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## Passive Building Model Guidelines for Minia City

### Based on Psychometric Chart & CBE Tools

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#### Abstract:

Passive design architecture is attractive to all of us; however, due to the present energy shortage, architects and engineers are interested in developing creative solutions that depend on nature's resources. This study investigates the design strategies that affect thermal comfort in residential buildings in Minia City. The study examined the Minia climate using a psychometric chart and CBE tool based on 12 passive strategies to develop building design recommendations. These recommendations will give architects the necessary knowledge throughout the project design phase to assist them in using natural resources, reducing operational energy usage, and preserving thermal comfort using passive approaches. The outcomes summarize the key findings and their implications to emphasize the significance of passive design strategies in achieving optimal thermal comfort.

#### 1. Introduction

Although passive design has received little attention, it is crucial to know how natural systems that mimic the ecological systems on Earth perform [1]. Climate type, adaptable thermal comfort, vernacular and contextual solutions, tools and evaluation techniques, microclimate, sun path, wind, rain, passive and active systems, and responsive forms are the main topics covered by the components of climatic design [2]. The passive strategy's goal is to enhance the situation by utilizing clean and renewable energy sources, as well as to decrease energy consumption and increase thermal comfort.

Bioclimatic buildings also use structural components like walls, windows, roofs, and floors to gather, accumulate, and transfer heat from the sun to avoid excessive heat. This research aims to create pleasant surroundings and make optimal use of climatic circumstances [3].

Numerous studies have found that an east-west orientation and a south-facing main façade are the superlative choices for a house's orientation to increase temperature uptake during the wintertime and minimize it in the summer [4]. All designers strive to improve people's quality of life, and sustainable development must include energy integrity and efficient utilization of resources from nature known as green design [5]. The foremost objective of the

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green strategy, which concentrates on creating flexible, energy-efficient structures, is to have as minimal influence as possible on the ecology and the environment by raising the building's overall performance. The evolution of green design will necessitate the utility of building materials [6].

Buildings should be planned to create the most comfortable indoor climate for occupants. However, thermal comfort is the mental state that expresses contentment with the environment. Victor Olgay first used the phrase "bioclimatic architecture" in the first half of the 1950s, and he described it in his manuscript "Design with Climate" in 1963. He merged elements of climate change, architecture physics, and the biology of people while fervently promoting architectural regionalism and sustainable design [7]. According to the "Housing and Building Research Centre (HBRC)", Egypt is located in the composite climatic zone, which characterized by extreme hot summers. Because of this, it is preferable to design buildings with increasing thermal and decreasing window wall ratios, but modern planners hardly consider these when designing them. As a result, the energy consumption in buildings increased. They might draw comfort-improving ideas from vernacular and climatic design, which uses less energy.[8]

Minia City, the capital of Minia Governorate, is the subject of the chosen case study. It is situated 245 km south of Cairo on the western bank of the Nile River. It was listed as having a desert environment and was located between the longitudes of 30° 45'1.08" east and the latitudes of 28° 6'35.57" north [9]. There are many tools that been used in the assessment of the climatic analysis. These tools are developed form year to year to follow up the new development in the green architecture, building design and thermal comfort to

achieve the best optimality for building designs.

**Goal of research:** The purpose of this work is to give passive building design guidelines for Minia City using the psychometric chart analysis [10] and CBE tool [11] that represent the best passive architecture schemes and their impacts on thermal comfort. Also, we will recommend passive design guidelines where the weather is warm and mostly dry.

**Problem of research:** Many studies investigate the design without the effect of thermal comfort strategy in residential buildings. So, there are insufficient recommendations that will give architects the necessary knowledge throughout the building design phase to help them in using natural resources specially in Egypt.

## 2. Literature Review

Passive design methods are chosen based on the local climate, where it's kind of mode is mostly determined by temperature and humidity. These strategies depend on the location of buildings and what you need to make it more comfortable. The cities in the winter require passive heating strategies, whereas in summer require passive cooling, and other parts need both heating and cooling strategies.

A multi-objective simulation-based optimization technique used by Gupta et al. [12] to examine the merging of the architectural modelling software Energy Plus with a non-sorting genetic algorithm to identify the optimal arrangements of various passive cooling components. The results demonstrated that passive cooling techniques may make traditional vernacular homes environmentally friendly and energy efficient.

