

# Towards Sustainable Housing: Sample Design Strategies for Gaza

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**Abstract**— In the light of successive wars against Gaza since, it has suffered from unprecedented destruction, with tens of thousands of housing units either severely damaged or completely demolished. The humanitarian crisis has intensified, prompting urgent calls for sustainable and context-sensitive reconstruction solutions. This paper aims to present an alternative design proposal for units that were completely destroyed in the strip taking in account the environmental, climatic, social, cultural issues of Gaza’s community. The methodology adopted a module of unit formed from four L-shape buildings which are forming a central courtyard between; each unit is linked with the neighboring units by a main and a secondary axis to facilitate movement from and between. Then a simulation of the proposed design was made on Design-Builder software to verify the design approach. The results of the analysis confirmed the positive effect of the passive techniques used in the design such as the courtyard, the wind-catcher and the mashrabiya.

## I. INTRODUCTION

The recent 2023–2025 war against Gaza has resulted in unprecedented destruction and displacement, surpassing the devastation of previous conflicts in 2008 and 2014. According to the Palestinian Central Bureau of Statistics, approximately 384,000 housing units have been damaged, including 87,000 that were completely destroyed, leaving over a million Palestinians homeless and displacing around 90% of the population. This extensive devastation has created an urgent need for comprehensive reconstruction to restore essential services and enable displaced residents to return to their homes. Gaza strip cities, like other Palestinian cities, are an interconnected society; combine their residents many social and cultural relations. Family is the key social unit to Gaza; Its solidarity and community networks are leading to strong cultural features, providing crucial support in difficult circumstances. The ongoing blockade and restrictions on material imports have severely hindered reconstruction efforts in the Gaza Strip. This has led to a growing reliance on local and alternative materials such as clay, earth, and recycled debris from damaged structures. These materials offer economic and logistical advantages due to their availability and low cost, but their effective use requires a well-considered architectural approach to ensure functionality, durability, and comfort. In this context, the adoption of passive design strategies becomes essential. Passive techniques—such as natural ventilation, thermal mass, solar shading, and daylight optimization—can significantly reduce

the need for mechanical systems and enhance indoor comfort using minimal resources. By integrating these techniques with local materials, it is possible to create buildings that are both environmentally sustainable and responsive to the local climate. Moreover, this approach aligns with the broader goals of preserving the cultural and social identity of the population. The use of traditional materials and context-sensitive design can strengthen the connection between residents and their built environment, fostering resilience and continuity amid ongoing challenges. This research, therefore, proposes a reconstruction strategy that leverages passive design and local materials as a sustainable response to the unique conditions in Gaza.

## II. RESEARCH APPROACH

The primary objective of this study is to explore the integration of traditional architectural elements in Gaza—such as mud construction, courtyards, and mashrabiya—with passive design techniques in contemporary architecture. This approach aims to enhance building sustainability and address critical challenges facing the construction sector in the Gaza Strip by improving energy efficiency, indoor comfort, and environmental responsiveness.

## III. METHODOLOGY

The methodology of this study follows six phases. Phase 1 is collecting data, statistics, and theories from previous studies, along with analysis of location, climate conditions, and related issues. Phase 2 examines two case studies in the Gaza Strip, focusing on passive design techniques. Phase 3 presents the architectural concept, proposed design, and sustainable ideas. In Phases 4 and 5, simulations using Design Builder and Dialux Evo are conducted and analyzed. Phase 6 concludes with key findings and recommendations.

Table 1: Flow chart of research methodology

Phase	Title	Description
Phase 1	The Inductive approach “Contextual and Theoretical Foundation”	Statistics, Data and theories from previous studies Location and study area Climate conditions, climate problems and objectives
Phase 2	Case Study Preview	Traditional building in Gaza strip Mashrabiya in Arab Area
Phase 3	Design Development of Housing Unit	Architectural Idea Design Drawings Details Sustainable ideas
Phase 4	Simulation	Design Builder /Dialux Evo
Phase 5	Results	Analysis of simulation results
Phase 6	Conclusions,Recommendation and restrictions	Adopting passive techniques in the design unit

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#### IV. THE STUDY CONTEXT

The location of the proposal is Beit Hanoun. Several factors are crucial for understanding the environmental and social context that shapes the reconstruction design and the application of sustainable and passive techniques there. Gaza is a coastal region in Palestine along the eastern Mediterranean, spans about 41 km in length and 6–12 km in width, covering 365 km<sup>2</sup>. It faces ongoing humanitarian crises due to a prolonged blockade by Israeli occupation and intermittent border closures. These restrictions, intensified after the October 2023 war, which has limited access to fuel, medical supplies, construction materials, and free movement, further isolating the population.

Beit Hanoun is a city in the northeastern Gaza Strip. It has suffered extensive damage during repeated conflicts, especially in the 2014 and 2023 wars. Alongside Gaza City, it ranks among the most affected areas in terms of destroyed infrastructure and housing, making it a key focus for reconstruction efforts. [8][9]



Figure 1. Beit Hanoun, Gaza Strip. Compared satellite images, from 6th to 25th July 2014, [10]

A plot of land about 4,220 square meters, which was completely destroyed is proposed for comprehensive planning and reconstruction. The redevelopment will apply environmental, cultural, and architectural strategies, focusing on sustainability and resilience.

Gaza has long, hot, and humid summers with clear skies, and cool, mostly clear winters. Temperatures range from 7°C in winter to 32°C in summer. The humid season lasts from late May to late October, with uncomfortable conditions about 24% of the time. Rainfall is seasonal, with a dry period from April to October lasting around 6.7 months.[11]

#### V. PASSIVE DESIGN STRATEGIES

To create sustainable and comfortable built environments, it is essential to address key climate-related challenges using passive design strategies. These approaches help reduce energy consumption, enhance indoor comfort, and minimize environmental impact. The following section outlines the passive solutions for managing humidity, temperature, and water scarcity:

- **Humidity:**  
In Gaza, limited electricity makes mechanical cooling difficult, making passive humidity control essential. High humidity hinders the body's cooling, but natural ventilation can ease discomfort by improving airflow. Passive strategies like cross ventilation, wind catchers, courtyards, and ceramic tubes enhance air movement and reduce reliance on energy-intensive systems.
- **Temperatures:**  
Due to Gaza's energy shortages and frequent power outages, passive temperature control is essential. Indoor heat is affected by weather, solar gain, and limited HVAC use. Passive solutions like insulated mud layers, green roofs, triple-glazed windows, sun blinds, mashrabiyyas, and plants help maintain comfort and reduce energy reliance.
- **Lack of water:**  
Gaza faces severe water shortages due to limited infrastructure, blockade restrictions, and groundwater overuse. With rising demand and limited supply, passive water solutions are crucial. Techniques like rainwater harvesting, atmospheric water generation, and greywater recycling provide low-cost, sustainable ways to ease scarcity and support daily needs.

