while Figure 2 illustrates the systematic research flowchart. The simulation process begins by importing individual city weather files into the software and applying the PMV model. Following data extraction, a comparative analysis was conducted to evaluate passive and active design strategies across the nine zones. Research assumptions established for this study include a metabolic rate of 1.1 Met, with clothing insulation levels (Clo) set at 1.0 for winter and 0.5 for summer. Consistent with this modeling framework, the MRT is assumed to be approximately equal to the dry-bulb temperature [13]. utilizing seasonal averages for relative humidity and dry-bulb measurements [25].

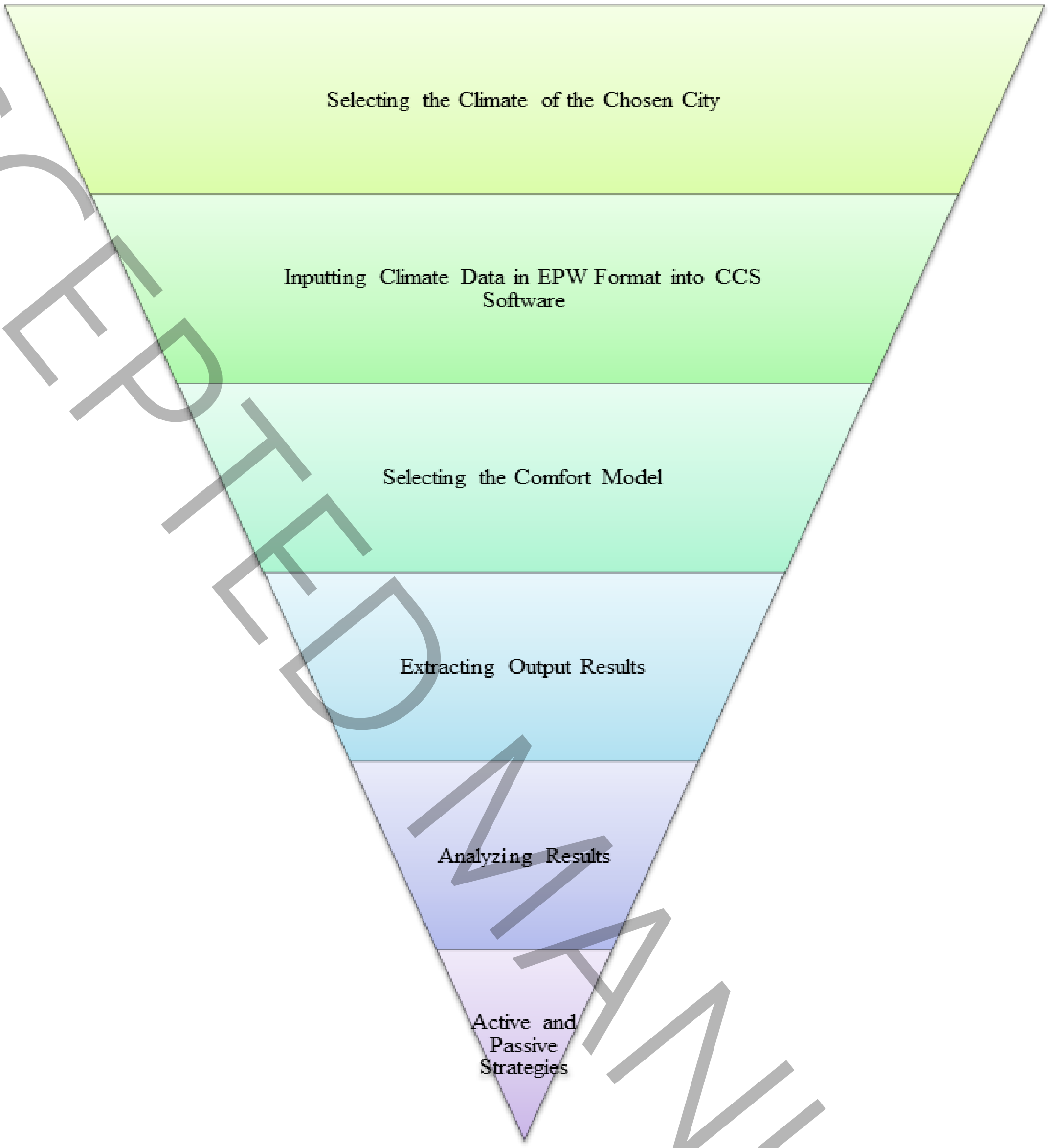


Fig. 2. Flowchart of the Research Process

2-1- Climate Conditions of Iran According to the Köppen-Geiger Method

The predominant weather condition of a region over a long period, which depends on meteorological parameters such as temperature, precipitation, humidity, radiation, wind, etc., is referred to as the climate of that region [16]. From the perspective of human thermal comfort, the climatic environment is shaped by the complex interplay of several atmospheric variables, notably solar exposure, ambient temperature, moisture levels, airflow velocity, and precipitation. Among the various established frameworks for global climate categorization, the methodology developed by the Austrian climatologist, Köppen, has emerged as a widely recognized and utilized standard. Geographically, Iran's position within the 25 to 40 degrees north latitude range places a significant portion of its territory in a predominantly warm climatic belt [1,11]. It is also a high plateau, with a very small percentage of its area being less than 475 meters above sea level [15,11] . Recent studies conducted between 1990 and 2014 show that out of 31 climate groups identified by the Köppen-Geiger method, Iran encompasses 9 of them (see Figure 3). According to the Köppen-Geiger classification, BWh, BSk, BSh, and Csa are the major climatic groups in Iran, covering a large portion of the country's area. Other groups, such as BWk, CSb, DSa, DSb, and CFa, occupy much smaller areas [15,18-20] (Figure 3).

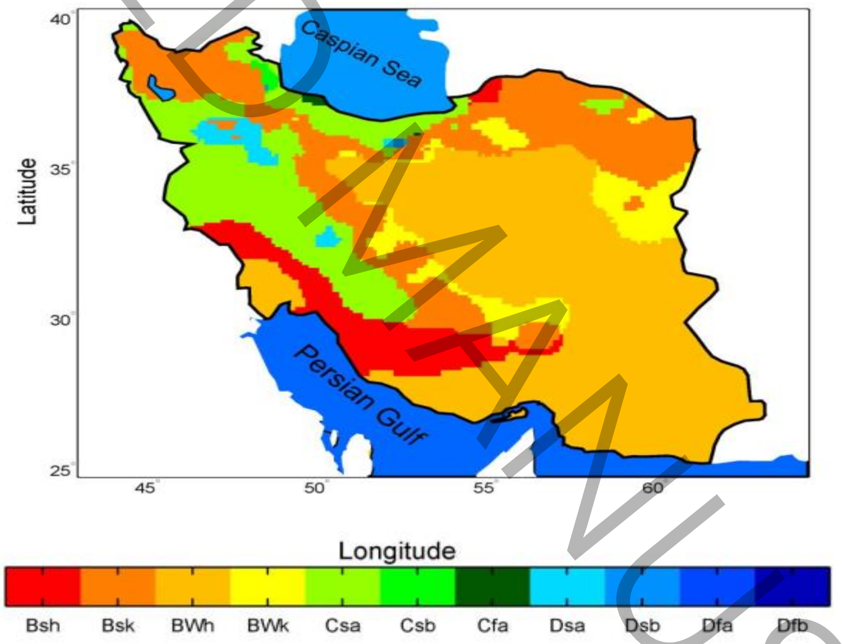


Fig. 3. Köppen-Geiger Climate Classification in Iran

Table 1. Meteorological Station Characteristics of Selected Cities in Iran's Köppen-Geiger Climate

City	Climate	Longitude (E)	Latitude (N)	Elevation (m)	Avg. Winter Dry Temp (°C)	Avg. Winter Relative Humidity (%)	Avg. Summer Dry Temp (°C)	Avg. Summer Relative Humidity (%)
Yazd	BWh	54.28	31.88	1237	10	40	27	18
Khorramabad	CSa	48.28	33.43	1184	6.5	65.5	22.5	31.6
Mashhad	BSk	59.57	36.27	1128	7.33	60.67	22.67	32
Sabzevar	BSh	57.66	36.21	941	9	53.8	25.5	27.8
Anzali	CFa	49.46	37.46	-26	9.8	85.33	22.5	81
Kerman	BWk	56.96	30.25	1754	8.6	45.33	23.16	21.33
Meshgin Shahr	CSb	47.1	38.23	1830	6.5	70	13	64
Hamedan – Nojeh	DSa	48.68	35.2	1680	-4	63	3.33	36.6
Abali	DSb	51.96	35.76	2057	2	58.66	17.66	35

2-2- Study Area

Iran located in southwestern Asia and borders Turkmenistan, Afghanistan, Pakistan, Iraq, Turkey, Armenia, and Azerbaijan [1,15]. The size of Iran is about 1,648,000 square kilometers and is located between 25-40 north latitude and 44-63 east longitude [15,21-23]. Conceptually, climate represents the integration of various meteorological factors, such as thermal profiles, moisture levels, precipitation volume, and atmospheric circulation patterns. The systematic categorization of climates is fundamental for developing adaptive architectural designs and is intrinsically linked to the depth of available climate change datasets. Since the primary objective of any structure is to provide a secure and protective environment for its occupants, defining distinct climatic zones is essential. These zones group together environmental conditions that facilitate specific human body heat dissipation methods and necessitate unique architectural characteristics to maintain comfort. Geographically, Iran's position between 25- and 40-degrees north latitude places it largely within a temperate region. Characterized by its high-altitude plateau, the vast majority of the Iranian landmass is situated at elevations exceeding 475 meters above sea level [1,15]. Despite the fact that Iran is located between two large water bodies, namely the Caspian Sea and the Persian Gulf, the impact of these water bodies is limited to the areas surrounding them because of the Alborz and Zagros mountain ranges and their positions[15]. As a result, these extensive water reservoirs do not often influence the country's internal temperature regulation[15]. Iran is a large country in terms of its size, which has led to different climatic zones, from the subtropical to the subarctic regions[15]. During the winter season, high-pressure systems move across the western and southern parts of Iran[15]. On the other hand, low-pressure systems form over warm water areas like the Indian Ocean, Persian Gulf, and Caspian Sea[15].