Kujundzic et al. [13] conducted a comparison analysis with worldwide sustainability rating systems to demonstrate the need to include more passive design

comfort-related parameters in ecological evaluation models. Regarding the health and well-being of structure occupants, a focus group of experienced architects responded to a survey on sustainability, comfort, and passive design. This confirmed the value of implementing passive design elements for delivering indoor comfort and achieving environmentally friendly goals.

Ozarisoy [14] examined the overheating threat and energy efficacy of six passive design solutions that tested and put into practice in an innovative terraced home in southern London during the prolonged heatwaves that occurred in both the UK and Europe in the summer. The findings revealed considerable differences in the base-case building's anticipated energy usage and in energy consumption and atmospheric indices of cooling through passive design techniques.

Zoure et al. [15] evaluated how much less energy needed for cooling and how much less used. Natural ventilation was shown to be the most efficient passive cooling strategy, reducing yearly discomfort hours by 40% and annual energy use by 30%. The simulations proved the efficiency of low-cost passive design alternatives that may be implemented even in current office buildings, as well as their relevance for the sustainable development of Sub-Saharan African nations that are rapidly urbanized.

Singh et al. [16] created an Artificial Neural Network (ANN) and a structure for energy modelling and optimization-based methodology to increase the efficiency of buildings and thermal comfort in Indian climatic conditions utilizing passive design techniques with a mixed-mode operating approach. When a set of passive design alternatives is chosen, the optimized results indicated a reduction of 46% in construction consumption of energy and 7.58% in discomfort hrs. The findings of best passive solutions for design might be useful for

planners to achieve energy-efficient buildings.

Yonzan et al. [17] compared historic houses, contemporary dwellings, and energy-efficient structures in terms of indoor thermal comfort. Rammed earth constructions are used less energy to preserve thermal comfort compared to other modern structures. The findings established that thermal efficiency is affected by thermal features of the users' physical and psychological circumstances.

Bekele et al. [18] examined sketches in 2D, modelling in 3D, and simulation of energy software to assess energy use in both actual and simulated settings. The study discovered that classic Mediterranean dwellings, with their wall thickness and built-in shading systems, need fewer kilowatt-hours for heating and cooling than modern residences.

Kolani et al. [19] surveyed the research on design of passive buildings for enhancing interior thermal comfort from 1984 to 2021. The findings revealed that real-time field investigations, as opposed to dynamic models, were the most remarkable study on the passive ventilation and thermal comfort of tropical structures. So, the studying of passive strategies in green architecture is the outperform work today's.

### 3. Methodology

This research aims to investigate how passive design approaches combine to affect thermal comfort in hot desert regions. The study uses the following approach to accomplish that objective, as shown in Figure 1.

The initial step is to investigate the city's passive characteristics. These characteristics are input as factors to the psychrometric chart and the Center for Built Environment (CBE) tools. The two tools are used to analysis the Minia city climate as some of recommendations. The outcomes of

the climatic research would then be utilized as a database to create the architectural ideas in the second stage.

The next stage is to look at passive design methods that implemented into the design's framework. The psychrometric chart aids in highlighting the many architectural design strategies that planners might use by the climatic information gathered that makes it possible to deploy passive technology to increase the building's thermal effectiveness. The decision as to which result(s) offers the finest choice for enhancing the metrics depends on the outcomes produced.

recommendations for sustainable building design.

**- Data Collection:**

Collect relevant climate data for Minia city, including temperature, relative humidity, wind speed, solar radiation, and other meteorological parameters. Utilize historical data, local meteorological stations, or simulation tools for this purpose.

**- Psychrometric Analysis:**

a. Psychrometric Chart Utilization: - Utilize psychrometric charts to analyze air properties, such as temperature, humidity, and enthalpy. - Plot representative data points on the psychrometric chart to understand the thermodynamic state of the air.