A study of traditional architecture in Gaza reveals a rich heritage of passive techniques that can inform contemporary sustainable design. Before cement became widespread, mud houses were built using locally sourced, low-cost materials that provided natural thermal comfort, fire resistance, and sound insulation—without the need for advanced construction skills [2][3]. These homes featured small living areas, larger spaces for storage or livestock, and a central courtyard that supported ventilation and social interaction. Roofs used stone arches (Kantara) or mud-covered wooden branches, while high, narrow openings ensured privacy and airflow. Mud provided key benefits like thermal mass, fire resistance, and sound insulation, with courtyards enhancing comfort through shade and cooling vegetation.[4][5]

One standout feature of traditional design is the Mashrabiya—a wooden lattice screen projecting from upper floors. More than a privacy tool, the mashrabiya functions as a passive environmental system: controlling solar gain, regulating airflow and humidity, and enhancing natural ventilation across seasons [6]. Its integration into Gaza's reconstruction can support sustainable architecture while preserving cultural identity [7].

## VI. DESIGN APPROACH

The design stage aims to create a sustainable, functional, and community-focused living environment suited to Gaza's social and climatic conditions. By integrating traditional urban principles with passive design strategies, it enhances livability, privacy, and environmental performance through efficient land use, natural ventilation, and daylighting.

### A. Urban Design Phase

The schematic grid system is employed at the planning level to ensure organized spatial distribution. A central courtyard system is integrated within the layout of clustered housing units, with the grid forming primary roads encircling the development and secondary paths facilitating pedestrian movement while preserving individual unit privacy.

### B. Unit Design Phase

The design comprises multiple units, each consists of four identical L-shaped multi-family buildings, symmetrically mirrored along both the X and Y axes to enclose a shared central courtyard—serving as a semi-private communal space. Each pair of L-shaped buildings along the X-axis is connected by a vertical circulation core, which also functions as a transitional node linking the housing units to surrounding secondary streets. Each building comprises three staggered apartments, strategically offset to expand courtyard space and introduce shaded areas along adjacent pedestrian routes, enhancing thermal comfort and outdoor usability.

### C. Apartment Design Phase

Given the average household size of 5.0 individuals in Gaza [12], an L-shaped apartment of 90 square meters was adopted in the design. The unit includes essential family spaces: three bedrooms, a kitchen, a living room, and a bathroom. The layout prioritizes natural lighting and ventilation, particularly in the kitchen and living areas where daily activity is most concentrated. Due to the tilting of the building at an angle of 35 degree from the north, all rooms are heavily sunlight throughout the day. Sun-exposed rooms are treated using horizontal and vertical breakers and shading devices, including mashrabiyas, to reduce glare and heat gain. The tilting also affected the ventilation of the building beside the effect of the courtyard which played a major rule in air circulation according to convection.

### D. Environmental Design Analysis

Sun-path and wind analyses were conducted to inform passive design strategies that maximize natural light, minimize heat gain, and enhance ventilation. By aligning the architectural layout with solar orientation and prevailing wind directions, the design achieves comfortable indoor environments with minimal dependence on mechanical systems.

#### • Sun-Path Analysis and Design Solutions

The building is oriented at a 35-degree tilt from true north, which allows controlled sunlight penetration into interior spaces throughout the day. Areas exposed to excessive sunlight exposure—particularly those exposed to glare and overheating—have been treated with sun blinds or mashrabiyas to mitigate thermal gain and improve indoor comfort. The southeast facade, which receives the most intense sunlight, has been designed as a mostly solid

surface with limited, strategically placed openings to support cross-ventilation while minimizing heat gain from direct sunlight.

Conversely, certain interior areas receive insufficient daylight, particularly zones distant from windows. These spaces were enhanced using mirrors and tubular daylight guidance systems (TDGS) to optimize natural light distribution throughout the day:

- Mirrors: Strategically integrated into the mashrabiya design, mirrors are used to scatter and redirect natural light into deeper or shaded interior zones, helping to illuminate areas that sunlight does not naturally reach during certain times of day.
- Tubular Daylight Guidance System: TDGS units are employed to capture and channel natural daylight into poorly lit areas, ensuring consistent illumination and reducing reliance on artificial lighting.

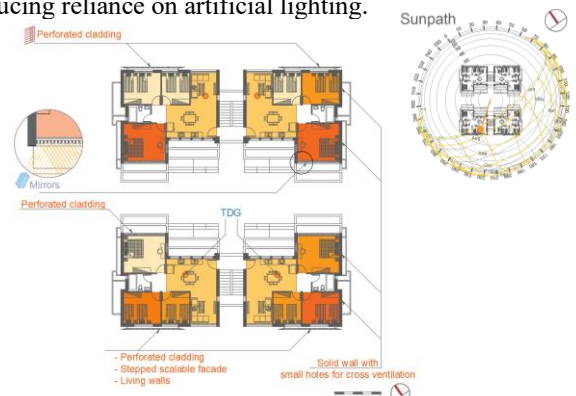


Figure 2. Sunlight analysis and Design Solutions

- Wind analysis and Design Solutions: The predominant wind direction in Gaza varies throughout the year. To harness this natural airflow, the design strategically incorporates a central courtyard that plays a vital role in directing wind movement, creating pressure differences that promote cross-ventilation and enhance overall airflow.

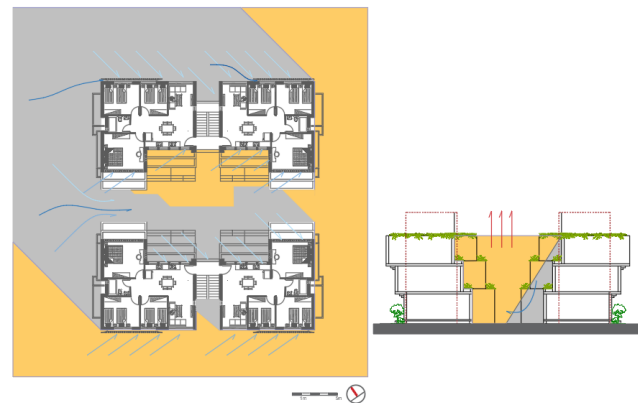


Figure 3. Wind analysis

This effect is further supported by wind catchers integrated through the staircases and alongside the mashrabiyas, as illustrated in Fig.4, maximizing natural ventilation and improving indoor comfort.