There are several climate classification systems. The climate zones of Iran were classified by Hariri and Milani (1985) into eight distinct types, while Kasemai (1992) categorized Iran into 12 separate groups [1,15,24, 25]. Among these, Köppen's approach (1936) has been widely accepted by scholars and scientists. A number of researchers have used the Köppen technique to develop climate zoning maps for Iran[1]. The first such map was published by Ganji in 1965, utilizing data from 56 scattered meteorological stations across the country at the time of the study, albeit with a short statistical period[1,15]. A few years later, Adel (1960), using data from 66 meteorological stations scattered throughout Iran, once again employed the Köppen technique to classify the country[1,15]. Although the specifics of these maps differ, Javadi (1966) published another climate zoning map for Iran using the Köppen method, which closely aligns with the overall structure of Iran's climatic zones as presented in the earlier maps [1,15,26, 27]. Until 2008, the Köppen method had not been used to precisely determine Iran's climatic zones[1,15]. In their book Climates of Iran (1387), Masoudian and Kaviani presented a map of Iran's climatic zones using the Köppen technique, which, unlike the earlier maps by Ganji (1955), Adel (1960), and Javadi (1966), provides more significant insights into Iran's climatic regions [1, 15, 28, 29].

Studying climate and climatic conditions is one of the most important steps in the construction of buildings, depending on the geographical location of the structure. These are solar radiation, temperature, humidity, precipitation levels, and wind patterns, and they influence the general layout and parts of the building and should be designed to suit the climate.

Köppen divided the Earth into five main climatic regions based on precipitation and temperature amounts, as well as seasonal variations, titled Tropical Rainy Climate (A), Dry Climate (B), Temperate Rainy Climate (C), Snowy Forest Climate (D), and Polar Climate (E) [3,15]. He then went further to divide each of these climates into subclimates according to the seasonal changes in temperature and precipitation [14-15, 30, 31].

Characteristics of the Köppen-Geiger Climate: Every climatic zone has its own features that are associated with the climate of the given territory. These are annual precipitation amount, average wind speed, and average monthly temperature[1,15]. These characteristics are presented in Table 2, and each of them will be discussed while focusing on a city that exemplifies the climatic region in Iran.

Table 2. Climate groups of Köppen-Geiger system that are found in Iran

No.	Köppen-Geiger Code	Climate Group	Characteristics
1	BWh	Dry	Desert climate, very hot and dry
2	BWk	Dry	Desert climate, cold and dry
3	BSh	Dry	Semi-arid, very hot and dry
4	BSk	Dry	Semi-arid, cold and dry
5	CSa	Temperate	Temperate with dry, very hot summers
6	CSb	Temperate	Temperate with dry, warm summers
7	Cfa	Temperate	Temperate with high rainfall and warm summers
8	DSa	Continental	Snowy climate with very hot, dry summers
9	DSb	Continental	Snowy climate with warm, dry summers

Arid Climate Group B:

The arid or desert climate is a subgroup of dry climates where evaporation exceeds precipitation[1,15]. Desert climates often feature bare, rocky, or sandy surfaces that are dry and do not retain much rainwater, so the small amount of rain that falls evaporates quickly [1,15,32]. Arid climates have several variations and microclimates:

Hot Desert Climate (BWh):

In this climate, clear skies and high-pressure lead to hot, dry conditions with intense sunlight[1,15]. During summer, when the sun is strongest, extreme heat prevails. Average air temperatures in hot months typically range from 29-35°C, reaching 43-46°C at midday[15]. Cities in Sistan and Baluchestan, Yazd, Hormozgan, Semnan, Isfahan, Qom, Ahvaz, South Khorasan, and Fars fall within the BWh hot desert climate zone. Yazd station is considered representative of the BWh climate in this research.

Cold Desert Climate (BWk) [15]:

Summers in cold desert climates (BWk) are usually warm (or in some cases dry), though typically not as hot as BWh climates. Unlike BWh, BWk climates usually have cold, dry winters. Snow is rare and minimal in these regions. Annual precipitation does not exceed 200 mm, and the average annual temperature is below 18°C. Kerman station is considered representative of the BWk climate [1,15,33, 34].

Hot Semi-Arid Climate (BSh) [15]:

The BSh climate is characterized by moderate to cool summer seasons, contrasted by intermittent periods of high thermal intensity during winters, accompanied by minimal rainfall. Typically situated on the peripheries of subtropical arid zones, these climates often exhibit precipitation cycles reminiscent of Mediterranean patterns, featuring increased moisture during winter months and pronounced dryness throughout the summer [15]. This climate is limited to cities like Yasuj and Sabzevar, the southern slopes of the Zagros in Khuzestan, Fars, and Bushehr provinces, and a small part of Golestan province in northeastern Iran[3,15]. These areas experience very hot summers. Night ventilation, high thermal mass, and evaporative cooling are appropriate in this climate. Internal heat absorption and retention and passive solar heating are recommended for heating. Sabzevar station is considered representative of the BSh climate [35, 36].

Cold Semi-Arid Climate (BSk) [15]:

BSk climates typically have hot to warm dry summers, though usually not as hot as BSh climates. Unlike BSh regions, areas with BSk climates usually have cold and potentially freezing winters [15]. Winter snowfall is common in these areas, though significantly less than in places with more humid climates at similar latitudes[15]. In BSk climate regions, which are typically at higher elevations than BSh areas, there can sometimes be significant temperature differences between day and night, occasionally up to 20°C or more[15]. Cities in Khorasan Razavi and North Khorasan, East and West Azerbaijan, etc., fall within the BSk zone. Mashhad station is considered representative of the BSk climate[15].

Temperate Climate Group C[15]:

ranges from an average of 0°C to 18°C, while at least one month maintains a mean temperature exceeding the 10°C threshold. The temperate group, designated as Group C, is further subdivided into various specific sub-climatic classifications [15].

Temperate Climate with Hot, Dry Summers (Csa) [15]:

The Csa subgroup represents the most prevalent variant of the Mediterranean climate, frequently referred to as the "typical Mediterranean climate" [15]. This classification is defined by thermal conditions where the warmest month exceeds a mean of 22°C, while the coldest month typically falls between 18°C and 3°C (or, in specific instances, between 18°C and 0°C) [15]. Furthermore, to distinguish it from cooler Mediterranean variants, a minimum of four months must maintain an average temperature above the 10°C threshold [15]. Characteristically, this climate features high-temperature, arid summers alongside mild, moisture-rich winters. Although summer conditions in these regions can approach the intensity of semi-arid zones, their proximity to large water bodies generally moderates extreme heat [15]. While winters are predominantly mild and humid across this subgroup, certain localities may encounter significant cold spells and intermittent snowfall [15]. In the Iranian context, the Csa climate encompasses several regions, including Gorgan, Sari, and portions of the Kurdistan, East Azerbaijan, and Markazi provinces, as well as cities like Urmia, Piranshahr, Ilam, and Kermanshah. For the purposes of this research, Khorramabad has been selected as the representative station for the Csa climatic zone [15].

Temperate Climate with Warm, Dry Summers (Csb) [15]:

The Csb subtype, often identified as the "cool-summer Mediterranean climate," is a less prevalent variant characterized by dry summers with moderate thermal intensity. A defining criterion for this classification is that the mean temperature of the warmest month remains below 22°C, while the coldest month typically averages between 18°C and 3°C (extending to 0°C in specific regions). Additionally, a minimum of four months must maintain an average temperature exceeding the 10°C threshold. Precipitation periods are generally humid, with conditions ranging from mild to sub-zero temperatures, including occasional snowfall. Despite the prevalence of rainfall during cooler seasons, these regions still experience frequent clear and sunny intervals. For the purposes of this study, Ardabil province and Meshgin Shahr have been designated as the representative locations for the Csb climatic zone [15].

Humid Subtropical Climate with Hot Summers (Cfa) [15]:

The humid subtropical climate, classified as Cfa, is defined by high-temperature, moisture-rich summers and winters that vary from mild to cold. Within this zone, thermal averages typically fluctuate between 0°C and 18°C during the coldest month, while the warmest month maintains a mean temperature of at least 22°C. In regions influenced by strong monsoonal flows, precipitation often reaches its maximum during the summer season. Distinct from Mediterranean patterns, Cfa zones exhibit more consistent or fluctuating rainfall cycles throughout the year, avoiding prolonged summer droughts. Most summer precipitation in these areas results from convective thunderstorms triggered by intense surface heating and high subtropical solar angles [15]. In the Iranian context, cities such as Rasht, Astara, Ramsar, and Anzali are categorized under the Cfa climate, with Anzali serving as the representative station for this study.

Continental Climate (Group D) [15]:

Continental climates are, therefore, marked by a high amplitude of temperature, which means that the temperature during the summer is much higher than that of the winter[15]. The continental climate is characterized by moderate precipitation, which is received mainly during the warmer parts of the year. It is a form of precipitation that produces snow on the ground for more than one month and as a percentage of the annual precipitation[15]. The continental regions also experience storms and high temperatures during summer, and the summer weather is comparatively better than the winter weather [37]. Continental climate has two subclimates as follows[15]:

Snow climate with very hot, dry summers (Dsa)

Snow climate with warm, dry summers (Dsb)

In these two subclimates, the coldest month is below 0°C or 3°C, the warmest month averages above 22°C, and at least four months have an average temperature above 10°C[15]. The wettest winter month has at least three times as much precipitation as the driest summer month in the humid continental climate, with hot summers influenced by Mediterranean conditions[15]. The difference between Dsa and Dsb climates is that Dsb has relatively cooler summers with more precipitation compared to Dsa[15]. Shahrekord and Talesh are in the Dsb climate. Hamadan-Nozheh station represents the snow climate with very hot, dry summers (Dsa), and Ab-Ali station represents the humid continental climate with hot summers influenced by Mediterranean conditions (Dsb) [15]. Table 3 summarizes key points for active and passive architectural design in arid, temperate, and continental climates.

Within the framework of this article, a comprehensive analysis of passive building design with near-zero energy consumption was conducted across nine climate categories as follows[15]. The selected cities and stations are:

1. Yazd station, representing the hot desert climate (BWh)
2. Kerman station, representing the cold desert climate (BWk)

3. Sabzevar station, representing the hot semi-arid climate (BSh)
4. Mashhad station, representing the cold semi-arid climate (BSk)
5. Anzali station, representing the humid subtropical climate (Cfa)
6. Khorramabad station, representing the hot-summer Mediterranean climate (Csa)
7. Meshgin Shahr station, representing the warm-summer Mediterranean climate (Csb)
8. Hamadan-Nozheh station, representing the hot-summer humid continental climate (Dsa)
9. Ab-Ali station, representing the warm-summer humid continental climate influenced by Mediterranean conditions (Dsb). Table 1 displays the climatic characteristics of the selected cities and stations.

Table 3: Key points in active and passive architectural design for various climates [27, 20].