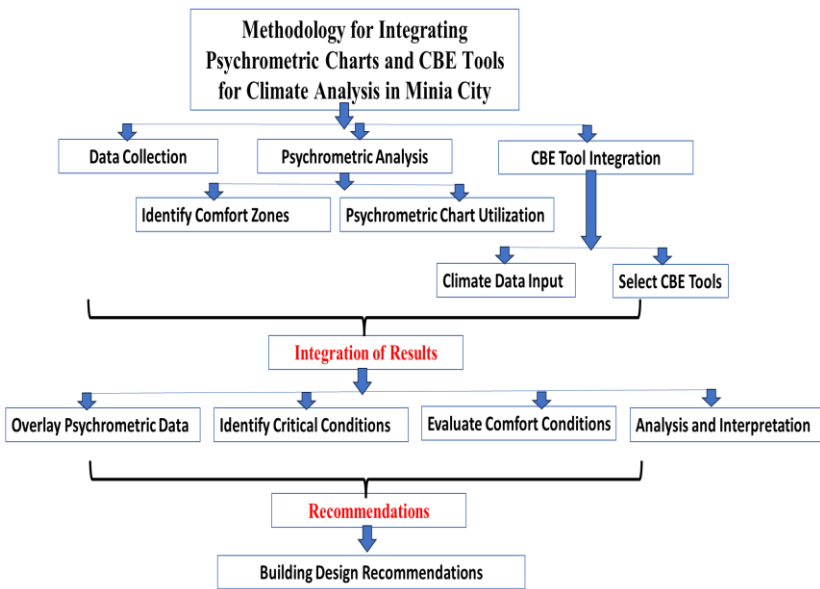
b. Identify Comfort Zones: - Identify comfort zones on the psychrometric chart based on ASHRAE or other relevant standards to assess the human comfort level.

**- CBE Tool Integration:**

a. Select CBE Tools: - Choose appropriate Computational Building Environment tools for climate simulation and analysis. Tools like EnergyPlus, OpenFOAM, or others may be suitable.

b. Climate Data Input: - Input the collected climate data into the CBE tools to simulate the thermal performance of buildings in Minia city.

**- Integration of Results:**



**Fig. 1: Methodology flowchart.**

for Integrating Psychrometric Charts and CBE Tools for Climate Analysis in Minia City:

**- Objective Definition:**

Clearly define the objectives of your study, such as understanding the local climate conditions in Minia city, identifying potential challenges, and proposing

a. Overlay Psychrometric Data: - Overlay psychrometric data onto the simulation results from CBE tools to visually correlate the psychrometric properties with the building's thermal performance.

b. Identify Critical Conditions: - Identify critical conditions where the building may experience discomfort or high energy consumption.

**- Analysis and Interpretation:**

a. Evaluate Comfort Conditions: - Analyze the comfort conditions based on psychrometric analysis and CBE tool results.

b. Identify Improvement Opportunities: - Identify areas for improvement in building design or HVAC systems to enhance comfort and energy efficiency.

**- Recommendations:**

a. Building Design Recommendations: - Propose building design modifications based on the integrated analysis to improve thermal comfort.

b. HVAC System Optimization: - Suggest HVAC system optimizations to align with the local climate conditions. Validate the recommendations through simulations or case studies to ensure practicality and effectiveness. Documentation and Reporting:

Document the entire process, including data sources, methodologies, results, and recommendations. Create a comprehensive report for stakeholders and decision-makers.

Feedback and Iteration:

Seek feedback from experts or stakeholders, and be open to iteration for continuous improvement of your methodology and recommendations.

By integrating psychrometric charts with CBE tools, you can gain a deeper understanding of the climate in Minia city and provide informed recommendations for sustainable building design.

#### **4. Egypt's Climate**

Egypt is a country in North Africa and the Mediterranean, having lengthy coastlines along the Mediterranean and Red Seas, and it is located between latitudes 22° and 32° North and 25° and 35° East. Over 94% of the land is desert, which is nearly one million kilometers [20]. The climate of Egypt is arid, warm, and desert-dominated. It enjoys a pleasant winter with raining along the coast and a dry and hot summer (May to September). Temperatures during the day fluctuate according to season and are affected by the winds that are blowing.

##### **4.1 Egypt Climatic Zones**

The “Egyptian Organization for Energy Conservation and Planning (EOECP)” [21] divided Egypt into seven distinct climatic design regions based on the analysis of climatic data detected at 45 meteorological classes crosswise the nation. Egypt has a significant range of climatic conditions. These seven climatic design zones are the mountain, the semi-desert, the desert, and the Mediterranean Sea coastline regions. The climatic conditions in these areas vary greatly.