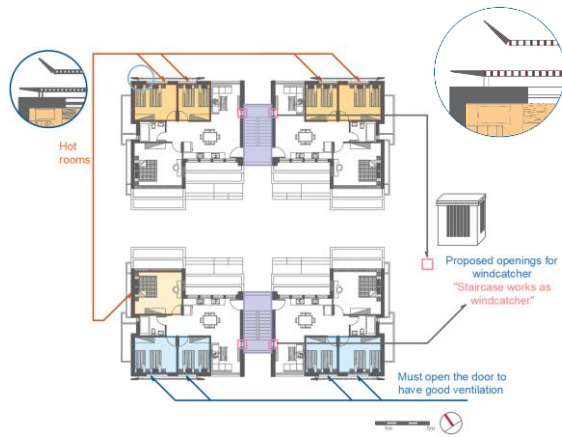


Figure 4. Indoor ventilation analysis

### A. Integrated Architectural and Environmental Design Details

This section highlights the specific architectural and environmental features integrated into the project to enhance comfort, sustainability, and cultural relevance.

- Sun Blinds:**  
 Indoor sun blinds were installed in the kitchen and living room to enhance thermal comfort and energy efficiency. These blinds offer privacy, reduce glare, and provide effective protection against overheating. They also allow for adjustable daylight control while maintaining a high level of visual transparency, ensuring comfortable and well-lit interior spaces.
- Mashrabiya/ Perforated Facade:**  
 Mashrabiya were integrated into bedroom designs to ensure high levels of privacy while enhancing environmental performance. Each mashrabiya consists of three functional layers: The outermost layer is composed of 10 cm thick clay, serving as an insulating barrier and incorporating voids filled with 1 cm thick ceramic cylinders. These cylinders help absorb moisture from the air, with the collected condensation directed toward green spaces planted in front of the mashrabiya. The inclination of the perforations is carefully calculated to admit winter sunlight while blocking summer rays, effectively functioning as seasonal sunshades. Behind this layer is an air gap, followed by a double-glazed panel with air insulation in between, which further improves thermal comfort and indoor climate control.

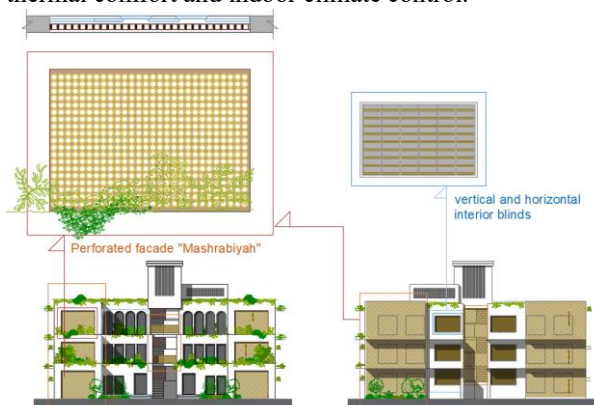


Figure 5. Sun breakers and Mashrabiya location

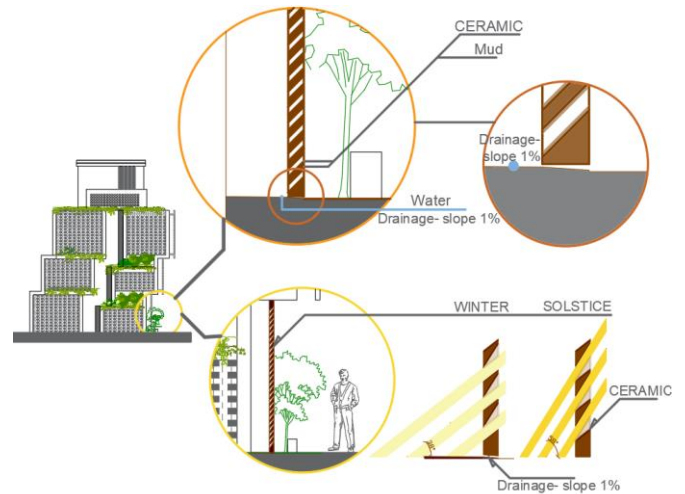


Figure 6. Mashrabiya Drainage Details

- Airflow/ ventilated windows for Bathroom:**  
 A ventilated window system was adopted to address ventilation challenges in the eastern and western bathrooms, particularly issues related to stagnant air, odor retention, and the reentry of moist air into the home.
- Northwestern bathrooms:**  
 In this orientation, where wind direction can be inconsistent or intense, a low-level inlet opening was incorporated to introduce fresh air at a moderated speed. This controlled intake prevents strong winds from forcing moist or odorous air back into the interior. The design leverages air density and temperature differences to promote natural convection: cooler air enters from the bottom, while warmer air rises and exits through an upper opening.

This passive ventilation strategy supports continuous airflow, effectively improving indoor air quality and reducing humidity and odors—without relying on mechanical systems. “Fig. 7”

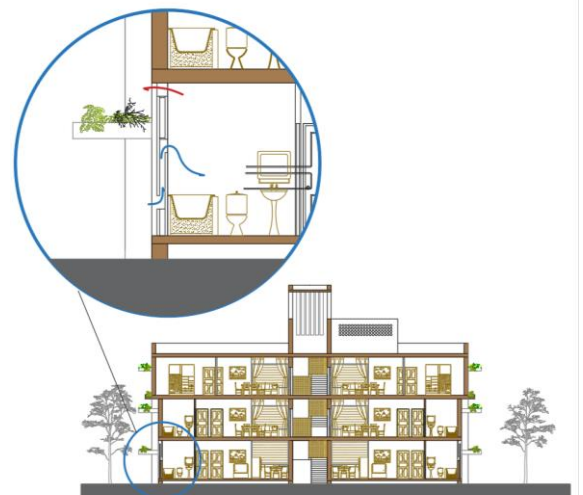


Figure 7. Bathroom Ventilation Details- Northwestern bathrooms

- Southeastern bathrooms:

The southeastern facade, receiving prolonged exposure to direct sunlight throughout the day, is designed to utilize stack ventilation as a passive cooling strategy. A thermal buffer layer absorbs solar heat, raising the temperature of the interior air. As this warm air becomes less dense, it naturally rises and exits through a high-level ventilation opening. Simultaneously, cooler outside air is drawn in from lower openings to replace it, creating a continuous upward airflow. This solar-induced stack effect improves indoor air circulation, enhances thermal comfort, and reduces humidity—crucial for maintaining healthy conditions in enclosed, moisture-prone areas such as bathrooms. “Fig. 8”



Figure 8. Bathroom Ventilation Details- Southeastern bathrooms

- **Staircase Passive Ventilation and Circulation Element:** The staircase functions as a wind catcher, particularly benefiting the southeastern units by directing prevailing breezes into interior spaces and enhancing natural ventilation. At the ground level, it also serves as a node within the secondary circulation axis, enabling efficient movement between units and main pathways while maintaining privacy. Its open connection to the central courtyard further amplifies airflow, generating a continuous air current that improves indoor thermal comfort. “Fig. 9”.

