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Review and Analysis of Bioclimatic Design Approach

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Abstract: The growing awareness of the environment's importance and the impact of climate change has led architects and designers to adopt sustainable building design approaches for enhancing their buildings quality. Bioclimatic design is one such approach that aims to create comfortable and energy-efficient buildings by utilizing natural resources and local climate data. This paper delves into the concept of bioclimatic design in detail highlighting different bioclimatic strategies for residential buildings that help in achieving bioclimatic design goals. The aim of this paper is to provide a systematic review that explores and categorizes the bioclimatic architecture approaches, analysis and assessment methods, and strategies in a clear and concise manner. The methodology employed in this study is a literature review of bioclimatic architectural designs in residential buildings to comprehend their design approaches, analysis and assessment methods, and strategies. This study focuses on bioclimatic design, thermal comfort, and energy efficiency. Future studies on bioclimatic building design should focus on analyzing current strategies in different climate zones, testing new technologies and materials, exploring more strategies suitable for the local climate, and evaluating the integration of bioclimatic design with other sustainable approaches to create efficient and cost-effective buildings.

Keywords: Bioclimatic architecture, Energy efficiency, Thermal comfort, Local climate, Architectural design approach.

1. Introduction

Indoor thermal comfort is crucial for occupant satisfaction and productivity, but achieving it comes at a cost as it accounts for a significant portion of energy consumption in buildings. Energy efficiency is essential for reducing operating costs and promoting sustainability [1–4]. Improving energy efficiency in buildings involves reducing energy demand for HVAC systems, which are the largest energy consumers. The residential sector is a major energy consumer globally, with Egypt's residential sector accounting for 42% of total electricity consumption. Therefore, implementing architectural strategies to improve indoor environmental quality while reducing energy consumption is crucial [1–6] Bioclimatic design is an architectural approach that utilizes solar energy and other environmental resources to provide human thermal comfort. It involves implementing design solutions appropriate for the local climate and environment, which can improve indoor air quality and building energy performance [7–10].

2. BIOCLIMATIC ARCHITECTURE

Bioclimatic design prioritizes energy conservation and integration with the natural environment [11], utilizing passive strategies to improve a building's energy efficiency and indoor comfort without additional energy consumption. Notable proponents include Olgyay, Szokolay, Kristinsson, and Yeang [12,13] Bioclimatic architecture is a design approach that adapts buildings to the needs of occupants while optimizing energy consumption based on local climate conditions, furthermore, ensuring that the building's form is appropriate for its intended purpose. This approach considers various factors such as form configuration, orientation, internal spatial arrangement, facade design, vegetation usage, natural ventilation, and building mass usage to reduce energy passively and reduce dependence on active systems.

Table 1 summarizes previous research on bioclimatic design.

TABLE 1: Bioclimatic design's research summary.

Year	Country	Research aim	REF
1996	Argentina	This study aimed to determine the best bioclimatic design strategies for the city of San Juan, Argentina, based on the area's temperature and relative humidity.	[14]
1998	Malaysia	This study aimed to analyze regional climate data from the Klang Valley, Malaysia, to develop a set of design strategies based on the bioclimatic chart and Mahoney tables. It highlighted several passive design techniques that are suitable for Malaysian buildings.	[15]
2001	International	This study aimed to analyze an adaptive model of thermal comfort and energy conservation in a built environment. In several moderate climate zones worldwide, it emphasized the potential for optimizing cooling energy by designing for natural or hybrid ventilation.	[16]
2006	UK	This study aimed to investigate the impact of architectural education and prior experience on the work of a group of architects. The architects' work exhibited strong bioclimatic integration characteristics.	[17]