The HBRC in Egypt created a second extra type of climate [22]. Egypt was classified into eight climatic zones according to the classification: Northern Coast Zone, Delta and Cairo Zone, Northern Upper Egypt Zone, Southern Upper Egypt Zone, East Coast Zone, Highlands Zone,

Desert Zone, and Southern Egypt Zone [23]. This categorization is based on the country's physical geography as well as the operational temperature, moisture content, precipitation, wind speed, altitude, and solar radiation. The HBRC categorization will be used in this study, nevertheless. According to the HBRC categorization, the climatic zones of Egypt are depicted in Figure 2.

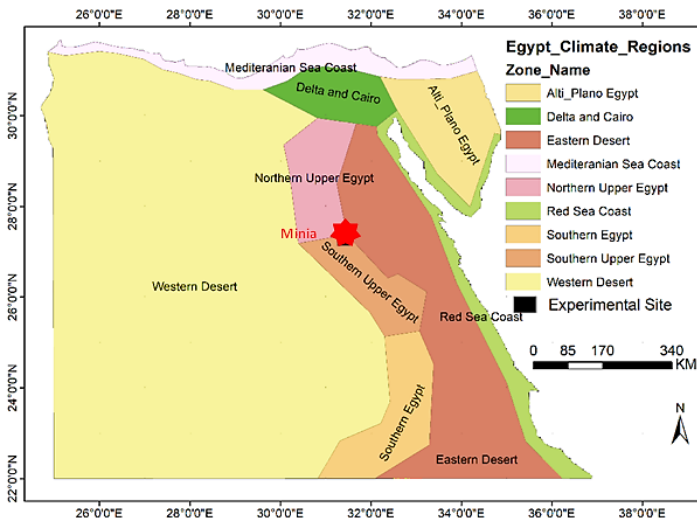


Fig. 2. Egypt's eight climatic zones, & Minia city's location [24].

#### 4.2. Climate of Minia

The study focuses on Minia City, where seasonal temperature variance in Minia City points to a dry climate with a pleasant summer and a peacefully cold winter. Whereas the average temperature ranges from a top of 36.6°C in July to a bottom of 19.4°C in January, the rainfall ranges from 52% to 25% in January, and the airspeed decreases from 4.2 to 3.4 in August, as seen in Figure 3. According to the study's research on the numerous environmental elements throughout the year, July and August are crucial months that must be taken into account to attain thermal comfort. The variation in wind speed is brought on by air flowing from the high to the low level at temperature variations. The

number of clockwise degrees measured away from the north indicates the wind direction.

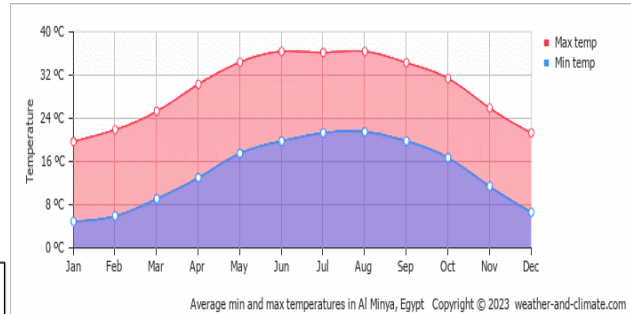


Fig. 3. Minia climate [25].

### 5. Comfort Analysis

Thermal comfort is known as the state of the mentality that represents pleasure with the thermal atmosphere. However, estimating the human requirement of comfort is an intricate method because there are different divergences from person to person, both physiologically and psychologically, so it is difficult to satisfy everyone [26].

The assessment of thermal comfort can be done globally by using climatic analysis and thermal indicators; therefore, the incorporation of knowledge will result in broad feedback for the early design phases. These indications shouldn't be immediately translated into energy-efficient designs, even if they are derived from datasets or measurements [27]. To aid designers in understanding tools like these indicators, this research offers a framework titled "How to Design" [28].

Additionally, the design strategy in various climates ("hot, arid, and desert") requires help tools from the ideas of green buildings to attain thermal comfort or to lower energy usage [29].