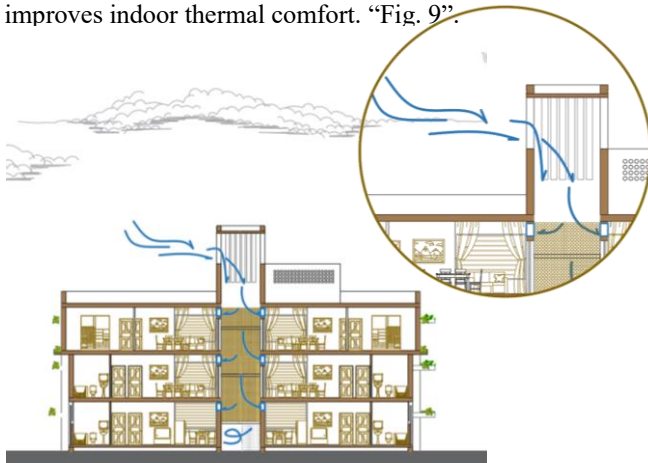


Figure 9. The staircase plays the role of wind catcher for the building

- **Courtyard:** The courtyard played an important role in environmental, social and cultural view. From an environmental point of view, areas exposed to sunlight, combined with areas in shade, create airflow movement to cool the air in general. In addition, some plants and green elements were added to the air to increase the movements of the air beside other environmental and psychological and advantages.

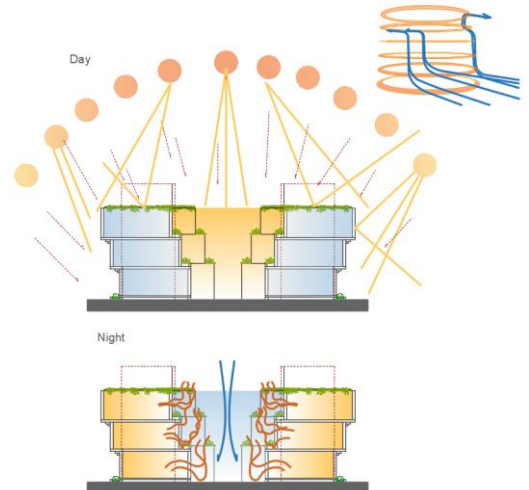


Figure 10. Courtyard concept through Day and Night

- **Stepped facades:** The building incorporates stepped facades through strategic floor setbacks to enhance the courtyard’s effectiveness and ensure that sunlight reaches the ground level, based on solar angle studies. These setbacks not only improve daylight penetration but also provide shaded walkways for pedestrians and accommodate green roofs on the courtyard-facing side contributing to both environmental performance and visual appeal. “Fig. 11”



Figure 11. Stepped Facade

- **Gray water:** Gray water from basins, baths, and showers is directed to a surge tank, where it is temporarily stored before being routed to an irrigation or treatment system. This system reduces water waste, supports sustainable landscaping, and minimizes demand on freshwater resources. “Fig. 12”

## VII. INTEGRATED SUSTAINABLE DESIGN STRATEGIES

This section outlines the project's integrated strategies for achieving sustainability, cultural continuity, and cost-efficiency. Drawing on traditional practices and climate-responsive design, the proposal addresses environmental challenges through thoughtful material choices, passive design techniques, and multifunctional architectural elements. From green roofs and mashrabiyas to water reuse systems and culturally rooted spatial configurations, each solution contributes to a resilient and livable environment tailored to Gaza's socio-climatic context.

### A. Building Envelope and construction materials:

Traditional building materials are combined with available local building materials such as clay, karkar and pottery.

External walls: The walls consist of six layers, as shown in "Fig. 7". Clay is used as the main facade coating for insulation, topped with white mortar to enhance durability and reflect heat. This assembly achieves a thermal transmittance (U-value) of 0.28 W/m<sup>2</sup>·K, improving energy efficiency and indoor comfort.

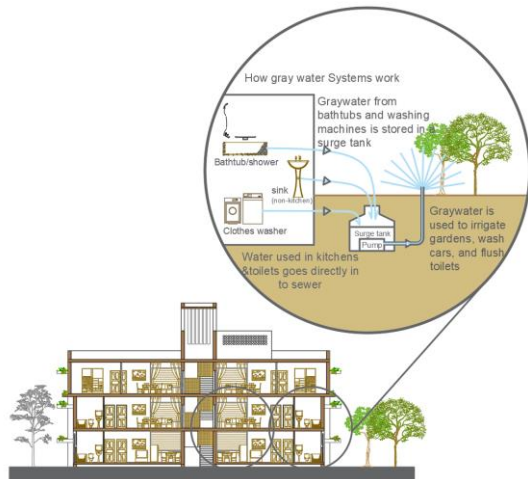


Figure 12. Gray Water system used in the project

- **Plants:**

Plants played a key role in ensuring privacy and tempering the general atmosphere, in addition to its psychological and social role. "Fig. 13"

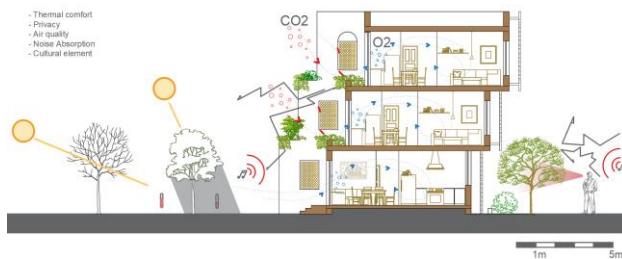


Figure 13. Analysis of Plant Benefits for the proposed design

- **Green Roofs:**

Green roofs were applied as an external layer over the flat rooftops of the residential units, offering multiple environmental and functional benefits. These include reducing air and noise pollution, sequestering carbon, enhancing biodiversity and habitat creation, retaining stormwater, improving energy efficiency, and helping to mitigate the urban heat island effect. "Fig. 14"