2007	Italy	This study aimed to reduce energy consumption while creating a sustainable and comfortable indoor environment for buildings in Pieve di Cento, Italy. The Givoni chart and Mahoney table were utilized to identify passive design techniques.	[18]
2009	Italy	This aimed to improve the energy efficiency and indoor comfort conditions of residential buildings. It achieved this goal through a combination of passive solar elements and traditional materials. After conducting a critical analysis of the simulation results, specific recommendations were made for achieving these objectives.	[19]
2011	Egypt	This study aimed to investigate the correlation between bioclimatic strategies and outdoor built environments in Egypt. Based on these findings, the study made recommendations for bioclimatic design in such conditions.	[20]
2012	Greece	This study aimed to implement a computational approach for bioclimatic design purposes in urban environments, while also developing strategies for dealing with urban heat islands.	[21]
2013	Romania	This study aimed to provide the essential information needed to comprehend the concept of bioclimatic architecture. Additionally, it highlighted several examples, which were inspired by vernacular architecture and recognized by modern architecture.	[22]
2014	Australia	This study aimed to investigate the potential of passive cooling techniques in hot and humid subtropical climates for natural ventilation in residential buildings.	[23]
2014	Kuala Lumpur	This study aimed to assess thermal comfort and user satisfaction in the residential units of the University of Malaya in Kuala Lumpur. The study concluded that implementing bioclimatic design strategies in these units would provide residents with improved comfort conditions.	[24]
2014	China	The study aimed to create a comprehensive and sustainable design approach for Shang-gan village in western China, using bioclimatic strategies.	[25]
2015	Cyprus	This study aimed to analyze the bioclimatic conditions of three different climatic zones in Cyprus and identify passive design techniques that are suitable for buildings in each zone.	[26]
2016	Italy	This study aimed to propose appropriate bioclimatic strategies based on Mediterranean vernacular architecture.	[27]
2016	Iran	This study aimed to analyze and compare common architectural examples in Ardabil, Iran, and their correlation with the local climate. The study suggested new design recommendations that are suitable for this climate.	[28]
2017	Algeria	This study aimed to enhance the energy efficiency of a bioclimatic house in Algeria. Experimental and software simulation evaluations demonstrated that bioclimatic strategies can be a promising solution, providing thermal comfort in the summer, space heating, energy savings, and reduced emissions of environmental pollutants.	[29]
2017	Europe	This study aimed to examine traditional design strategies in some South-Eastern European countries. It described and discussed the significant features, differences, and similarities in architectural designs of these regions.	[30]
2017	Brazil	This study aimed to examine the thermal comfort conditions in office buildings located in a humid subtropical climate in Brazil.	[31]
2018	Iran	This study aimed to analyze the conventional climate-responsive solutions used in ancient Iranian buildings. The authors examined appropriate climate solutions in the vernacular architecture of the West of Guilan in their study.	[32]
2018	Iran	This study aimed to propose design recommendations for appropriate natural ventilation in Rasht city.	[33]
2018	Mozambique	This study aimed to discuss the recent implications of indoor thermal comfort models, vernacular/bioclimatic approaches, and the applied strategies in hot and hot-humid climates.	[34]
2019	Algeria	This study aimed to investigate the bioclimatic potential of climate zones in Algeria.	[35]
2020	India	This study aimed to develop an analysis tool for evaluating the cooling capabilities of passive techniques in various Indian climatic zones. The study included 18 cities that represented four distinct climate zones.	[36]
2020	Greece	This study aimed to present examples of the author's work on various passive bioclimatic approaches.	[37]
2020	France	This study aimed to propose a new set of indicators that prioritize on bioclimatic design. It sought to enhance the decision-making process for designing fully space-conditioned buildings in hot and humid climates.	[38]
2021	India	This study aimed to investigate the implications of current and future bioclimatic potential for passive heating and cooling design strategies.	[39]
2021	China	This study aimed to review extant studies on bioclimatic architecture. It sought to identify potential future research directions that may help in achieving building energy efficiency.	[40]

2.1 Bioclimatic Design Approaches

Contemporary bioclimatic building design can be approached through the replication of vernacular solutions or an analytical study of climate characteristics (Figure 1) [13].

