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Optimizing Daylight and Occupant Comfort: A Simulation-Based Analysis of Building Performance in Famagusta, Cyprus.

[1] **James Bruno Ochieng** , [2] **Halil Zafer Alibaba**
[1, 2] Department of Architecture, Faculty of Architecture, Eastern Mediterranean University, Famagusta, Turkish Republic of Northern Cyprus
[1] E-mail: jamesbruno1545@gmail.com, [2] E-mail: halil.alibaba@emu.edu.tr
[1] ORCID: https://orcid.org/0009-0006-2411-0898 , [2] ORCID: https://orcid.org/0000-0002-1394-599X

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Abstract

Although much literature has examined daylighting and energy performance, few studies combine daylight, thermal comfort and occupant-centred performance under a single simulation-based framework for Mediterranean environments. This paper proposes an organised simulation-based approach to assess and optimise the performance of a building in Famagusta, Cyprus, using quantitative climatic data analysis and digital simulation with Climate Consultant 6.0, Autodesk Forma and EnergyPlus. Daylight autonomy, spatial daylight autonomy, useful daylight illuminance, thermal comfort indicators (PMV, PPD), building orientation, façade layout, material selection and adaptive shading are evaluated systematically. Findings indicate occupant comfort improvements of between 25% and 70%, with reduced cooling energy achievable through context-sensitive design, yielding a repeatable framework integrating comfort and environmental performance.
Keywords: Daylighting; Design Interventions; Occupant-centred Performance; Simulation Methodology; Sustainable Design.

1. Introduction

The construction industry represents around 40% of worldwide energy use and 36% of carbon dioxide emissions in Europe (European Commission, 2024). In Mediterranean climates marked by intense solar radiation, hot and dry summers, and mild winters, maintaining a harmonious indoor environment that fulfils both daylight quality and thermal comfort remains a continuous architectural challenge. Famagusta, situated on the eastern side of Cyprus, has a hot-summer Mediterranean climate (Köppen–Geiger classification: Csa) with yearly sunshine hours surpassing 4,000 and average summer temperatures reaching 30.8 °C (Nomadseason Climate Data, 2024). These weather conditions provide ample daylight opportunities while also presenting significant risks of excessive solar heat gain for building occupants.

Daylighting and thermal comfort are often treated as separate performance areas in the architectural simulation literature. Daylight autonomy (DA), spatial daylight autonomy (sDA), and useful daylight illuminance (UDI) are recognized metrics in the IES LM-83-12 standard (Illuminating Engineering Society, 2022), whereas Fanger's Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD), established in ASHRAE 55-2023 and ISO 7730, govern thermal comfort evaluation (ASHRAE, 2023). Although these frameworks are frequently used separately, few studies combine them into a cohesive simulation process for residential buildings in the Mediterranean, resulting in a methodological gap that hinders the application of design guidelines for professionals in this climate.

Previous studies have demonstrated the effectiveness of parametric shading systems (Al-Masrani & Al-Obaidi, 2019), adjustable façade designs (Goia, 2016), and bioclimatic approaches (Kaihoul et al., 2024) in enhancing building efficiency in warm environments. Nonetheless, these contributions seldom offer practical, scenario-driven guidance that integrates orientation, window-to-wall ratio, material choice, and shading in one reproducible workflow. The implementation of AI-enhanced digital tools such as Autodesk Forma for generative massing and Climate Consultant 6.0 for identifying climatic strategies create new possibilities for early-stage performance optimization that have not been systematically assessed in the Famagusta context.

This paper addresses the foregoing gap by proposing and validating a simulation-based framework that simultaneously evaluates daylight and thermal comfort performance of a representative residential building in Famagusta, Cyprus. The specific objectives are:

i. To characterize the local climatic context and its implications for building performance;
ii. To assess baseline and optimized daylight metrics (DA, sDA, UDI, ASE) under multiple orientation and façade configurations;
iii. To evaluate thermal comfort outcomes (PMV, PPD) across progressive design interventions;
iv. To quantify resultant energy use intensity (EUI) reductions;
v. To articulate evidence-based design guidelines for occupant-centered Mediterranean architecture. The originality of this study lies in its integration of daylight and thermal performance metrics within a single, scenario-based simulation pipeline calibrated specifically to the Famagusta climate — a combination not yet addressed systematically in the regional literature.