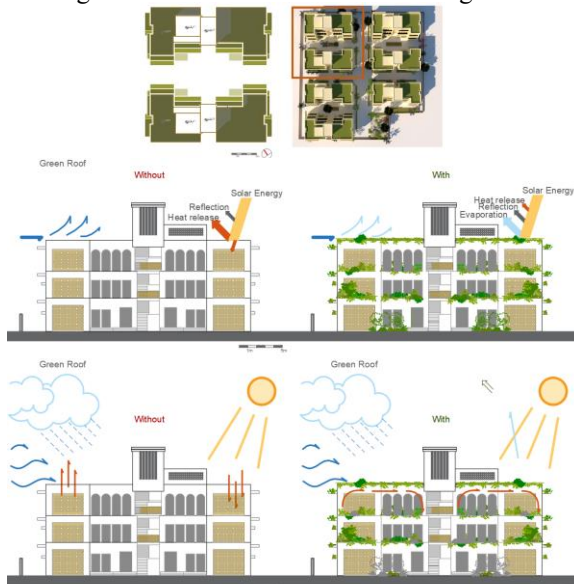


Figure 14. Green Roof Concept

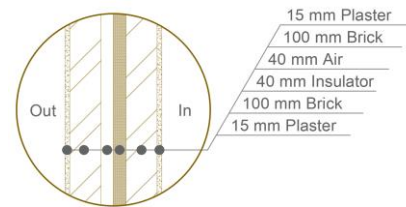


Figure 15. External Wall Layers

- **Columns and Roofs**

Traditional materials were used for columns and roofs to support potential vertical expansion. The flat concrete roof was treated with green layers to enhance insulation, reduce heat gain, and support biodiversity. Where a full green roof system posed structural or cost challenges, climbing plants were introduced as an alternative. These provide similar benefits -such as shading, cooling, and a green aesthetic- without the need for heavy soil layers, offering a lighter, cost-effective solution.

Openings - Glass: Openings are fitted with triple-layer Low-E (LoE) clear glass, with the first layer incorporating an insulating air gap. This configuration improves thermal performance, reduces heat gain, and enhances indoor comfort by minimizing energy loss.

### B. Economic Aspect treatments

This section highlights sustainable strategies that provide both financial benefits and environmental advantages, supporting long-term economic resilience within the project.

- **Green roof:** While green roofs typically require higher initial investment compared to traditional roofs, they offer significant long-term economic benefits. By increasing the roof's R-value (thermal resistance) and lowering surface temperatures, green roofs reduce HVAC energy demands and associated

costs. However, to expand their use in agricultural applications, challenges such as installation expenses and structural weight limits must be carefully addressed.

- Climbers: they can be added to enhance the green element, providing additional shading and insulation. Choosing edible climbers, such as grapevines or beans, can further increase the economic value by producing food, contributing both to sustainability and local food supply.
- Pigeon house “Lofts”: Integrating pigeon lofts within the project adds both economic and environmental value. Pigeon meat is flavorful, nutritious, and restorative, serving as an important source of protein. Commercial pigeon farming creates a sustainable income opportunity for residents, supported by the birds’ continuous reproduction through eggs. Moreover, pigeon droppings provide a natural fertilizer that enriches the project’s green spaces, promoting agricultural sustainability and healthier plant growth.
- Gray water: Gray water from basins, baths, and showers is stored in a surge tank before being reused for irrigation or treated, helping conserve water and reduce freshwater demand.

### C. Social and Cultural Aspect:

This section highlights the social and cultural design treatments incorporated into the project, emphasizing how architectural elements and materials foster community, privacy, and cultural identity.

- Traditional, locally sourced materials such as clay, karkar, and pottery, along with architectural elements like arches and courtyards, not only reflect and preserve the region’s cultural heritage but also support social interaction by creating familiar, welcoming spaces that strengthen community bonds and a shared sense of identity.
- Courtyard: Each unit opens onto a private courtyard that extends the living space and connects four units around a shared central area. This design supports gatherings, celebrations, and daily interactions, fostering strong social and cultural ties among residents while ensuring privacy and creating a welcoming, intimate communal environment.
- Mashrabiyas: These traditional architectural elements provide visual privacy between homes, allowing families to maintain their privacy while staying connected and fostering respectful social interaction. Their intricate designs embody the region’s cultural identity and craftsmanship, preserving local heritage and enriching the project’s architectural character.
- Public garden: A shared space with shaded plants and benches that fosters social interaction and community cohesion, reflecting the cultural importance of communal gathering and outdoor life in Gaza society.

### D. Environmental treatments

- Horizontal and vertical breakers: Due to the inclination of the building from the north at an angle

of 35 degrees, the horizontal and vertical movable sun-breakers were adopted as a single unit in the southeastern and southwestern façades. They maximize sunlight harvesting during winter while effectively blocking harsh rays in summer, enhancing energy efficiency and occupant comfort.

- Mashrabiyas: Constructed from a 10 cm thick clay layer that acts as natural insulation, these mashrabiyas incorporate 1 cm thick ceramic cylinder voids designed to absorb moisture from the air. The collected water is then redirected to irrigate plants positioned in front of the mashrabiyas. The angled holes are precisely calculated to allow sunlight penetration during winter while blocking excessive heat in summer, functioning effectively as sun breakers. This clay layer is followed by an air cavity and two layers of glass separated by an air gap, enhancing thermal performance and indoor comfort.
- Northwestern Bathrooms: Openings at the bottom allow air to enter at a controlled, reduced speed, preventing winds from carrying moisture and odors back into the house. This design facilitates natural airflow by enabling air movement based on air density differences, while hot air is expelled through an opening at the top, promoting effective ventilation.
- South-Eastern Bathrooms: With the facade exposed to sunlight for most of the day, a heated middle layer is created. An opening at the top allows hot air to escape, drawing in cooler air through the lower vacuum space. This natural ventilation promotes continuous airflow, effectively cooling the space by pulling warm air out and replacing it with cooler air.
- Mirrors: Strategically added to the facades, mirrors reflect sunlight away from sun-exposed areas and redirect it into shaded zones, enhancing natural light and reducing reliance on artificial lighting.
- Staircase: Beyond its primary role in vertical circulation, the staircase was designed as a wind-catcher that channels airflow through strategically placed openings. Its integration with air passages connecting to the courtyard helps generate cross-ventilation, enhancing natural airflow and improving indoor environmental quality.
- Courtyard: The courtyard was designed as a passive ventilation element, utilizing the thermal contrast between sunlit and shaded zones to generate natural air circulation through ventilation principles. This airflow helps regulate indoor temperatures and enhance thermal comfort. Additionally, the inclusion of plants improves air quality and contributes to a cooler, healthier microclimate.
- Stepped facades: They enhance courtyard effectiveness by allowing sunlight to reach the ground floor, based on studied solar angles. These rear-facing setbacks also serve dual purposes—providing shaded walkways for pedestrians and accommodating green roofs on the courtyard side to support environmental sustainability.
- Plants: Plants played a key role in ensuring privacy and tempering the general atmosphere.

- Green roof: Increased R-value of the roofing system, along with reduced temperatures on the roof lessens HVAC loads, resulting in energy cost savings.
- Pigeon house” Lofts”: Pigeon droppings are used as a natural fertilizer for plants.
- Gray-water: Reused water is collected and redirected for irrigating gardens and landscaping, conserving fresh water and promoting sustainable resource use.