2.1.1 Symptomatic bioclimatic design approach

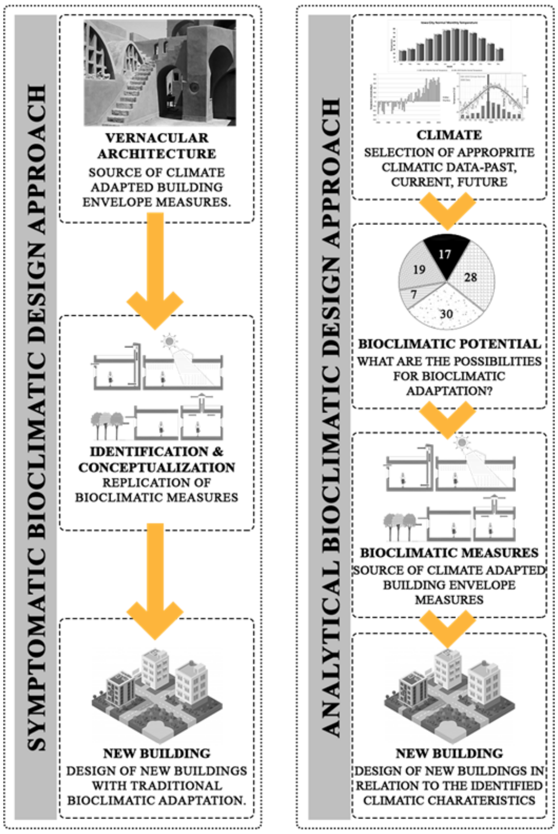

Fig 1: Bioclimatic design approaches, Ref: The researcher after [18]

Bioclimatic design is the oldest approach to building design, with roots tracing back to early human settlements. Throughout history, there have been periods of intense interest in designing buildings with consideration for the climate, interspersed with periods of indifference. The historical significance and evolution of bioclimatic design can be seen in various examples of vernacular architecture[41–47]. Traditional architecture has evolved over centuries to adapt to specific climate conditions, and contemporary bioclimatic buildings should consider the vernacular architecture of the location. Scientifically based engineering methods should be used to evaluate the performance and validity of design solutions. To achieve contemporary climate-adapted buildings, the first step is to identify vernacular examples for inspiration, followed by identifying bioclimatic measurements used in traditional buildings and conceptualizing them into clear Passive Solar Architecture (PSA) approaches. However, this approach assumes of a static climate and may not be the best solution for ongoing anthropogenically induced climate shifts. The symptomatic bioclimatic design method is also questionable considering accelerated global warming [48,49].

2.1.2 Analytical bioclimatic design approach

According to this approach, Bioclimatic building design involves analyzing the climate, identifying constraints and opportunities for climate adaptation, and assessing bioclimatic potential to estimate shared time of comfort and potential design strategies for climate adaptability [70].

Table 2: Adapting the vernacular architecture strategies.

Year	Country	Research summary	REF
1981	France	This study aimed to utilize local climate characteristics to minimize heat loss and optimize direct gains for various projects in Languedoc, France.	[50]
1983	Saudi Arabia	This study aimed to investigate the natural resources and bioclimatic techniques of traditional communities in Al Tihama and Al Hijaz. Based on the findings, the study recommended a potential future direction for architectural designs in this region.	[51]
1994	Mediterranean countries	This study aimed to explore the current state and trends in using heating, cooling, and solar energy for hot water production. Additionally, it examined how the Mediterranean climate context affects the potential of bioclimatic architecture.	[52]
1996	Italy	This study aimed to highlight essential architectural elements for a successful design. These include using natural heating/cooling sources, microclimate elements, vegetation, air convection, and the thermal mass of materials.	[53]
2001	Nigeria	This study aimed to examine and analyze the climate of Nigeria, while considering parameters such as air velocity, temperature, relative humidity, and solar radiation. It concluded with design recommendations for achieving physiological comfort.	[54]
2004	Spain	This study aimed to review some bioclimatic strategies used in traditional Spanish buildings and develop them to contemporary ones.	[55]