Parameter/Climate	Dry Climate	Temperate Climate	Continental Climate
Ventilation	Night ventilation and evaporative cooling are suitable.	Prevent overheating in summer with thermal mass (and night ventilation) for temperature stability, and provide shading if needed.	Night ventilation in summer.
Thermal Mass	High thermal mass slows down internal heating during summer days with thermal mass and shading.	High thermal mass for temperature stability and high insulation levels prevent infiltration.	High thermal mass for temperature stability and high insulation levels prevent infiltration.
Solar Energy	For heating in this climate, absorb internal heat, prevent its loss, and utilize passive solar heating.	Usable.	Orientation for solar gain.
Heating	Natural heating in winter through orientation and opening design for solar gain.	Reduce heating energy demands using buffer zones and insulation to reduce winter heat loss – Trombe wall – water wall.	Natural heating using solar gain – ground-source heat pumps for winter heating.
Cooling	Rapid cooling in summer evenings with wind towers or cross ventilation and use of natural	Green roof.	Natural heating and cooling with sun and wind–ground tubes

	cooling if water is available.		for summer cooling, Slinky coils.
Glass and Window Features	Very low g-value (g-value or Solar Heat Gain Coefficient (SHGC) measures the window's ability to allow solar gain. The higher the g-value, the greater the solar gain. Single-pane glass is ideal but has poor U-value.) Low-E (surface 2), low U-value, and necessary shading.	High g-value (with necessary summer shading). • Low-E (surface 3) • Low U-value.	High g-value (with necessary summer shading). • Low-E (surface 3 or 5 if triple glazing) • Very low U-value.

3- The results and discussion

In the present study, nine climate types in Iran were considered according to the Köppen-Geiger classification system. These climates are as follows:

1. BWH climate: Including cities in Sistan and Baluchestan, Yazd, Hormozgan, parts of Semnan province, Isfahan, Qom, Ahvaz, parts of South Khorasan province, parts of Fars province, etc. Yazd station was considered representative of the BWH climate.
2. BSk climate: Including cities in Khorasan Razavi and North Khorasan, East and West Azerbaijan, etc. Mashhad station represents the BSk climate.
3. BSh climate: Cities such as Yasuj, Sabzevar, and the southern slopes of the Zagros in Khuzestan, Fars, and Bushehr provinces, and a small part of Golestan province in northeastern Iran. Sabzevar station was considered representative of the BSh climate.
4. BWk climate: Kerman city represents this climate.
5. Cfa climate: Including cities of Rasht, Astara, Ramsar, and Anzali. Anzali station represents the Cfa climate.
6. Csa climate: Including cities of Gorgan, Sari, Kurdistan, parts of East Azerbaijan, Urmia and Piranshahr, Khorramabad, Ilam, Kermanshah, Markazi, Chaharmahal and Bakhtiari (except

Shahrekord), and Hamadan. Khorramabad station was considered representative of the Csa climate.

7. Csb climate: Ardabil province and Meshgin Shahr represent this climate.
8. Dsa climate: Including Shahrekord and Talesh. Hamadan-Nozheh station was considered representative of the Dsa climate.
9. Dsb climate: Ab-Ali station represents this climate.

The parameters of average dry-bulb temperature in winter and summer and average relative humidity in winter and summer for these cities are shown in Table 2. Analysis of Figure 4, the temperature diagram of Iran's nine climates, indicates that for approximately 60% of the year, the temperature is between 0 and 21 degrees Celsius, necessitating passive and active heating strategies. In these climates, about 20% of the year, the temperature is between 21 and 27 degrees Celsius, and approximately 10 to 15% of the year, the temperature is between 27 and 38 degrees Celsius. For about 5% of the year, the temperature exceeds 38 degrees Celsius.

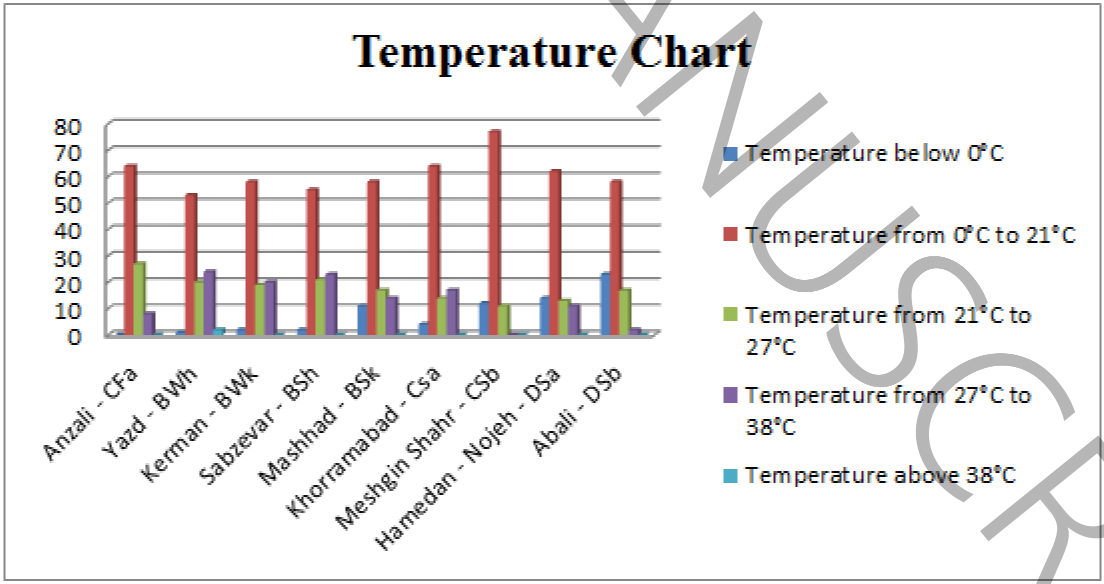


Fig. 4. Temperature diagram of Iran's 9 climates

Solar Radiation: Solar radiation is important in climate design from two perspectives: the amount of solar energy received and the use of natural daylight for space illumination. These two factors depend on indices such as the degree of cloud cover or clear sky. Figure 5 shows the annual solar radiation received in Iran's nine climates. The blue, red, and green bars represent direct normal irradiance, global horizontal irradiance, and diffuse horizontal irradiance. The minimum and maximum average radiation in these climates ranges from 300 to 450 watts per square meter per hour.

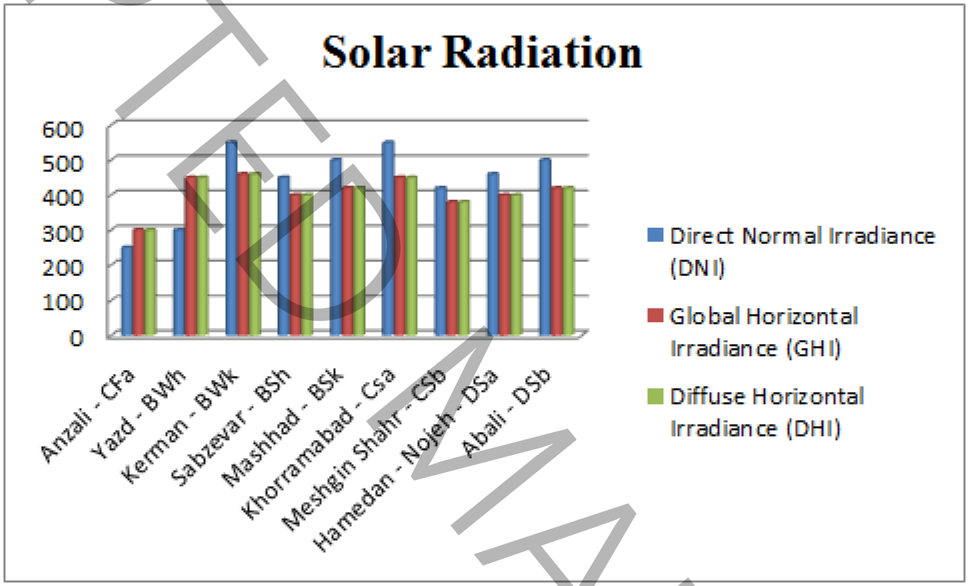
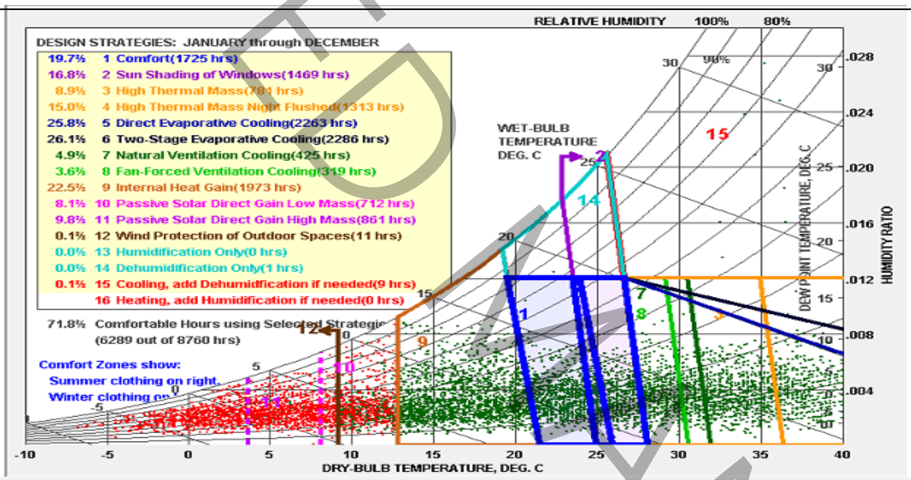
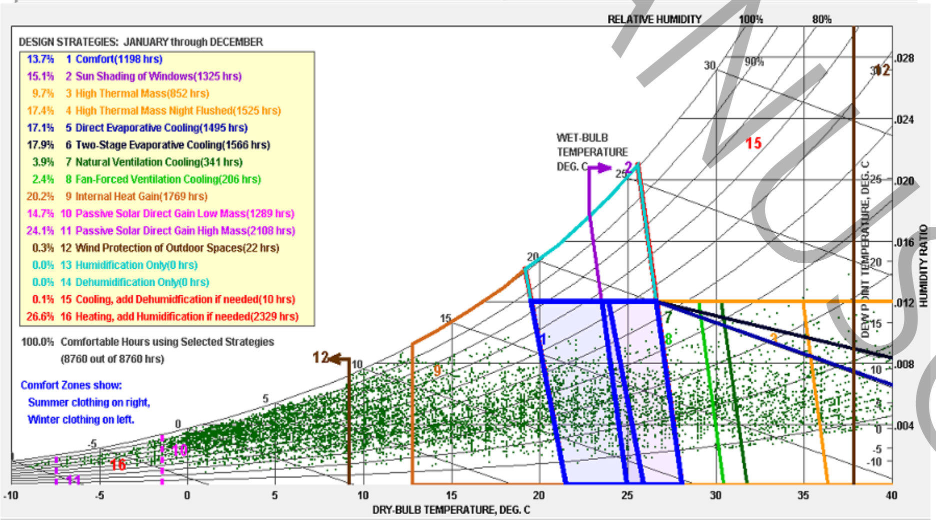
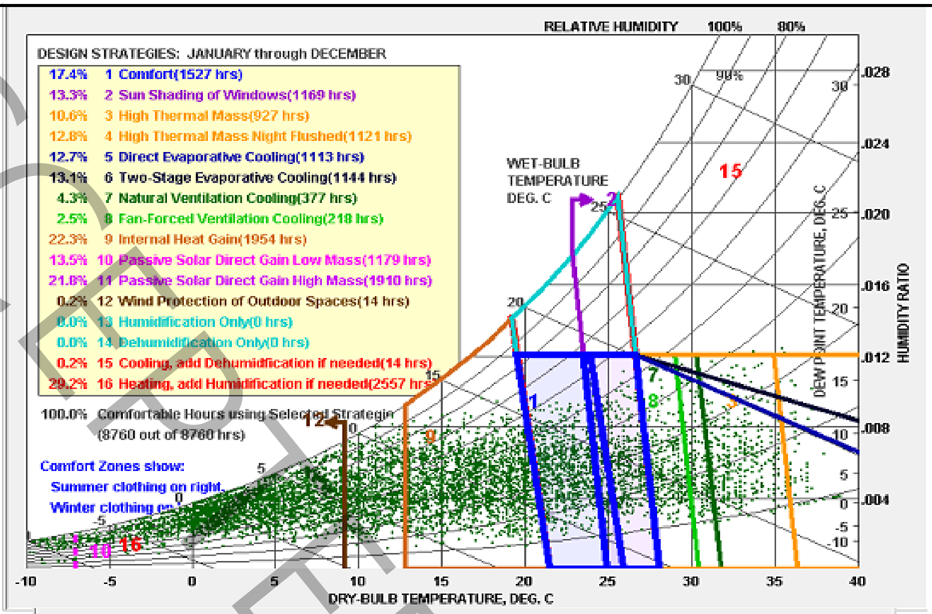