### VIII. SIMULATION AND VIRTUAL MODEL VALIDATION

Design Builder, an Energy Plus-based simulation software, was utilized in this project to simplify and optimize building performance analysis. Design Builder is developed to ease up the building simulation process. In this project Design Builder was used:

- Evaluation of facade options for overheating, energy use, and shading performance.
- Optimization of daylight usage.
- Analysis of indoor temperature, air velocity, and pressure using the CFD (Computational Fluid Dynamics) module
- Thermal simulations for naturally ventilated spaces

Additionally, DIA-Lux evo, a professional lighting design tool, was employed to assess and optimize natural daylight levels in the proposed virtual model (Ciugudeanu, Beu, 2016).

A virtual model of the proposed design was developed using Design Builder software, taking into account the site location and building orientation. A detailed simulation of the ground floor apartment was conducted to assess the effectiveness of the proposed environmental strategies. Multiple scenarios were tested to identify the optimal building materials and construction layer configurations to achieve thermal comfort. Plans and charts for Daylight, ventilation, cooling and heating, temperature, PPD, PMV and air change studies for the building were obtained.

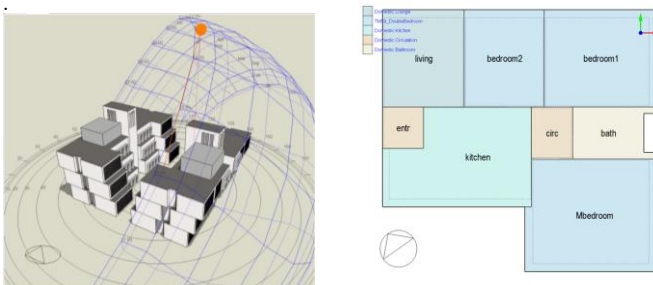


Figure 16. Virtual model for the unit in Design Builder software  
Design builder zoning for South-East ground floor apartment.

Additionally, simulations were performed to assess the impact of the building and its central courtyard on surrounding wind movement. These analyses helped determine the optimal orientation for openings and shading breakers.

#### A. Daylight analysis:

Daylighting analysis was conducted to assess and optimize the natural lighting within the project, aiming to create visually comfortable and aesthetically pleasing interior

spaces while reducing the need for artificial lighting and minimizing cooling loads.

Daylight levels inside the units were evaluated using Design Builder software through Daylight Factor analysis, and further quantified using DIA-Lux by calculating illuminance (lux) levels on the working plane (80 cm above floor level). The results demonstrated that daylighting in the design meets the recommended illuminance levels required for efficient and accurate visual task performance. To mitigate glare and control the penetration of direct sunlight, sun blinds and mashrabiyyas were integrated into the design. In areas with limited daylight exposure, a light tube system was proposed as a supplementary feature to increase interior illumination. Additionally, mirrors were strategically positioned to reflect sunlight onto shaded facades, further enhancing natural light distribution throughout the space. “Fig. 17-Fig. 18-Fig. 19”

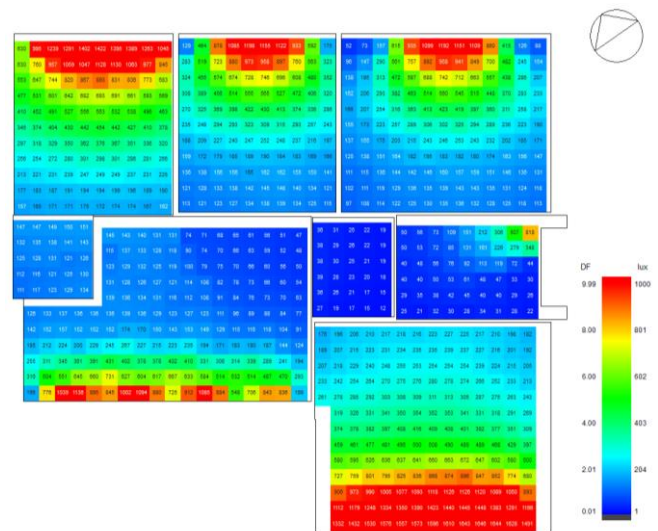


Figure 17. The illumination level results for indoor unit (ground plan) before optimization on Design Builder software

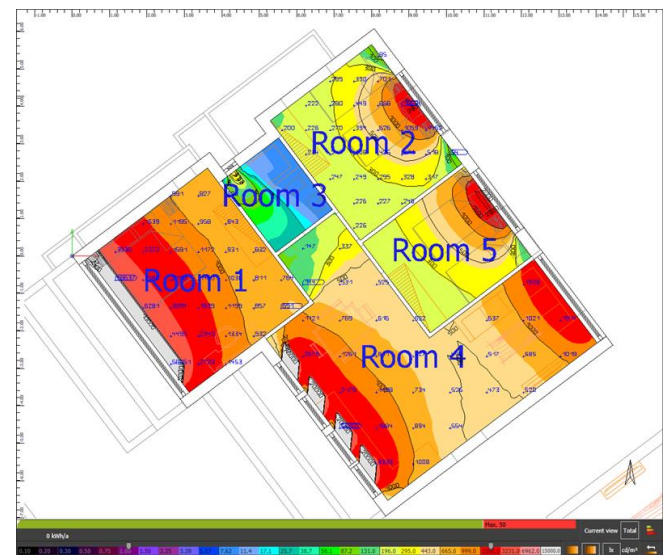


Figure 18. The illumination level contour diagram for indoor unit (ground plan) before optimization on DIA Lux- evo

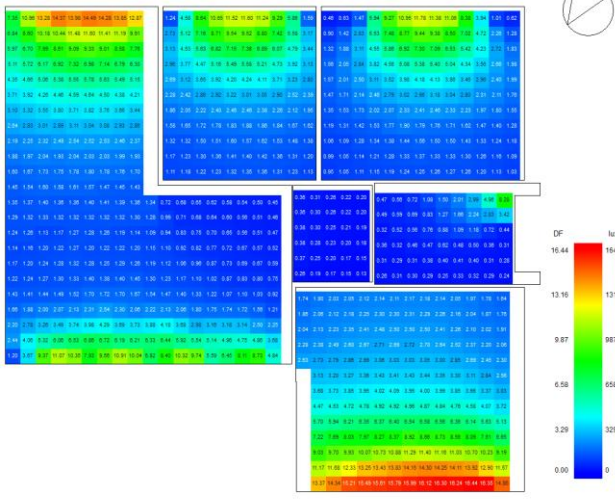


Figure 19. The Daylight Factor (DF) Grid for indoor unit (ground plan) before optimization on Design Builder software

### E. Heating:

The Heating Design Diagram indicates that the indoor air temperature reached 11.11°C, while the operating temperature was 11.39°C. In comparison, the external dry-bulb temperature was recorded at 6.40°C. This results in an indoor-outdoor temperature difference of approximately 5°C. Figure (20). Although additional measures may be required to reach optimal thermal comfort, the simulation confirms the effectiveness of the current passive design in improving indoor temperatures. “Fig. 20”