2004	Spain	This study aimed to establish the fundamentals of bioclimatic construction by learning from traditional architecture. It sought to identify the design strategies used in vernacular architecture and adapt them to the local context.	[56]
2006	Iraq	This study aimed to analyze traditional constructions, with a focus on passive bioclimatic strategies and their corresponding effects on Basrah's macroclimate.	[57]
2006	Mexico	This study aimed to analyze the bioclimatic strategies used in vernacular and historical houses in Tecozautla, Mexico.	[58]
2006	Brazil	This study aimed to highlight the development of climate-responsive buildings that can adapt to the hot and humid weather of the Amazonian region. It explored various architectural techniques that can be used in these buildings.	[59]
2007	Bulgaria	This study aimed to investigate how ancient Bulgarian houses interact with their surroundings and how their design incorporates various solar energy and energy efficiency tools. These tools include thermal mass, direct and indirect gains, sunspaces (atrium case), convectional loops, and solar chimney.	[60]
2009	Algeria	This study aimed to conduct a comparative analysis between existing traditional housing and typical modern housing.	[61]
2009	Greece	This study aimed to investigate the environmental characteristics of traditional communities in Mt. Verno, Greece. This includes examining their architecture, materials, and bioclimatic potential.	[62]
2009	Cuba	This study aimed to investigate the comfort level of residential buildings in Old Havana through field measurements. It also provides some preliminary design recommendations for such buildings.	[63]
2010	India	This study evaluated the various house typologies in a vernacular settlement in Marikal. The goal was to establish a set of guidelines that balances vernacular architecture with modernization.	[64]
2011	Greece	This study aimed to assess the architectural and bioclimatic techniques used in traditional buildings located in Florina, northwestern Greece, and evaluate their impact on the environment.	[65]
2011	Iran	This study aimed to demonstrate that it is possible to achieve thermal comfort in Esfahan city by following architecturally authentic principles and utilizing natural energy resources.	[66]
2011	Spain	This study aimed to showcase the various types of rammed earth structures that have been built in Spain in recent years. The authors emphasized that rammed earth has great potential.	[67]
2012	India	This study aimed to explain solar passive techniques for all climatic zones in the northeastern region of India. These techniques are related to building form and orientation, envelope design, shading, use of natural ventilation, internal space arrangements, and the activities of the residents.	[68]
2018	Spain	This study aimed to investigate and characterize the bioclimatic strategies of vernacular architecture in the Valencian region of La Serrana.	[69]

Table 3: Bioclimatic architecture's experimentation in construction**.**

Year	Country	Research summary	REF
1983	Italy	This study aimed to describe 44 bioclimatic dwelling units in Rignano sull'Arno, Florence. The study highlighted the development of emerging passive solar techniques for the construction of multifamily residences and facilities, with particular emphasis on achieving low operating costs through the utilization of renewable energy systems.	[71]
1985	Australia	This study aimed to present the bioclimatic analysis of Australian climate conditions for the six major zones. It discusses the current practice of the built environment and attempts to point out a few major trends.	[72]
1998	Italy	This study aimed to present Nicoletti Studio's experience in constructing a low-energy building.	[73]
2001	Bahrain	This study aimed to theoretically determine bioclimatic design strategies based on the local climatic conditions of Bahrain.	[74]
2002	Venezuela	This study aimed to determine the relationship between outdoor spaces and the energy flows that influence human thermal comfort.	[75]
2005	Greece	This study aimed to create a regression model for energy efficiency that considers the building characteristics, environmental conditions, and passive solar technology. The study analyzed 77 bioclimatic buildings, 45 of which were homes, located in Greece, as well as other Mediterranean and European countries.	[76]
2006	Colombia	This study presented a naturally ventilated complex commercial building in Colombia. The project aimed to balance the integration of architectural features, bioclimatic requirements, cost-benefit	[77]