Fig. 5. Solar radiation reception levels across Iran's nine climates

Psychrometric Chart: Table 4 presents the psychrometric charts for selected cities in Iran's nine climate zones. This chart is one of the most powerful design tools in the Climate Consultant software. It displays dry-bulb temperature at the bottom and air humidity at the top. This vertical humidity scale, also known as absolute humidity, can be represented as the humidity ratio in pounds of water per pound of dry air (or grams of water per kilogram of dry air) or as vapor pressure. The curved line on the left is the saturation line (100% relative humidity line), indicating that air can hold less moisture at lower temperatures compared to higher temperatures. The term "internal heat generation" is an approximate estimate of the heat added to the building by internal loads such as lights, people, and equipment. It is highly dependent on the building type and design. The balance point temperature is the outdoor air temperature at which internal loads alone maintain the building within the comfort zone. Well-designed and insulated buildings have a much lower balance point temperature, thus consuming significantly less heating energy. Some building types (such as houses and warehouses) have relatively low internal loads and require more additional heating, so the balance point may be 60°F (15.6°C). Other buildings with high internal loads (such as factories) require almost no additional heating and may have a balance point close to 20°F (-6.7°C).

Table 4. Psychrometric charts for selected cities in Iran's nine climate zones

Psychrometric charts	City - Climate
	Yazd - BWh
	Korram Abad - Csa



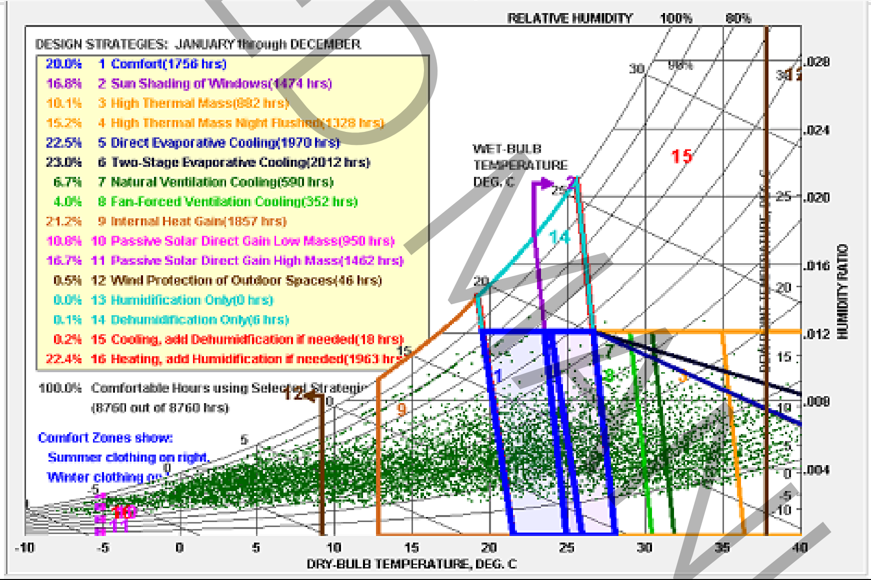
DESIGN STRATEGIES: JANUARY through DECEMBER

17.4% 1 Comfort(1527 hrs)
13.3% 2 Sun Shading of Windows(1169 hrs)
10.6% 3 High Thermal Mass(927 hrs)
12.8% 4 High Thermal Mass Night Flushed(1121 hrs)
12.7% 5 Direct Evaporative Cooling(1113 hrs)
13.1% 6 Two-Stage Evaporative Cooling(1144 hrs)
4.3% 7 Natural Ventilation Cooling(377 hrs)
2.5% 8 Fan-Forced Ventilation Cooling(218 hrs)
22.3% 9 Internal Heat Gain(1954 hrs)
13.5% 10 Passive Solar Direct Gain Low Mass(1179 hrs)
21.8% 11 Passive Solar Direct Gain High Mass(1910 hrs)
0.2% 12 Wind Protection of Outdoor Spaces(14 hrs)
0.0% 13 Humidification Only(0 hrs)
0.0% 14 Dehumidification Only(0 hrs)
0.2% 15 Cooling, add Dehumidification if needed(14 hrs)
29.2% 16 Heating, add Humidification if needed(2557 hrs

100.0% Comfortable Hours using Selected Strategie
(8760 out of 8760 hrs)

Comfort Zones show:
Summer clothing on right,
Winter clothing on

Mashahd – BSk



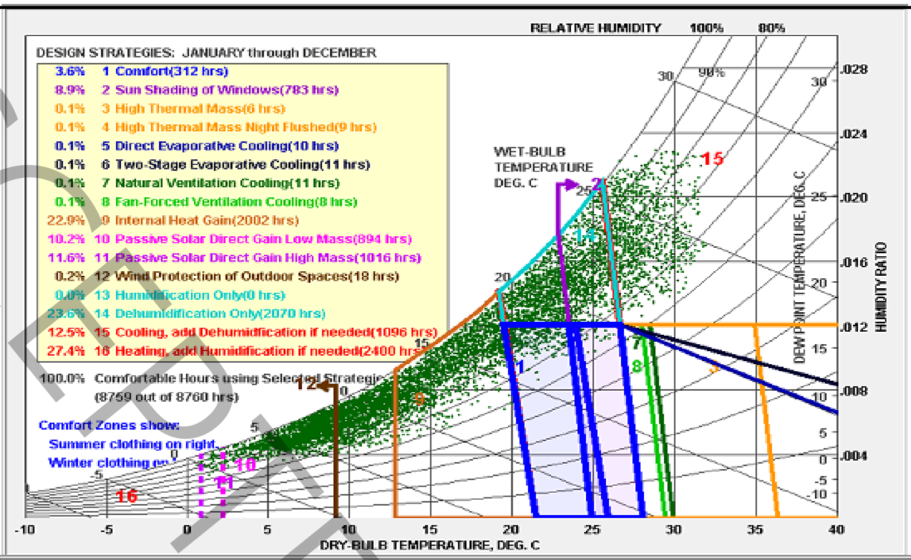
DESIGN STRATEGIES: JANUARY through DECEMBER

20.0% 1 Comfort(1756 hrs)
16.8% 2 Sun Shading of Windows(1474 hrs)
10.1% 3 High Thermal Mass(882 hrs)
15.2% 4 High Thermal Mass Night Flushed(1328 hrs)
22.5% 5 Direct Evaporative Cooling(1970 hrs)
23.0% 6 Two-Stage Evaporative Cooling(2012 hrs)
6.7% 7 Natural Ventilation Cooling(590 hrs)
4.0% 8 Fan-Forced Ventilation Cooling(352 hrs)
21.2% 9 Internal Heat Gain(1857 hrs)
10.8% 10 Passive Solar Direct Gain Low Mass(950 hrs)
16.7% 11 Passive Solar Direct Gain High Mass(1462 hrs)
0.5% 12 Wind Protection of Outdoor Spaces(46 hrs)
0.0% 13 Humidification Only(0 hrs)
0.1% 14 Dehumidification Only(6 hrs)
0.2% 15 Cooling, add Dehumidification if needed(18 hrs)
22.4% 16 Heating, add Humidification if needed(1963 hrs

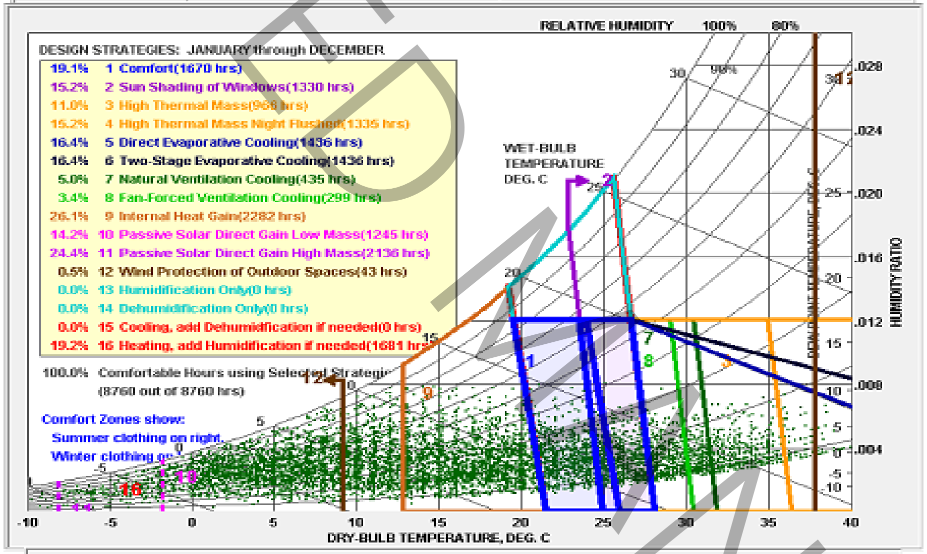
100.0% Comfortable Hours using Selected Strategie
(8760 out of 8760 hrs)