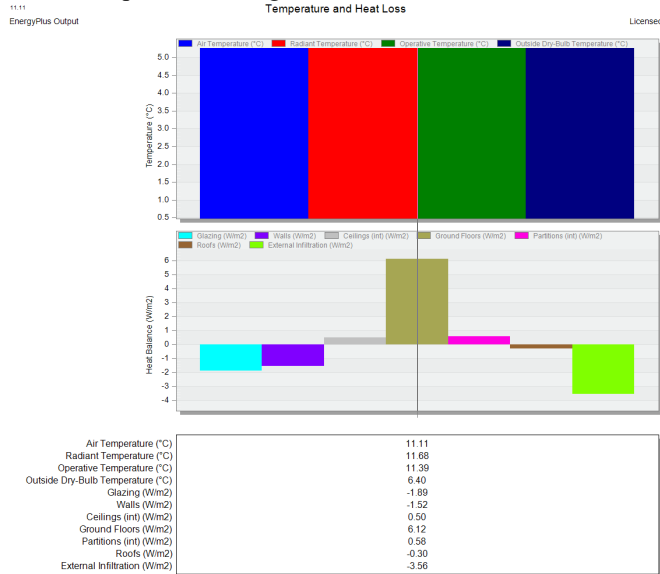


Figure 20. shows the results of the indoor unit Heating Design Chart

### F. Cooling:

The Cooling Design Diagram indicates that the average indoor air temperature was 25.88°C, while the outdoor temperature reached 32°C, resulting in a temperature difference of approximately 6°C. Figure (21). By maintaining indoor temperatures well below outdoor levels,

the system enhances thermal comfort while minimizing the need for mechanical cooling—contributing to both energy savings and occupant well-being. “Fig. 21”

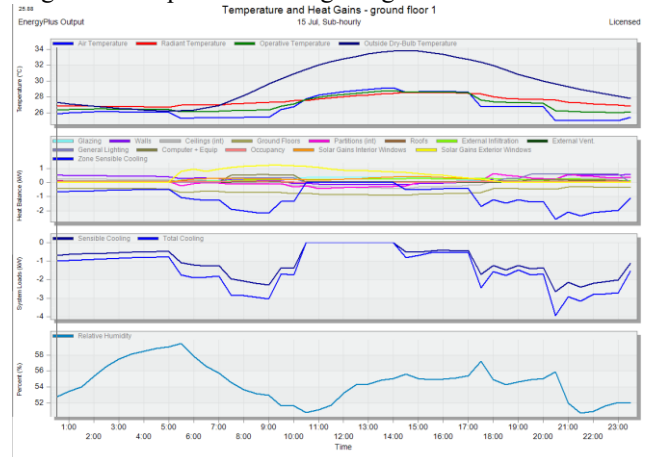


Figure 21. Results of the Ground floor Cooling Design Chart

### G. Temperature Chart.

The internal CFD analysis revealed a consistent temperature range of 18.76°C to 19.67°C throughout the interior spaces. Specifically, temperature readings in both the living area and kitchen fell within this same range, indicating uniform thermal conditions across commonly used spaces. “Fig. 22”

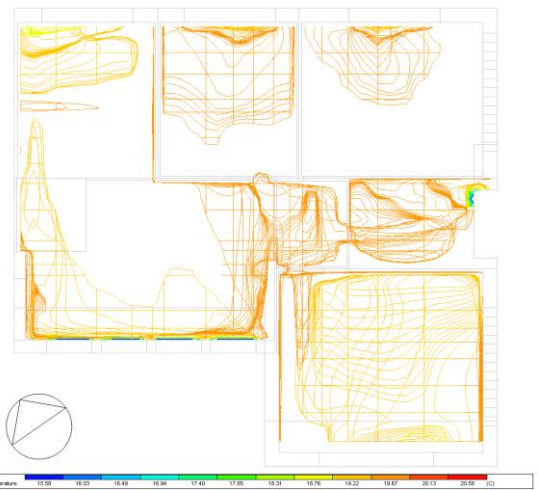


Figure 22. CFD Temperature results for indoor unit (plan) heat

### H. CFD (Computational Fluid Dynamics) Analysis

The CFD analysis showed effective outdoor airflow within the comfort range, supporting thermal comfort around the building's exterior. Internally, the air movement was found to be sufficient to maintain comfortable thermal conditions, validating the success of the proposed design strategies.

- CFD for the apartment:

The results indicated efficient air circulation within the apartment, primarily due to the building's 35° tilt from the north, which strategically exposed most rooms to prevailing western and northern winds. This orientation significantly enhanced natural ventilation, contributing to thermal comfort across interior spaces.

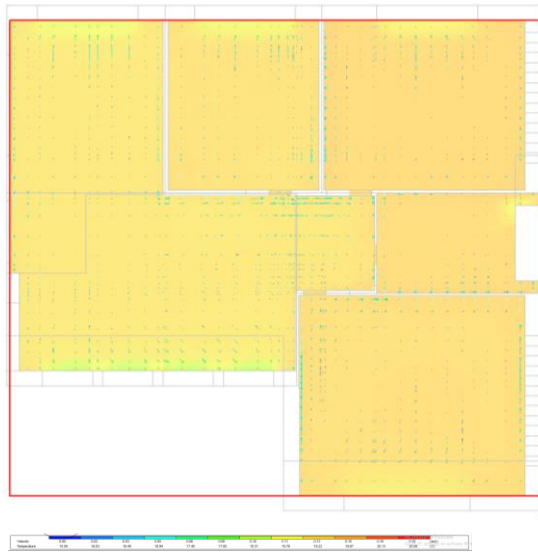


Figure 23. CFD results for indoor apartment (plan) heat

- **CFD for the Unit**  
The CFD analysis revealed effective air circulation throughout the unit, contributing to both thermal comfort and wind flow within the courtyard and adjacent apartments.