		considerations, and construction needs.	
2007	Canada	This study demonstrated an integrated approach to the design process, with the main goal of achieving thermal and luminous comfort in a new educational building extension at Laval University in Canada.	[78]
2007	Venezuela	This study aimed to discuss the predicted energy efficiency results of using an evaporative cooling technique in a tropical climate.	[79]
2007	Greece	This study described a process for designing and implementing various techniques based on bioclimatic architecture and energy conservation strategies. Its aim was to improve thermal comfort conditions in outdoor spaces in the Greater Athens area.	[80]
2011	Iran	This study aimed to explore the vernacular architecture of Iran, specifically the design and function of wind catchers throughout history.	[81]
2013	Indonesia	This study aimed to offer a more comprehensive design guide by exploring the bioclimatic approach. This approach is particularly valuable for designers who are new to incorporating sustainability principles into the design of multi-story buildings in tropical regions.	[82]
2017	Malaysia	This study aimed to evaluate the condition of hostel building (Dayasari RC) and validate the effectiveness of the bioclimatic design approach. The evaluation of the building's condition was based on temperature and relative humidity.	[83]
2017	Spain	This study aimed to compare the thermal load of two fully occupied buildings in Madrid that were constructed with different criteria. The older one (conventional) was built in the 1960s, while the newer one (bioclimatic) was built in 2008 using energy efficiency principles.	[84]
2018	Slovenia	This study aimed to assess the bioclimatic potential of five systematically chosen locations. Additionally, it presents a simulation of the current and future energy performance of existing bioclimatic and non-bioclimatic residential buildings.	[48]
2019	Russia	This study aimed to investigate and assess the bioclimatic comfort of residential buildings to improve the environmental quality.	[85]
2019	Argentina	This study aimed to assess the impact of climate change on the energy efficiency of residential buildings, and to determine if bioclimatic strategies are appropriate for present and future building designs amidst changing climate conditions.	[86]
2019	Algeria	This study aimed to identify the most effective and low-cost local alternatives for a typical four-person residence in Algeria. The primary objectives are to minimize energy consumption while maintaining thermal comfort.	[87]
2019	Russia	This study aimed to identify the zones in Krasnodar Krai that provide optimal bioclimatic comfort. The investigated bioclimatic indices consider the impact of temperature, wind speed, atmospheric pressure, relative humidity, and solar radiation in different combinations.	[88]
2020	Morocco	This study aimed to optimize the design of a residential building in northern Morocco using the bioclimatic approach.	[89]
2020	Russia	This study aimed to identify the environmental control methods used in Melnikov's house. Melnikov's house is a historical example of bioclimatic architecture designed for the Russian climate.	[90]
2020	Panama	This study aimed to assess the effectiveness of bioclimatic architecture strategies for improving thermal comfort performance in three different building typologies in Panama.	[91]
2020	Madagascar	This study aimed to evaluate the bioclimatic potential of several climatic zones in Madagascar. The study analyzed and compared energy consumption and carbon emissions in six different building categories, which are located across the country's six climatic regions in Sub-Saharan African cities.	[92]
2020	Iran	This study aimed to compare the performance of bioclimatic variables in two scenarios between 2001 and 2017. Scenario I utilized instrumental precipitation and temperature records, while scenario II used remote sensing data.	[93]
2020	Spain	This study aimed to present an energy performance analysis of a bioclimatic educational building, which has earned the best energy performance label in Spain.	[94]
2021	International	This study aimed to assess, analyze, and compare indoor air quality and energy consumption in a multi-family building constructed in eight Sub-Saharan African cities across eight different countries.	[95]
2021	Egypt	This study aimed to validate the optimal bioclimatic design strategy based on the Mahoney tables method in the hot desert climatic zone, using Minia city as a case study.	[96]