Comfort Zones show:
Summer clothing on right,
Winter clothing on

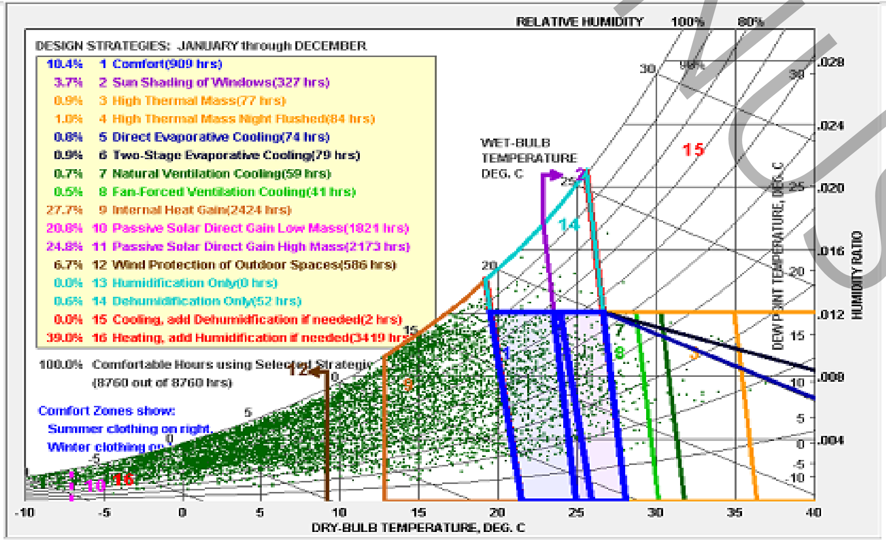
Sabzevar – BSh



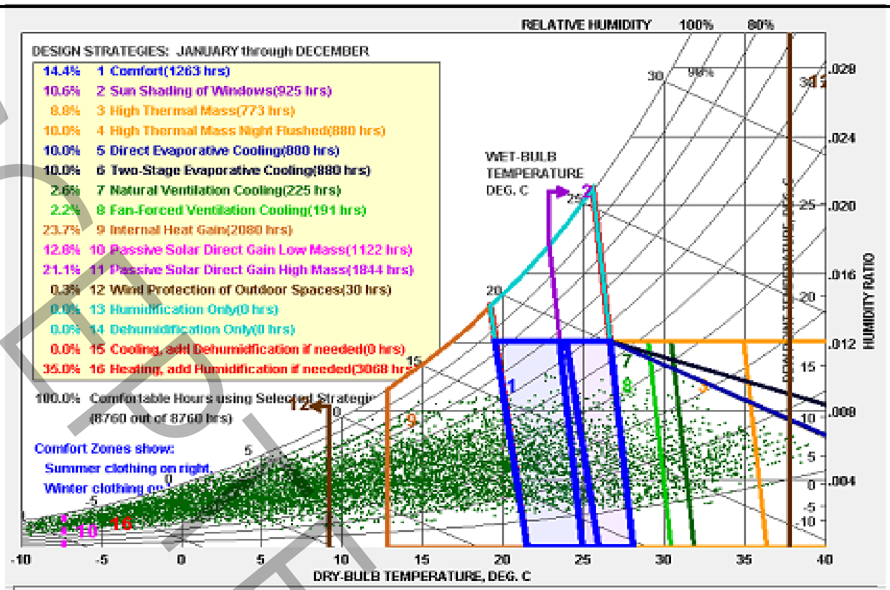
Anzali – Cfa



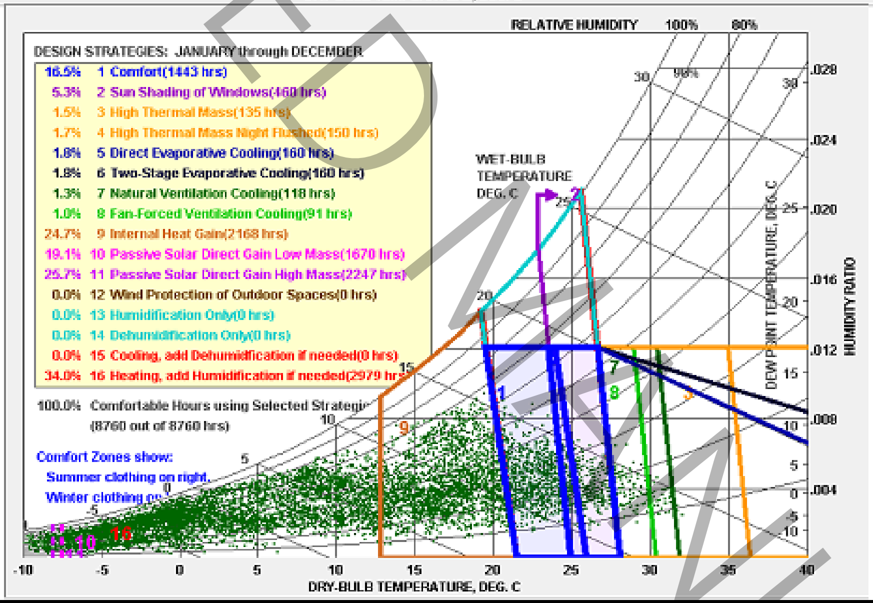
Kerman – BWk



Meshkin Shahr – Csb



Hamedan-Noje Dsa



Abali - Dsb

Results psychrometric charts for nine climates of Iran presented in Figure 6 reveal that winter heating is the major need for all Iranian climates. It is found that passive means of internal heat gains and window shading are the most effective means of enhancing comfort conditions. Besides, the CSb climate is only influenced by disruptive winds, while such winds do not influence other climates. We will be dealing with these topics in more detail later.

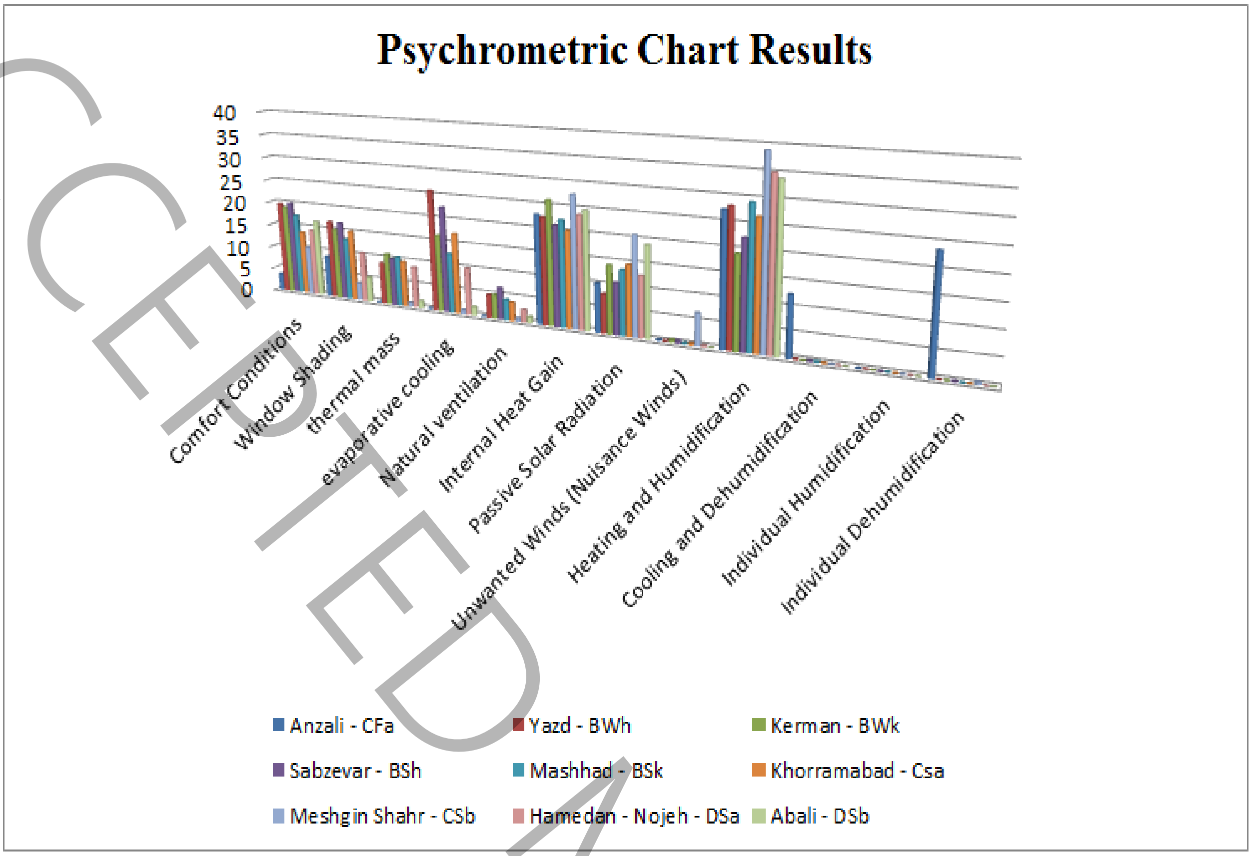


Fig. 6. Results of psychrometric charts for Iran's nine climate zones

Figure 7 shows that, except for the CFa climate, which requires cooling and dehumidification in summer, almost all other climates can achieve comfort conditions through evaporative cooling or passive cooling. For winter heating, most Iranian climates require mechanical and active systems. According to the results of passive strategies, internal heat generation, active solar radiation, and window shading have the most significant impact and contribute most to increasing the comfort percentage in all climates.