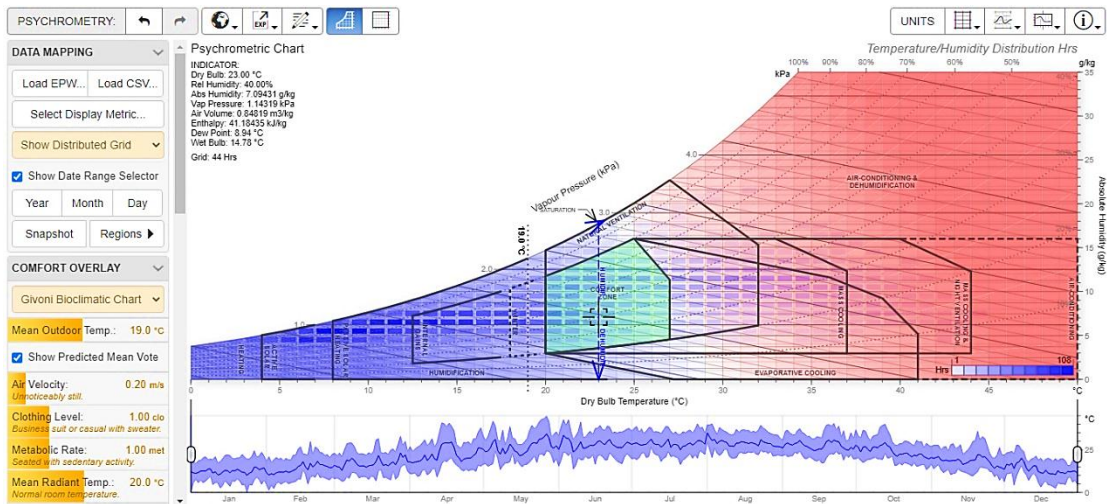
The thermal index is a way to explain how many climatic factors affect people. In this study, the building design recommendations are developed by analysing the comfort conditions and

climate of Minia using the psychometric chart and CBE tool. Natural ventilation, lighting, passive heating and cooling methods, and other architectural elements would combine to create Minia City's climatic architecture.

**5.1. Psychometric Chart**

Givoni's Psychometric Chart illustrates the correlation between Temperatures of the dry and wet bulbs, relative and absolute humidity, and moist air vapor pressure [30]. Additionally, distinct zones are indicated in the chart based on the characteristics of the air, offering design suggestions for achieving thermal comfort. These zones are as follows: the Comfort Zone, the Evaporative Cooling Zone, the High Thermal Mass with Night Flush Zone, the Ventilation Zone, the Window Shading Zone, the Passive Solar Heating Zone, and the Conventional Heating or Cooling Zone.

The climatic data of Minia city is plotted on the Psychometric chart in Figure 4, and the ratio of hours per month that fall within each of the proposed design options' various zones. The temperature is below a comfortable level in January, February, November, and December, where passive heating is recommended. In addition, ventilation with window shade is recommended in June, July, August, September, and October due to high temperatures and high humidity.



**Fig. 4. Non comfort psychometric Chart.**

of time for the number of hours falling under each strategy series while noting that changing any default criteria or building design parameters will alter these figures. In our case study, we show the overall cooling system, Natural Ventilation, Sun Shading, and high thermal mass.

**5.2 CBE Tool**

The Centre for the Built Environment

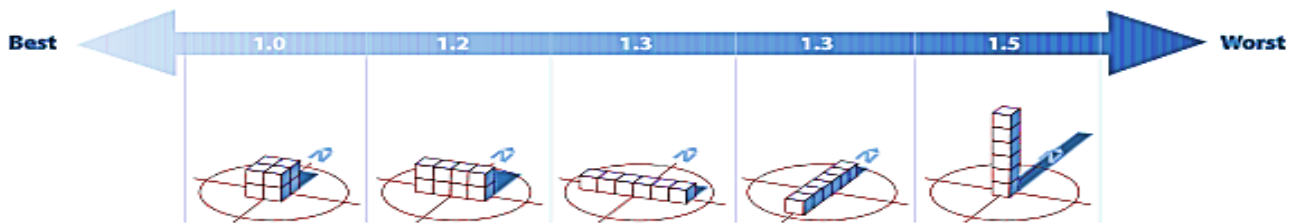


Fig. 7. Energy efficiency and the ratio of envelope to volume [32].