Bioclimatic design is the oldest approach to building design, with roots tracing back to early human settlements. Throughout history, there have been periods of intense interest in designing buildings with consideration for the climate, interspersed with periods of indifference. The historical significance and evolution of bioclimatic design can be seen in various examples of vernacular architecture[41–47]. Traditional architecture has evolved over centuries to adapt to specific climate conditions, and contemporary bioclimatic buildings should consider the vernacular architecture of the location. Scientifically based engineering methods should be used to evaluate the performance and validity of design solutions. To achieve contemporary climate-adapted buildings, the first step is to identify vernacular examples for inspiration, followed by identifying bioclimatic measurements used in traditional buildings and conceptualizing them into clear Passive Solar Architecture (PSA) approaches. However, this approach assumes of a static climate and may not be the best solution for ongoing anthropogenically induced climate shifts. The symptomatic bioclimatic design method is also questionable considering accelerated global warming [48,49].

2.2 Analysis & Assessment methods

The researcher categorized the most significant publications on bioclimatic analysis and assessment methods into three major categories, which are described in the following paragraphs:

- **The first group of studies**

According to this group of studies, the publications discussed the earliest examples of using bioclimatic charts to analyze climate and provide design recommendations. Mollier's chart is the most well-known and widely used, while Olgyay's chart was the first to use dry bulb temperature and relative humidity to determine the comfort zone. Givoni and Milne made significant contributions in 1979 by combining various bioclimatic design strategies. Other notable charts include Mahoney Tables, Dekay and Brown's chart, and Košir and Pajek's BCchart. Recent research has applied these charts to local contexts and incorporated solar radiation effects [46,97–100].

- **The Second group of studies**

According to this group of studies, Designers use building performance simulations to evaluate climate potential and provide design recommendations. Choosing the appropriate combination of design aspects is complex and requires a high level of expertise. Building dynamic simulation tools can accurately evaluate energy performance, but a disparity between simulated and actual behavior can be observed. Various studies have used software such as TRNSYS, Autodesk Ecotect, Climate Consultant, Design Builder, and ArchiCAD to evaluate bioclimatic design strategies, passive cooling techniques, energy and lighting performance, and indoor comfort and energy consumption of different building typologies [46,97–100].

- **The Third group of studies**

According to this group of studies, Designers used bioclimatic charts and building performance simulations to evaluate climate and provide recommendations. Studies analyzed the bioclimatic potential of passive heating and cooling design strategies in various locations, including India, Slovenia, Algeria, and Morocco. Nematchoua and Reiter evaluated thermal comfort, energy consumption, and carbon emissions for residential buildings across eight Sub-Saharan African countries using the ASHRAE 55-2017 adaptive comfort model and Design-Builder software [46,97–100].

The mixed approach allows validating design recommendations by comparing simulation results with bioclimatic potential analysis. Furthermore, validated design recommendations are classified based on this approach, contributing to the consolidation of bioclimatic design knowledge at the national level.

2.3 Bioclimatic strategies

The Givoni diagram (Figure 2) is a bioclimatic tool used to identify climatic conditions and develop architectural strategies for achieving human comfort within a building by shifting the environmental conditions into the comfort zone [98]Passive strategies are recommended as a priority for buildings to reduce energy consumption. To determine appropriate bioclimatic architectural strategies, assess the building's location on the Givoni diagram based on its climatic data. If the building is in the comfort zone, no thermal adjustments are needed, but if not, architectural strategies can be implemented to bring it back to the comfort zone [1,7,36].