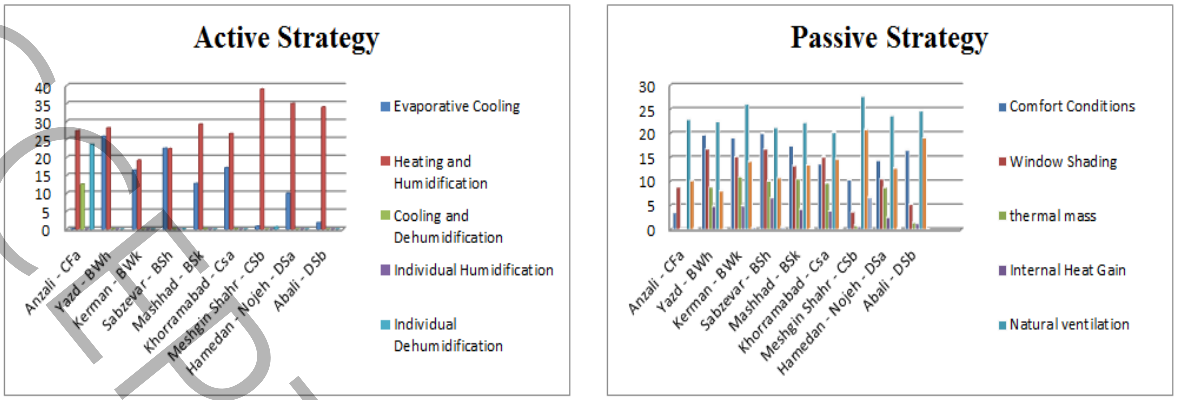


Fig. 7. Results of active and passive strategies for Iran's nine climate zones

The cities of Rasht, Anzali, Astara, and Ramsar represent the temperate and rainy climate with hot summers and no dry season, known as CFa. This type of Iranian climate is only found on the Caspian Sea coast. The results for the CFa climate, as shown in Figure 8, indicate that heating and humidification in winter and internal heat generation have the most significant impact on achieving comfort conditions. Furthermore, evaporative cooling and natural ventilation are not applicable in this climate, and high-efficiency active and mechanical systems should be used. The comfort conditions in this climate are around 5%, which can be increased to approximately 40% of the year (3500 hours annually) through internal heat generation, passive solar heating, and window shading.

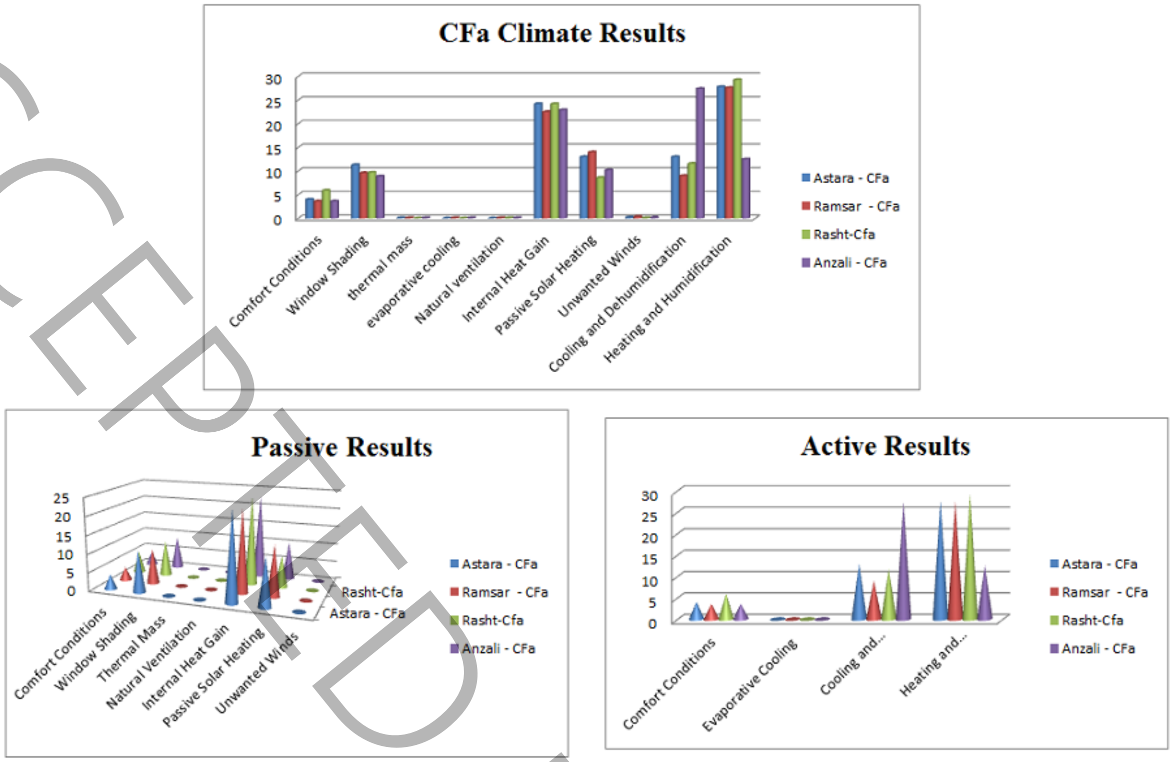


Fig. 8. Results for CFa climate

Khorramabad station represents the temperate climate with dry and very hot summers (CSa), which covers a large part of the Zagros, Alborz, and Caspian regions. Cities such as Sari, Ilam, Hamadan, Sanandaj, Kermanshah, Arak, and Urmia are located in this climate, and Figure 9 shows its results. The results indicate that in the CSa climate, the primary priority for improving comfort conditions is heating and humidification in winter, requiring mechanical and active systems for approximately 30% of the year. Naturally, comfort conditions are met for 15% of the year, and with passive strategies of internal heat generation, passive solar heating, and window shading, we can increase comfort conditions to 65%. In this climate, evaporative cooling systems can be used to some extent, although the need for individual humidification equipment is also observed in some cities within this climate zone.

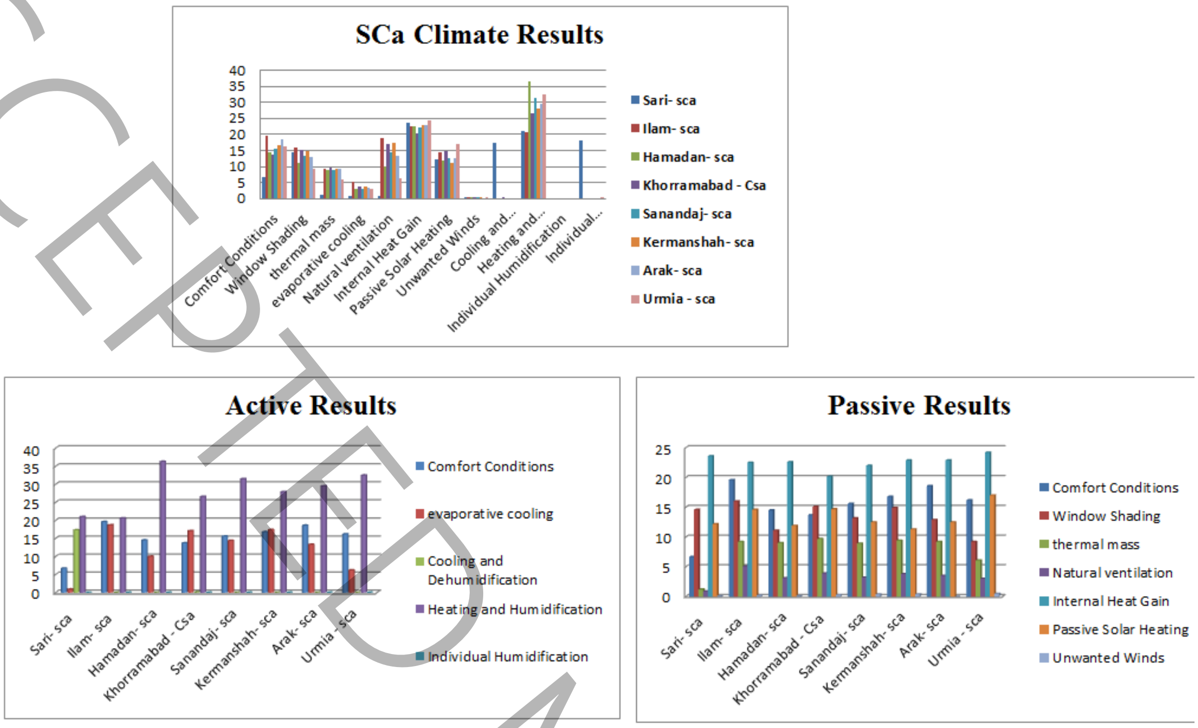


Fig. 9. Results of active and passive strategies for the SCa climate.

The prevailing climate in Iran is arid (BW) and semi-arid (BS), with the temperate climate being restricted to the Zagros Mountains and the northern part of the Alborz range. Yazd station falls in the hot desert climate category and is classified by the World Meteorological Organisation as BWh. Other cities that fall under the BWh climate include Zahedan, Qom, Isfahan, Bandar Abbas, Ahvaz, Bandar Lengeh, Abadan, and Kashan.

As illustrated in Figure 10 below, it is evident that comfort conditions in this climate are achieved about 20% of the year. In such a scenario, window shading, internal heat gain, and passive solar heating can raise the comfort level by 70 percent. Besides, direct and indirect evaporative cooling can be used in this climate as well. Nevertheless, for cities such as Bandar Abbas and Bandar Lengeh, because of high humidity, the evaporative coolers are not suitable. Hence, cooling and dehumidification systems like air conditioners should be used instead of the two.

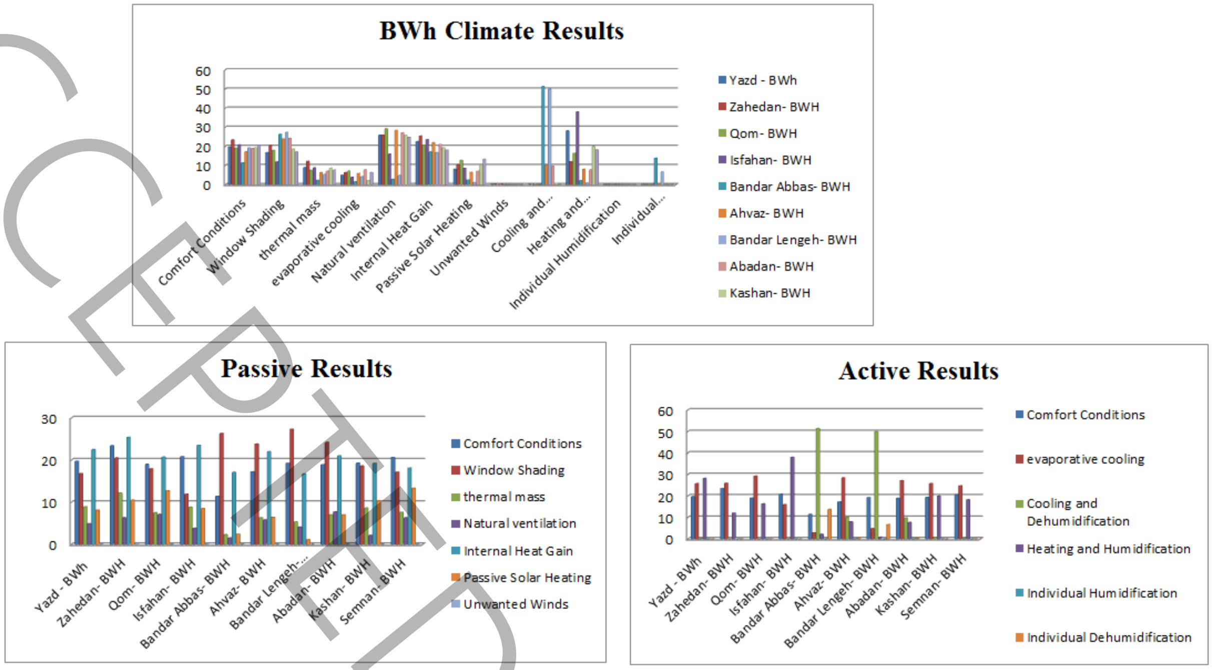


Fig. 10. Results for BWh climate

Mashhad station is characterized by the BSk climate, which is the cold semi-arid climate, whereas Kerman station is characterized by the BWk climate, which is the cold desert climate. Figure 11 shows the findings for cities in these two climates. Regarding the BSk climate, comfort conditions are observed in about 20 percent of the year, and the main issue is heating in winter. In the BWk climate, internal heat gains dominate the comfort conditions and occur approximately 25% of the time.