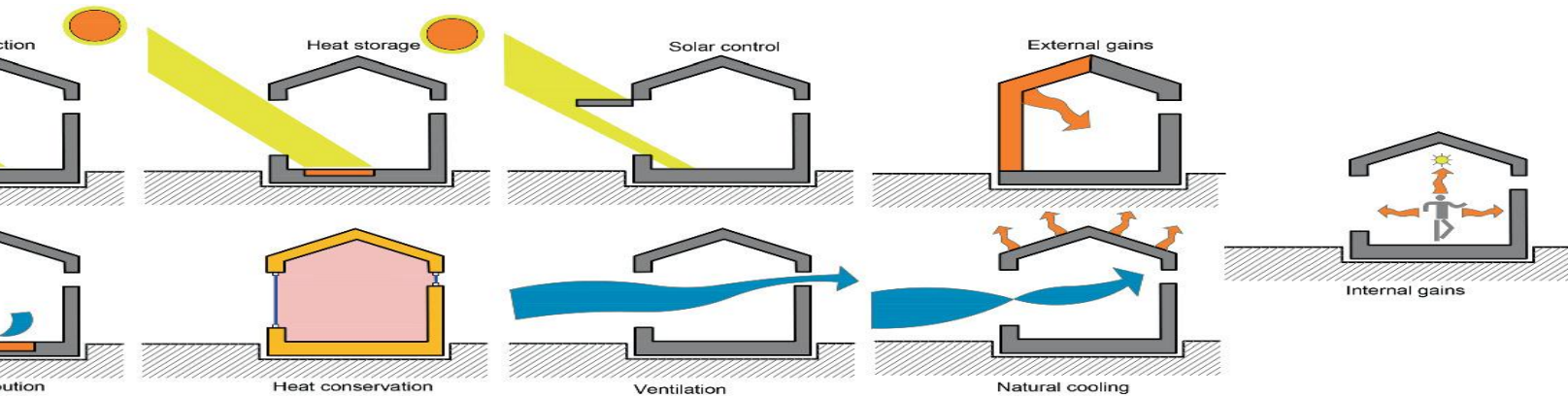


Fig. 8. Passive solar heating and cooling techniques [4].

Addition:  
window shade are advised in March, April, and May because of the hot and dry weather. Whereas Figure 5 displays the psychrometric chart along with numerous additional customizable choices on the panel on the left. For instance, you can select a month's worth of direct sunlight, wind speed, or sky cover. The upper left side of the document offers a table of effective design strategies that displays the percentage

(CBE) tool automatically calculates the relative airspeed where, it is a completely free online tool that fulfils the ASHRAE 55-2017 Standards for thermal comfort estimates and visualizations. It includes fundamental thermal comfort analyses such as the Predicted Mean Vote (PMV), Standard Effective Temperature (SET), adapting models, regional discomfort



theories, SolarCal, and dynamic predictive clothing insulation. Thermal comfort zones are also

As illustrated in the modeling findings below in Figure 7, a compact building design reduces the building's energy intensity and the need for active mechanical systems. Massing optimization may frequently be used to increase passive performance while lowering capital costs [32, 34].