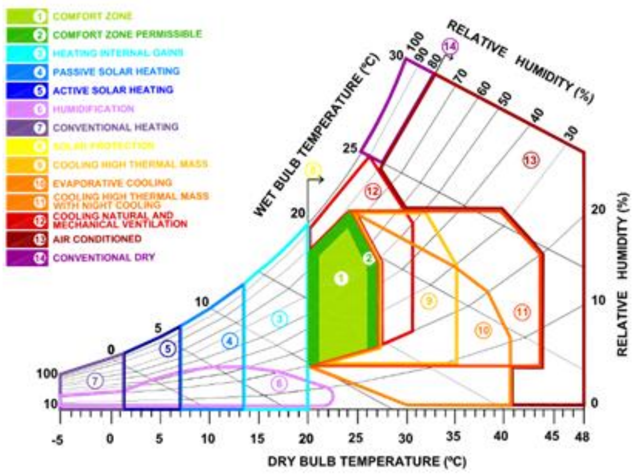

Fig 2: Psychrometric chart adapted from Givoni, Ref:[1]

2.3.1 Comfort and permissible comfort zones

There are two types of comfort zones: the regular comfort zone where 70% of the population can remain comfortable with minimal energy expenditure, and the permissible comfort zone where 80% of the population can adapt with an acceptable minimum expenditure of energy, based on various factors such as temperature, humidity, gender, metabolism, size, and activity level [1,7,36].

2.3.2 Heating internal gains

In zone 3 of Figure 2, internal heat gain is necessary to adjust the temperature to a comfortable range of 13.5°C to

20°C. Internal heat gain comes from various sources such as lighting, equipment, and metabolic rate, and architects need to manage these parameters to achieve the desired thermal conditions [1–7,11,101].

2.3.3 Passive solar heating

In zone 4 of Figure 2, Passive solar heating is an effective way to convert solar energy into heat energy for comfortable indoor temperatures. Techniques include direct daylighting, Trombe wall, greenhouse effect through glass chambers, atrium, and double skin façade. Building openings and specific glass window specifications can prevent radiation from escaping [1–7,11,101,102].

2.3.4 Active solar heating

In zone 5 of Figure 2, Active solar heating circulates heated fluid through a building to distribute heat, while passive systems can help reduce energy consumption. Low-temperature solar thermal or photovoltaic cells can capture energy and produce electricity for conventional thermal conditioning systems, distributed through radiant heated floors, radiators, and a water heater [1].

2.3.5 Humidification

In zone 6 of Figure 2, Low humidity can cause respiratory disorders and dry skin. Designers can increase humidity by adding water vapor using passive or active methods to improve comfort in specific climate zones [103].

2.3.6 Conventional heating

In zone 7 of Figure 2, Passive solar strategies may not always provide enough indoor thermal comfort in climate-sensitive areas, requiring additional heating devices that use electricity, gas, oil, or coal to raise the temperature by 20°C. Turning off heating at night is sufficient, and heating systems should be placed below windows for optimal heat radiation. Biomass is a promising renewable source for heating, and blocking radiators with furniture is not recommended [7,99,100,104].

2.3.7 Solar protection

In zone 8 of Figure 2, To prevent heat gains from solar radiation and maintain a comfortable temperature [1], shades are a crucial component of architectural design that should cover all building openings and the entire building envelope. Solar protection can be achieved naturally or using exterior blinds, slats, movable louvers, and weather-sensitive facades [7].

2.3.8 Cooling through a high thermal mass

In zone 9 of Figure 2, The thermal mass of a building envelope is crucial for heat absorption and release, and night ventilation can reduce cooling demand. Capacitive materials can create an energy transmission phase difference, and dissipating heat at night can be achieved through mobile daytime protection devices, especially in mild climates [1,36].

2.3.9 Evaporative cooling

In zone 10 of Figure 2, In hot and dry climates, it is recommended to increase comfort levels by lowering temperatures through water evaporation and increasing relative humidity. Humidification techniques include using exterior vegetation, vegetative roof cover, and water spraying on the roof, which can also decrease temperature and increase relative humidity through an evapotranspiration process [1,36,102].