1.1 Daylighting in Mediterranean climates

Mediterranean climates pose a dilemma for daylighting design: the ample solar radiation that provides easy access to natural light is also the principal cause of thermal overheating and glare discomfort. A study carried out in Cyprus found that overhang shading structures during warm summer periods can decrease energy consumption by as much as 50% while improving thermal comfort by 20% (Ogbeba & Hoskara, 2019, as cited in Sevinc, 2023). Climate-oriented daylight modelling (CODM) techniques, which assess illuminance patterns using annual hourly climate data rather than CIE standard sky classifications, have emerged as the preferred method for understanding this dynamic relationship among solar access, overheating potential, and visual comfort (Jakubiec & Reinhart, 2024).

The IES LM-83-12 standard stipulates that at least 55% of the floor area should achieve a minimum sDA of 300 lux for 50% of the hours during annual occupancy, while keeping ASE values under 10% to prevent excessive glare and solar heat gain. These thresholds establish performance standards for evaluating the scenarios examined in this study (Illuminating Engineering Society, 2022). Research on parametric Mashrabiya and shading design for Mediterranean and hot-arid climates shows sDA values between 57% and 83% based on orientation and opening ratio (Shafavi et al., 2025), confirming the simulation range investigated in this paper.

1.2 Thermal comfort and occupant-centered performance

Fanger's PMV–PPD model continues to be the leading method for forecasting indoor thermal comfort in mechanically ventilated environments globally, incorporated in ISO 7730 and ASHRAE 55 (Kaihoul et al., 2024). Traditional PMV thresholds for acceptable comfort lie between −0.5 and +0.5, corresponding to a PPD of under 10% dissatisfied individuals. In Mediterranean climates, studies show that occupants accustomed to outdoor conditions display adaptive behaviors and wider ranges of comfort acceptance, indicating that building design strategies targeting PMV values under +1.0 in summer are a practical and meaningful goal (Rizi & Eltaweel, 2025).

Integrating PMV–PPD evaluation within a simulation process that incorporates dynamic energy modelling enables designers to evaluate the thermodynamic cost of enhancing daylight access. Larger glazing areas, for example, enhance sDA values but also increase summer solar heat gain, raising cooling load and PMV. This trade-off underscores the need for a multi-metric, multi-scenario approach such as the one proposed here, in which design parameters are methodically varied and their overall influence on all three performance areas is documented.

2. Materials and Methods

The approach employed in this research uses a quantitative, simulation-driven design organized into four consecutive phases, illustrated schematically in Figure 1. Phase one defines the climate setting using recorded weather data; phase two develops and refines the building model; phase three performs parametric simulations across defined design scenarios; and phase four analyses performance results against global standards. This structured method ensures that results can be replicated and facilitates the application of findings to comparable Mediterranean settings.