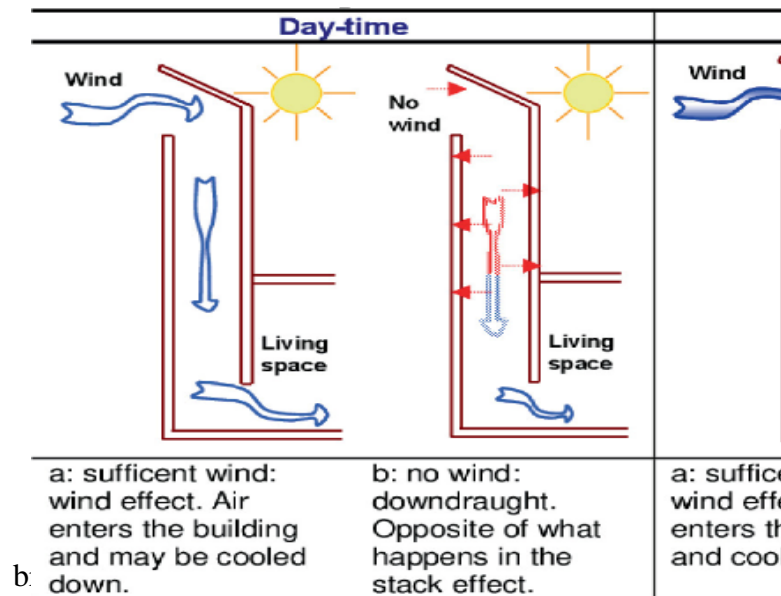
**6.1.4. Crosscut Ventilation**

As seen in Figure 8, the building may benefit from cross-cut ventilation, heat preservation, shading devices, heating storage, and direct external solar gain to improve internal thermal comfort.

**6.1.5. Ventilation Chimneys**

The ventilation chimney can be used to lower the structures' energy requirements. Three ventilation chimneys form the foundation of the system. One of them is utilized for air expulsion, while the other two are for air entry. Due to temperature variations, such chimneys cool the air during the night through the stack effect, as shown in Figure 9 [35].

A convective loop is produced during the winter by solar radiation hitting the transparent portion of the chimney that is facing south. Additionally, the heat gathered from the crowds is transported to the rooms through the interior chimneys. This integrated passive system may achieve energy efficiency, which enhances the environment's quality and thermal comfort. Specific modifications are needed for the building's southern façade. There should be



It is crucial to emphasize that the heat collected in the chimney will be used to heat and ventilate the rooms at night.

**Fig. 9. chimneys cooling**

## 6.2 Thermal Mass

Thermal mass is a material's ability to absorb, keep, and dissipate high temperature. Heat is absorbed and stored by substances such as concrete, bricks, and tiles. They are therefore said to have high thermal mass.

### 6.2.1. Building Material

The material properties of Thermal Resistance, Surface Convective coefficient, Absorptivity, Reflectivity, Emissivity, and Heat Capacity affect how quickly heat moves into and out of a structure and, consequently, how much energy is required for air conditioning or heating [36]. As a result, the heat conductivity of different insulating materials varies. Common building insulation materials include mineral wool, polystyrene, polyurethane, light concrete, and wood fiber slabs. Heat conductivity, cost, weight, chemical and mechanical durability, safety, airtightness, humidity resistance, and fire resistance are some of the criteria that affect the choice of insulation materials.

### 6.2.2. Building Type

Homes that are planned and built in accordance with climatic design concerns use natural energy rather than mechanical heating and cooling. As a result, its design generates ideal environments for human satisfaction while consuming less energy [37].

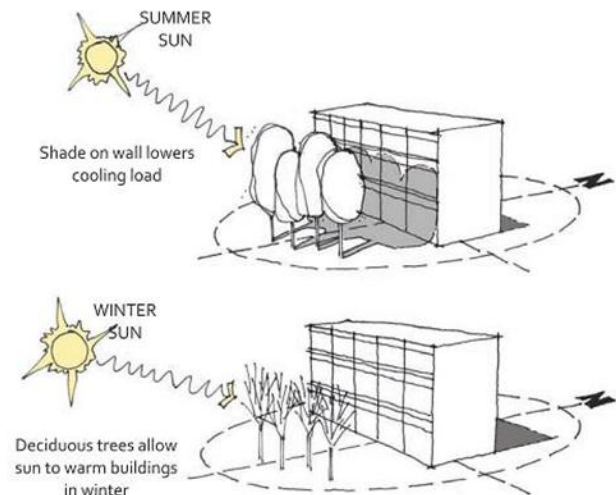
## 6.3. Wind Protection

The most popular sort of windbreak is dense green trees and bushes placed to the north and northwest of the residence.

### 6.3.1. Building Site Selection and landscape

The design approach begins with several landscape considerations. In many site design decisions, setbacks, street trees, street arrangement, and usage of landscape buffer sectors can serve as controlling principles. To effectively use the passive method in the initial phases of design, landscaping must be carefully considered, as numerous benefits of vegetation are demonstrated in Figure 10 [38].