2.3.10 Cooling by high thermal mass with nocturnal renovation

In zone 11 of Figure 2, To implement passive cooling strategies, buildings should be closed during the day and opened at night for dissipation and nocturnal ventilation. The building envelope should include capacitive materials that transfer energy with the maximum possible phase difference [1,7,36,105].

2.3.11 Cooling through natural and mechanical ventilation

In zone 12 of Figure 2, To achieve better thermal sensation and air purification indoors, various methods such as cross ventilation, chimney effect, solar chamber, subterranean ventilation, wind towers, evaporative towers, vertical spaces, or patios can be used. Mechanical ventilation can also be employed to enhance the effect [1].

2.3.12 Air conditioning

To increase comfort, air conditioning units can be installed in zone 13 Figure 2, but during summer, it is recommended to set the thermostat to 26°C and turn off devices when leaving to save energy [1].

2.3.13 Conventional dehumidification

In zone 14 of Figure 2, To create a comfortable environment with high temperature and humidity, absorbent salts and saline cells can be used, but additional strategies are necessary to supplement this method [1,103].

3. COMFORT INDOOR ENVIRONMENT

3.1 Health and comfort in buildings

According to the World Health Organization, health is not just the absence of disease but complete physical, mental, and social well-being. Indoor comfort involves more than just climate control elements, but also considers human well-being from the consumer's perspective [8].

3.2 Indoor environmental quality (IEQ)

The IEQ refers to four environmental categories: thermal comfort, indoor air quality, visual comfort, and acoustics. Personal user experience is also taken into consideration [107].

3.3 Indoor thermal comfort

Thermal comfort is influenced by factors such as air temperature, movement, humidity, radiation, metabolic rate, and clothing insulation. It is important to establish a level of comfort that can satisfy most occupants since it is not practical to create a thermal environment that suits every individual [4].

3.4 Indoor air quality

It is important for the health, thermal comfort, and productivity of occupants, and there is growing concern about its impact on well-being. Improving IAQ is a challenge for stakeholders, including building owners, residents, policymakers, and governments, and it is crucial to understand its significance [108,109].

3.5 Visual comfort

Visual discomfort caused by glare or lack of lighting is a challenge for indoor environmental quality. Visual comfort depends on the physiology of the human eye, physical quantities that describe light, and the spectral emission of the light source. Factors that affect visual comfort include the amount, uniformity, quality of light in rendering color, and prediction of occupants' risk of glare [110,111].

3.6 Acoustics

Opening windows for natural ventilation during summer can improve thermal and indoor air comfort but can also decrease acoustic comfort due to disruptive noise. Acoustic comfort refers to a building's ability to protect occupants from noise, which can arise from various sources such as airborne noise, noise from adjacent spaces, and outdoor noise [112,113].

3.7 User experience

The purpose of a home is subjective and shaped by personal experience and cultural background. Comfort is influenced not only by the building itself but also by its surroundings, which can range in size and evolve over time in response to trends. Therefore, people have diverse comfort requirements for their homes based on how they use them [113].

4. Energy efficiency of the built environment

Buildings are a major contributor to global energy use, and early design decisions can have lasting impacts [4,96,114].Energy efficiency is a top priority, involving reducing consumption levels and increasing savings. There is a misconception surrounding "energy conservation," but energy-efficient architecture can be comfortable, environmentally friendly, humane, visually appealing, and cost-effective [115].

5. CONCLUSION AND RECOMMENDATIONS

This study highlights the importance of bioclimatic design in improving the energy efficiency and thermal comfort of residential properties. Key strategies, such as internal heat gain, evaporative cooling, and solar protection, are discussed. Additionally, the study emphasizes the need to understand local climate data and suggests approaches to improve the implementation of bioclimatic design. The study recommends the following actions to enhance awareness of local climate data and its effects on thermal comfort: utilizing advanced building technologies, conducting research to improve the building design process and increase resilience to climate change, and promoting bioclimatic strategies for residential buildings.

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