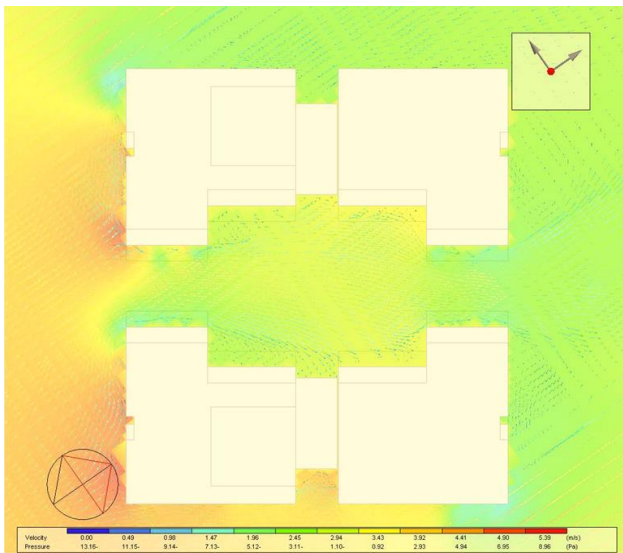


Figure 24. CFD for the unit at Ground floor level

### I. Age of Air

Simulation results indicated an air change rate of approximately 9 times per hour, aligning with ASHRAE standards. The Age of Air in the living room and kitchen averaged 399 seconds (ranging from 375 to 422 seconds), equivalent to 9–10 air changes per hour. In the master bedroom, the age was around 422 seconds (8–9 changes/hour), while in the other bedrooms, it was approximately 304 seconds, achieving 12 changes/hour, reflecting efficient ventilation throughout the apartment.

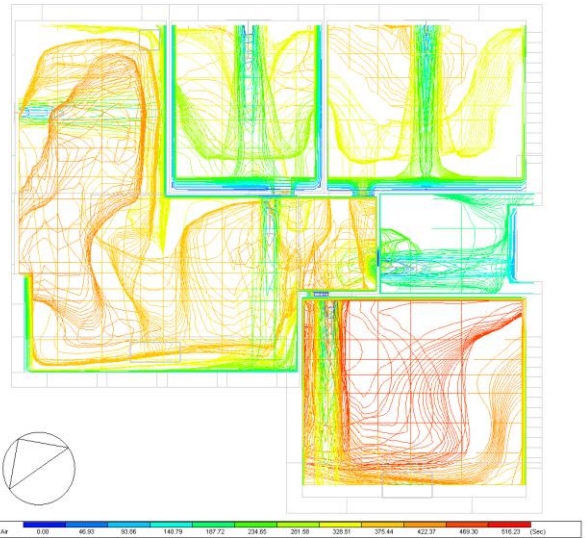


Figure 25. Age of Air Chart results for indoor unit (perspective)

### J. Predicted Mean Vote (PMV):

According to ASHRAE standards, the PMV values for all rooms in the indoor unit remained within the acceptable thermal comfort range, with average values between 1.36 and 1.9, all below the threshold of <2. These results indicate that the indoor thermal conditions are generally comfortable for occupants during the evaluated period. “Fig. 26”

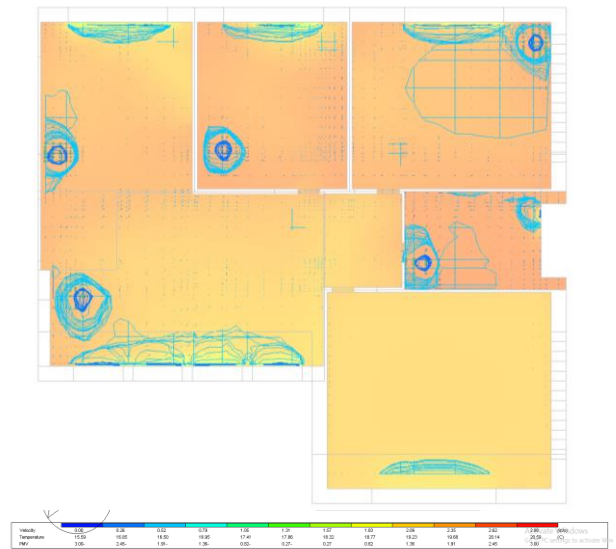


Figure 26. Graph PMV showing the level of passenger satisfaction in space

### K. PPD (Predicted Percentage of Dissatisfied):

Simulation results indicate favorable thermal comfort conditions in the indoor unit. As shown in “Fig. 27”, all occupied areas recorded a PPD of less than 20%, which meets the acceptable threshold defined by ASHRAE standards.

## IX. CONCLUSION

The results demonstrate that implementing passive design strategies in buildings across the Gaza Strip is effective in enhancing energy conservation. These findings are instrumental in supporting the development of passive house standards tailored for Gaza and contribute to further optimization efforts aimed at achieving energy efficiency and environmentally responsive residential architecture—especially critical during frequent electricity outages in the region.

This study focused on applying passive techniques in building designs for areas severely affected by destruction. A virtual model of the proposed design was developed, and energy performance simulations were conducted using Design Builder software. Various passive cooling strategies were applied and comparatively analyzed to evaluate their impact on energy consumption and overall sustainability.

Key strategies include optimized building orientation, enhanced natural ventilation, and the use of local, sustainable materials to reduce humidity. Traditional design elements such as mashrabiya, courtyards, green roofs, and vegetated facades were incorporated to promote environmental sustainability, while also supporting cultural heritage and social cohesion. These design choices contribute to economic sustainability by reducing energy costs and fostering resilient communities that preserve cultural identity and social interaction. The following is a summary of the findings in the proposed design and analysis of passive cooling techniques used in it:

- Insulated building envelopes incorporating local mud layers effectively reduce thermal transfer through external walls across seasons.
- Using ceramic in building layers and perforated facades help in decreasing internal humidity levels.
- Enhanced glazing significantly decreases cooling and heating loads throughout the year, both during the day and night.
- Mashrabiya (perforated facades) reduce daytime cooling loads and offer visual privacy, reflecting the cultural needs of local communities.
- Interior horizontal and vertical blinds allow for flexible daylight control, glare reduction, and increased privacy, while also contributing to energy savings.
- Staircases functioning as wind-catchers improve natural airflow and promote thermal comfort.
- Green elements such as plants, green walls, and green roofs enhance indoor environmental quality and help achieve thermal comfort. besides its economic value.
- Courtyards play a critical role in improving natural ventilation and also uphold strong cultural significance within the built environment.

However, this study has some limitations. A detailed, time-based parametric analysis of each technique's energy-saving potential and its impact on occupant comfort could not be completed due to time constraints and computational limitations. Future research should employ more advanced tools and broader datasets to provide a comprehensive evaluation of passive strategies and their influence on building energy demand and thermal comfort in similar contexts.

## RECOMMENDATION

To address environmental challenges and energy demands, the following sustainable strategies are essential for the sector's future development:

- Growing environmental concerns and rising energy costs highlight the urgent need for sustainable development and energy conservation in the sector.
- Passive design techniques should be more widely adopted—whether in restoring damaged buildings, rebuilding demolished structures, or constructing new ones—as they offer cost-effective solutions to reducing energy demand while ensuring thermal comfort for residents.
- Greater emphasis should be placed on utilizing locally available materials such as mud and ceramic, given their proven sustainable properties and suitability to the local climate.
- Integrating cultural and social considerations into design must be a priority to ensure that new developments resonate with the community's identity and support social cohesion

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