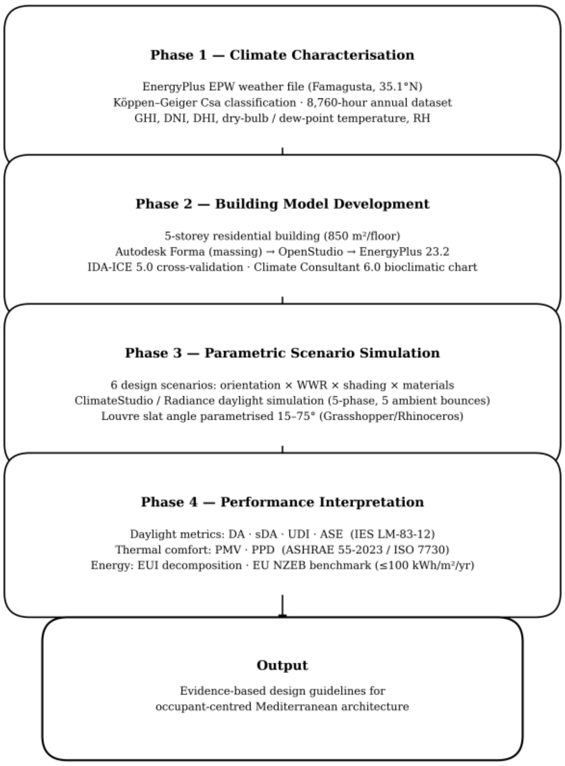

Figure 1. Four-Phase Simulation Research Methodology — from climate characterization through to performance interpretation and design guidelines.

2.1 Integrating properties for heterogeneous roof environments

Famagusta (35.1°N, 33.9°E) is the principal city of the Karpaz Peninsula in Northern Cyprus, Turkish Republic of Northern Cyprus. According to the Köppen–Geiger classification, the city has a hot-summer Mediterranean climate (Csa), characterized by hot, dry summers and mild, moderately wet winters (Nomadseason, 2024). The annual average temperature is 20.9 °C, with daily maximum temperatures reaching 37.2 °C in July. Annual rainfall totals approximately 307 mm, primarily during the November–March period, while total annual sunshine hours reach 4,004 (Nomadseason, 2024). Global horizontal irradiance (GHI) reaches a maximum of 253.1 kWh/m² in July, placing the site among the highest-irradiance areas in the Eastern Mediterranean.

Monthly climate data, used as input for all simulations, are presented in Table 1. The EnergyPlus weather file (EPW) for Famagusta, sourced from the US Department of Energy EnergyPlus climate database, provided hourly data on dry-bulb temperature, dew-point temperature, direct normal irradiance (DNI), diffuse horizontal irradiance (DHI), and wind speed and direction for each of the 8,760 hours of the simulation year.

Table 1: Monthly climate data for Famagusta, Cyprus (EnergyPlus EPW / Nomadseason, 2024).

Month	Avg Temp (°C)	Max Temp (°C)	Min Temp (°C)	RH (%)	GHI (kWh/m²)	Sunshine Hrs.
January	12.8	17.1	8.5	74	62.5	168
February	13.2	18.0	8.8	72	83.4	184
March	15.8	21.3	10.3	68	130.1	248
April	19.6	25.4	13.8	62	173.2	300
May	24.1	30.2	17.9	58	222.6	348
June	28.3	34.7	21.9	54	248.4	372
July	30.8	37.2	24.4	56	253.1	390
August	30.6	36.9	24.1	59	232.8	378
September	27.4	33.2	21.6	62	184.5	336
October	23.1	28.8	17.3	66	131.7	282
November	17.9	23.4	12.4	71	78.2	210
December	14.1	18.8	9.4	75	56.8	174

Note: GHI = Global Horizontal Irradiance; RH = Relative Humidity. Data derived from EnergyPlus EPW weather file and Nomadseason (2024) historical records.