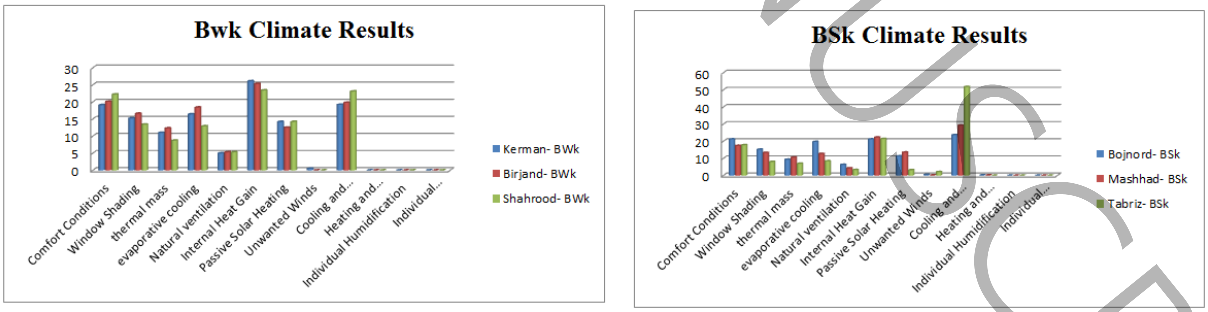


Fig. 11. The results for BSk and BWk climates

Sabzevar station has a hot semi-arid climate (BSh). The following figure shows the findings for cities in this climate, as presented in Figure 12. Thus, by using passive measures, the comfort conditions can be raised from 10 to 50 percent. Furthermore, Busheir is humid and needs air conditioning and dehumidification, so it cannot use evaporative coolers. Yasuj and Sabzevar have colder climates than Bushehr and need more heating and humidifying systems.

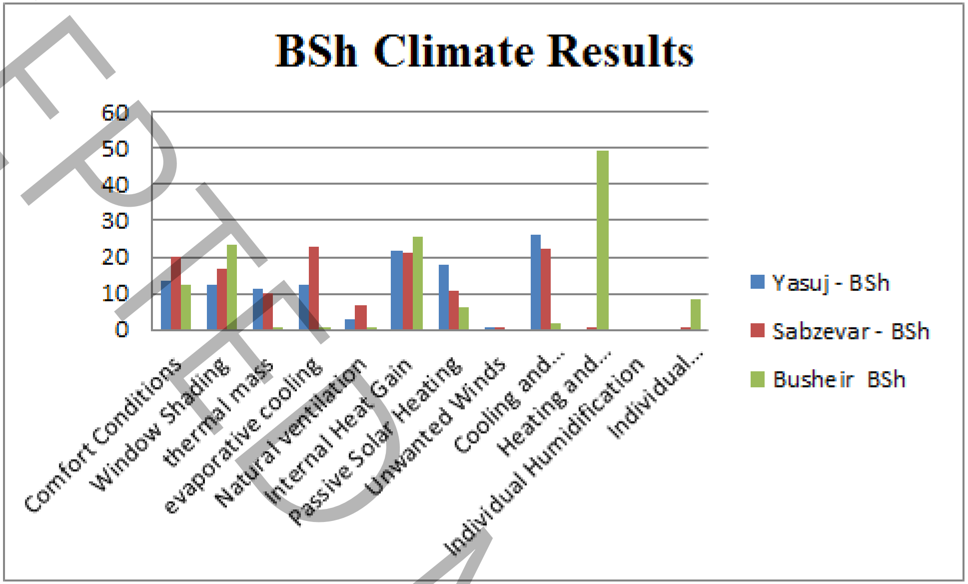


Fig. 12. Results for BSh climate

Additionally, temperate climates in Iran, such as the warm-summer Mediterranean climate (Csb) represented by Meshgin Shahr station, the hot-summer continental climate (Dsa) represented by Hamadan-Nojeh station, and the warm-summer continental climate (Dsb) represented by Ab Ali station, are limited in extent. The results for these climates are presented in Table 5.

Table 5 shows that for the Dsa climate (Hamadan-Nojeh station), 14.4% of the year falls within the comfort zone. This can be extended by 10.6% through window shading, 23.7% through internal heat gain, and 12.8% through passive solar heating. For the Dsb climate (Ab Ali station), window shading can extend the comfort zone by 5.3%, evaporative cooling by 1.8%, internal heat gain by 24.7%, and passive solar heating by 19.1%. Table 5 presents other design strategy parameters for various climates.

Table 5. Design strategies for different climates

Design Strategy	Percentage of Comfort Creation in Climates								
	BWh (Yazd)	CSa (Khorramabad)	BSk (Mashhad)	BSh (Sabzevar)	CFa (Anzali)	BWk (Kerman)	CSb (Meshgin Shahr)	DSa (Hamedan - Nojeh)	DSb (Abali)
Comfort Range	19.7	13.7	17.4	20	3.6	19.1	10.4	14.4	16.5
Window Shading	16.8	15.1	13.3	16.8	8.9	15.2	3.7	10.6	5.3
Evaporative Cooling	25.8	17.1	12.7	22.5	0.1	16.4	0.8	10	1.8
Internal Heat Gain	22.5	20.2	22.3	21.2	22.9	26.1	27.7	23.7	24.7
Use of Passive Solar Energy	8.1	14.7	13.5	10.8	10.2	14.2	20.8	12.8	19.1
Cooling with Dehumidification	0.1	0.1	0.2	0.2	12.5	0	0	0	0
Heating with Humidification	28.2	26.6	29.2	22.4	27.4	19.2	39	35	34
Protection from Annoying Winds	0.1	0.3	0.2	0.5	0.2	0.5	6.7	0.3	0

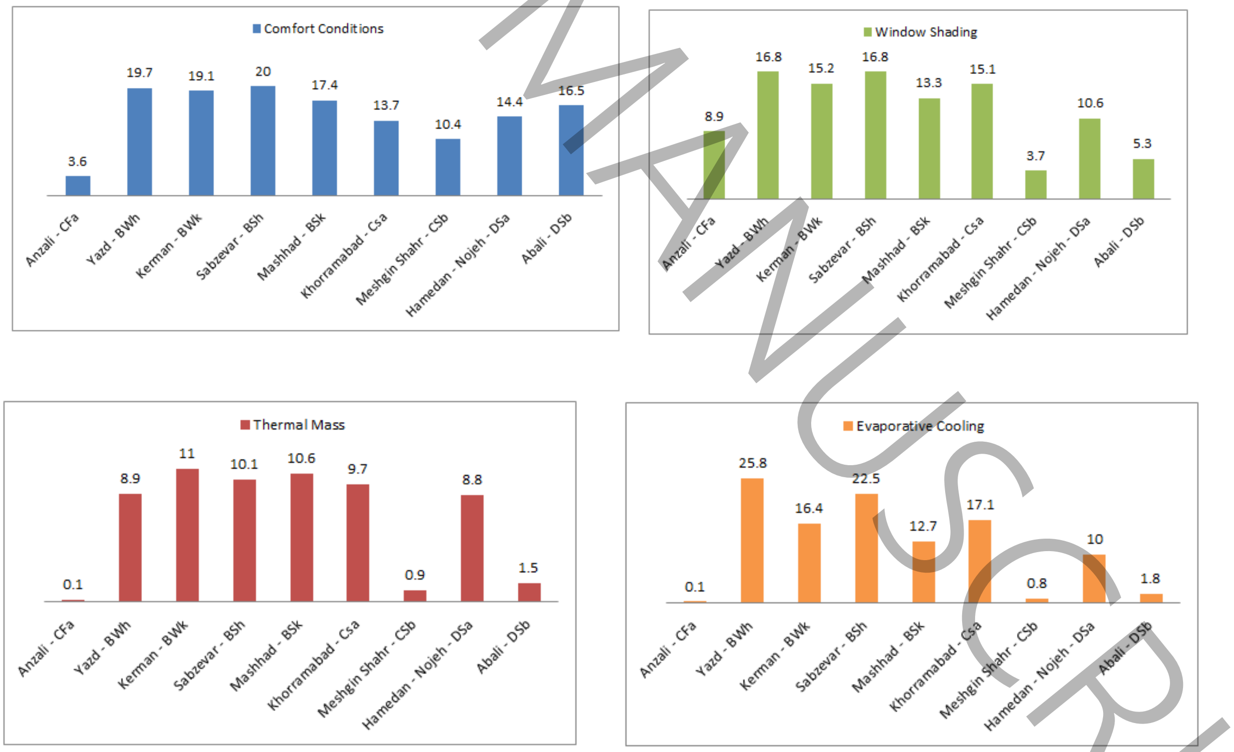
Table 6. Number of agreements with proposed design parameters for different climates

	Agreement ✓ or Disagreement ✕ for Climates								
Design Parameters	BWh (Yazd)	CSa (Khorramabad)	BSk (Mashhad)	BSh (Sabzevar)	CFa (Anzali)	BWk (Kerman)	CSb (Meshgin Shahr)	DSa (Hamedan - Nojeh)	DSb (Abali)
Comfort Range	✓	✓	✓	✓	✕	✓	✓	✓	✓
Window Shading	✓	✓	✓	✓	✕	✓	✕	✓	✕
Evaporative Cooling	✓	✓	✓	✓	✕	✓	✕	✓	✕
Internal Heat Gain	✓	✓	✓	✓	✓	✓	✓	✓	✓
Use of Passive Solar Energy	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cooling with Dehumidification	✕	✕	✕	✕	✓	✕	✕	✕	✕
Heating with Humidification	✓	✓	✓	✓	✓	✓	✓	✓	✓

Protection from Annoying Winds	×	×	×	×	×	×	✓	×	×

As seen in Table 6, the agreements with proposed design parameters have different numbers based on the climatic zone[15]. When the weather conditions are considered in the analysis, Yazd exhibits the highest level of compatibility with the proposed design parameters, while the compatibility of Anzali and Ab Ali is lower.