The benefits of using vegetation in designing can be concluded as follow: reducing the surrounding temperature and the heat island effect, adding "green" roofs and walls made of vegetation, and shielding the structure from the sun, wind, and precipitation can all help reduce the solar intensity



**Fig.10. Landscape for illumination management and passive solar heating [32].**

## 6.4. Passive Solar

A passive solar house absorbs heat from the sun as it shines through south-facing windows and stores it in heat-storage materials known as thermal mass [39].

### 6.4.1. Passive Solar Techniques

Techniques that use passive solar energy are influenced by the local environment, and the predominance of heating or cooling needs. The heating needs of a structure may be aided by solar energy. Solar heat collection, heat circulation, heat storage, and heat preservation are the most practical methods. As shown in Figure 11, the structure may profit from both the direct and indirect gains of the sunlight [40]. Direct gain is a typical strategy. The structure must face south and have windows straight into the living space to provide thermal comfort.

### 6.5. Cooling

Natural cooling [41, 42] entails the use of airflow or natural heat sinks to dissipate heat from indoor environments.

#### 6.5.1. Daylighting and Natural Cooling

Daylighting and natural resources are the only processes that take place spontaneously, without the aid of mechanical parts or energy contributions and are subject to passive cooling. The goal is to keep the unwanted heat to a minimum. The first thing that has to be controlled is how much heat from hot air and solar radiation enters the structure. To limit internal heat gain from appliances and residence, it is necessary to minimize unwelcome solar heat within the skin of the building or apertures. Heat sinks must be used to remove any residual unwelcome heat.

#### 6.5.2 Building Occupancy

It needs to be emphasized that humans utilize energy. The structure doesn't require a lot of energy, but the occupants need. The

four primary aspects to take into account are the intensity of building occupancy, activity type, user attitude and behavior, management, and organization. Also, the

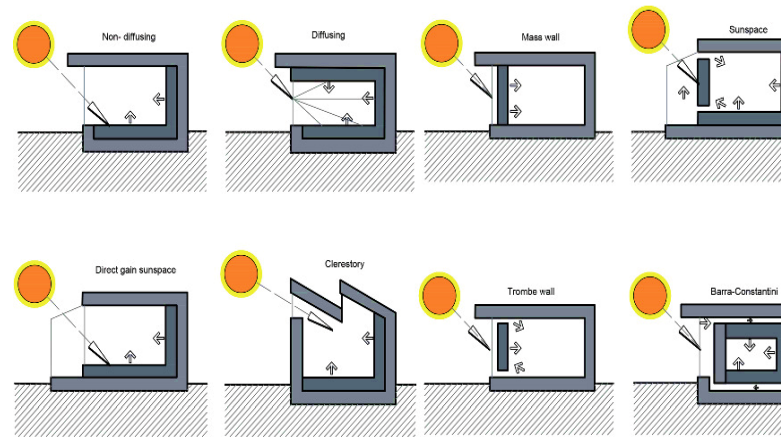


Fig. 11. The profit from both the direct and indirect

number of inhabitants has the major impact on energy usage.

### 6.6. Sun Shading

Solar shading refers to a variety of techniques that regulate the quantity of light and heat received from the sun into a structure.

#### 6.6.1. Shading Devices

Sun shading panels provide improved comfort for persons within the structure by blocking sunlight and reducing solar gain. This eventually improves the interior conditions for residents by balancing temperature, humidity, and light brightness. These shading systems are adaptable and meant to be durable and economical.

## 7. Conclusions and Future Work

The study focuses on how passive design elements affect many factors for building design. The natural system generates a closed or semi-closed system by considering

factors like wind, rain, sun path, microclimate, active and passive structures, and responsive forms. Programs for simulation are crucial for the design process; however, they may be applied to gain the best understanding of the bioclimatic design's overall strategy, beginning with the preliminary design phase.

Based on two valuable tools as psychrometric chart and CBE, we investigate multi parameters from 12 passive strategies that can affect the thermal comfort for building in Minia city. The outcomes suggested many recommendations that should be taken in case to achieve the optimality for thermal comfort. The outcomes suggested many recommendations that should be taken in case to achieve the optimality for thermal comfort. The outcomes summarize the key findings and their implications to emphasize the significance of passive design strategies in achieving optimal thermal comfort. Where in future work, we suggest potential avenues for future research in the field, considering emerging technologies or further refinement of passive design strategies based on multi agents and AI technology.

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