Figure 13. compares the different parameters for Iran's nine climatic regions, such as comfort conditions, window shading, thermal mass, evaporative cooling, natural ventilation, internal heat gain, passive solar gain, undesirable wind, heating and humidification, cooling, and dehumidification[15].



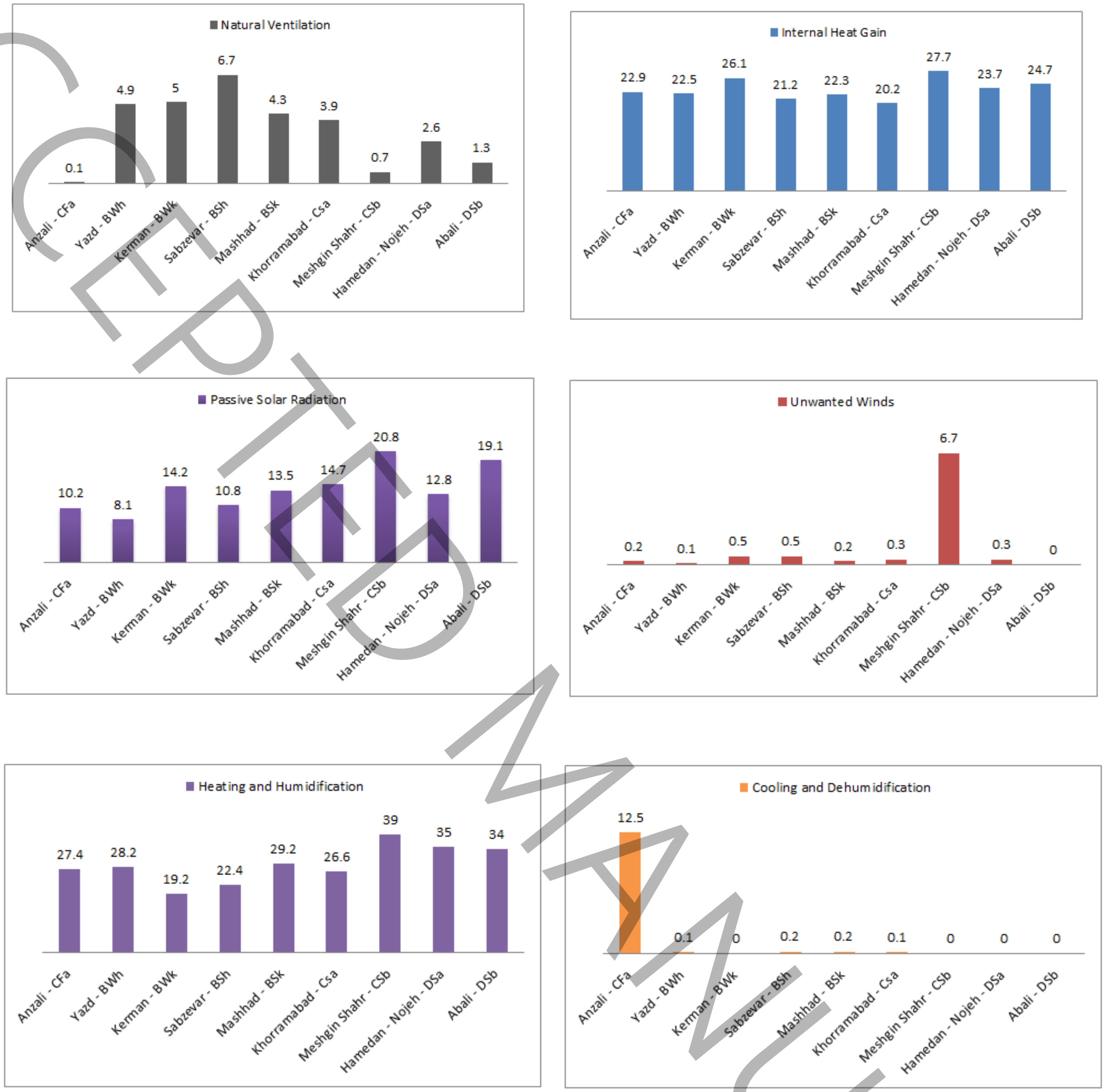


Fig. 13. Comparison of the parameters of the nine climate zones in Iran

The accuracy of the current datasets is rigorously validated through a comparative analysis with the findings of reference [15]. In that study, which also utilized Climate Consultant Software (CCS) to evaluate the cities of Tabriz, Sari, and Yazd, the software's recommendations aligned closely with our observations. Specifically, for residential units in Tabriz, the primary CCS strategy was identified as "heating, plus humidification if required," whereas for the climatic conditions of Sari, "natural ventilation" was established as the most critical design intervention. Furthermore, "evaporative cooling" was highlighted as the essential comfort factor for buildings in Yazd. The results indicate that Yazd, representing an arid climate, exhibits the highest correlation with the software's suggested design criteria, a trend that progressively declines for Tabriz and Sari. However, it is important to emphasize that while CCS effectively models internal thermal variables, it does not account for external environmental challenges; for instance, the prevalence of sandstorms in Yazd remains a vital architectural consideration that falls outside the software's analytical scope. [15].

4-The conclusion

This study examined passive design strategies for nearly zero-energy buildings across 9 of the 31 Köppen-Geiger climate classifications identified for Iran, including BWh, BSk, BSh, BWk, CSa, CSb, CFa, DSa, and DSb climates. Weather data in EPW format was input into Climate Consultant software, utilizing ASHRAE Standard 55. Output results for cities, including temperature, radiation, and psychrometric charts, were analyzed.

As demonstrated in Table 5, window shading is a crucial factor in house design for arid (B) microclimates. Implementing an appropriate shading system for windows can increase comfort time in a house by up to 15%[1]. However, this system shows less significant improvement (approximately 3-8%) for (C) and (D) subclimate zones.

Table 5 also illustrates that the utilization of passive solar energy and internal heat generation are important factors in house design across all climates. Internal heat generation can contribute to comfort conditions in buildings by approximately 20-25%, while passive solar energy can contribute 10-15%.

Heating with humidification is the most critical parameter in the nine climate zones of Iran, potentially increasing comfort conditions by approximately 20-39%. Evaporative cooling systems can be utilized in all climates except Cfa. In the Cfa climate, other active systems should be employed, and except for the Cfa climate, other climates do not require humidification.

Key findings include:

1. In the hot desert climate (BWh), represented by Yazd station, results showed that passive strategies could maintain comfort conditions throughout 71.8% of the year (6,289 hours out of 8,760 annual hours). During cold months, 28.2% (2,471 hours) require active heating and humidification. In hot months, evaporative cooling systems can achieve comfort conditions for 25.8% (2,263 hours)) of the year. Internal heat generation contributes to comfort for 22.5% (1,973 hours) and passive solar radiation for 8.1% (712 hours)) of the year.
2. Khorramabad station, representative of the hot-summer Mediterranean climate (CSa), which covers large parts of the Zagros, Alborz, and Caspian regions, showed that passive strategies could maintain comfort conditions for 73.4% of the year (6,431 hours). Cold months require heating for 26.6% (2,329 hours)) of the year, while hot months achieve comfort through evaporative cooling for 17.1% (1,495 hours). Window shading contributes 15.1%, passive solar heating 14.7%, and internal heat generation 20.2% of the year to comfort conditions.
3. Results for the cold semi-arid climate (BSk), represented by Mashhad station, indicated that passive strategies could maintain comfort conditions for 70.8% of the year (6,203 hours). Cold months require heating for 29.2% (2,557 hours), while hot months achieve comfort through evaporative cooling for 12.7% (1,113 hours) of the year. Window shading contributes 13.3%, passive solar heating 13.5%, and internal heat generation 22.3% of the year to comfort conditions.
4. Results for the hot semi-arid climate (BSh), represented by Sabzevar station, showed that passive strategies could maintain comfort conditions for 77.6% of the year (6,797 hours). Cold months require active heating for 22.4% (1,963 hours), while hot months achieve comfort through

evaporative cooling for 22.5% (1,970 hours) of the year. Window shading contributes 16.8%, passive solar heating 10.8%, and internal heat generation 21.2% to comfort conditions.

5. Anzali station, representative of the humid subtropical climate (CFa) found only in the Caspian coastal strip, demonstrated that passive strategies could maintain comfort conditions for 60.1% of the year (5,263 hours). Hot months require cooling and dehumidification for 12.5% (1,096 hours or 45 days), while 27.4% (2,400 hours) require heating and humidification to achieve comfort. Internal heat generation contributes 22.9% (2,002 hours), dehumidification 23.6% (2,070 hours), and passive solar radiation 10.2% (894 hours) of the year to comfort conditions.

6. In the cold desert climate (BWk), Kerman station showed that passive strategies could maintain comfort conditions for 81% of the year (7,096 hours). Cold months require heating for 19% (1,668 hours), while hot months achieve comfort through evaporative cooling for 19.4% (1,700 hours) of the year. Window shading contributes 17%, passive solar heating 11.5%, and internal heat generation 27.2% of the year to comfort conditions.

7. The warm-summer Mediterranean climate (CSb), represented by Meshgin Shahr station, indicated that passive strategies could maintain comfort conditions for 60.3% of the year (5,281 hours). Cold months require heating for 39.7% (3,479 hours), while hot months achieve comfort through evaporative cooling for only 0.5% (48 hours) of the year. Window shading contributes 3.7%, passive solar heating 18.5%, and internal heat generation 26.1% of the year to comfort conditions.

8. Hamadan-Nojeh station, representative of the hot-summer continental climate (DSa), which has very cold winters but very hot summers, showed that passive strategies could maintain comfort conditions for 65% of the year (5,692 hours). Cold months require heating for 35% (3,068 hours), while hot months achieve comfort through evaporative cooling for 10% (880 hours) of the year.

Window shading contributes 10.6%, passive solar heating 12.8%, and internal heat generation 23.7% of the year to comfort conditions.

9. Results for the warm-summer continental climate (DSb), represented by Ab Ali station, which has cooler summers and higher precipitation compared to the DSa climate, showed that passive strategies could maintain comfort conditions for 66% of the year (5,781 hours). Cold months require heating for 34% (2,979 hours), while hot months achieve comfort through evaporative cooling for only 1.8% (160 hours) of the year. Window shading contributes 5.3%, passive solar heating 19.1%, and internal heat generation 24.7% of the year to comfort conditions.

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