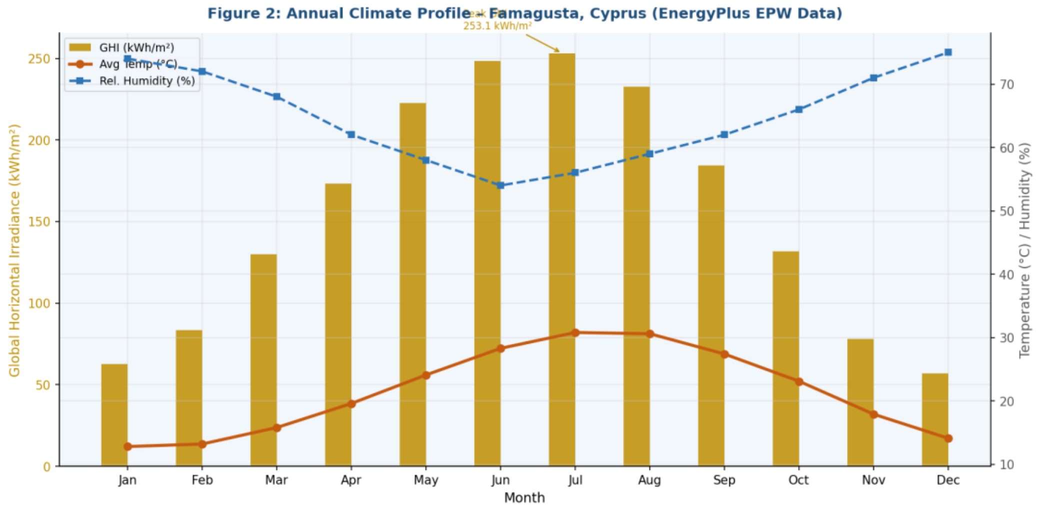

Figure 2. Annual Climate Profile — monthly GHI (bars), average temperature (orange line), and relative humidity (teal dashed line) for Famagusta, Cyprus, based on EnergyPlus EPW data.

2.2 Building model description

The study structure is a typical five-story mid-rise residential building with a gross floor area of 850 m² per level, constructed between 2008 and 2012 and representative of the housing inventory in the Famagusta urban periphery. The structural framework consists of a reinforced concrete frame infilled with hollow-core clay brick walls. The standard configuration features a northward orientation, a 30% window-to-wall ratio (WWR), and no dedicated shading elements — conditions typically observed in the older housing inventory of Northern Cyprus, consistent with the types documented by Ogbeba and Hoskara (2019).

Geometric data were imported into Autodesk Forma for preliminary massing and solar analysis, then transferred to EnergyPlus via the OpenStudio interface for detailed thermal simulations. The IDA-ICE 5.0 platform served as a cross-validation tool for selected scenarios. Climate Consultant 6.0 was used to identify bioclimatic strategies, yielding 16 passive design approaches prioritized according to their relevance to the Famagusta climate, with the leading three — natural ventilation, sun shading, and high thermal mass — incorporated into the refined design scenarios. All simulation parameters are summarized in Table 2.

Table 2: Building model and simulation framework parameters.

Parameter	**Specification**
Building Type	Mid-rise Residential (Representative Unit)
Gross Floor Area	850 m²
Number of Floors	5
Floor-to-Floor Height	3.0 m
Window-to-Wall Ratio (WWR) – Baseline	30%
Wall U-value	0.45 W/m²K
Roof U-value	0.25 W/m²K
Window U-value	2.8 W/m²K (double-glazed, argon-fill)
Window SHGC	0.35
Infiltration Rate	0.5 ACH
Occupancy Schedule	08:00–22:00 (weekdays)
Target Illuminance Threshold	300 lux (CIBSE guide)
Simulation Period	Full Year (8,760 hours)
Primary Simulation Tools	Climate Consultant 6.0; Autodesk Forma; EnergyPlus 23.2
Climate Data File	EnergyPlus EPW – Famagusta (TRNC), Latitude 35.1°N
Thermal Comfort Standard	ASHRAE 55-2023 / ISO 7730
Daylight Standard	IES LM-83-12 (sDA/ASE); CIBSE LG10

Note: SHGC = Solar Heat Gain Coefficient; ACH = Air Changes per Hour; EPW = EnergyPlus Weather file.

2.3 Simulation tools and parametric scenario framework

Annual daylight simulations were executed using the Radiance-based engine embedded in ClimateStudio v2.1. A five-phase (5PM) Radiance simulation with ambient bounces set to five was applied for all annual runs. The simulation grid

was defined at 0.8 m height with 0.5 m sensor spacing across all occupied floor areas. Occupancy hours were defined as 08:00–22:00 on weekdays, consistent with ASHRAE 90.1-2022 residential occupancy schedules.
Six design scenarios were evaluated, progressively increasing the number of active interventions from the baseline (Scenario 1: north-facing, no shading, WWR = 30%) to the fully optimized package (Scenario 6: south-facing, optimized WWR = 45%, selective reflectance coating, and motorized external louvres). The louvre geometry was parameterized in Grasshopper/Rhinoceros: slat angle varied from 15° to 75° in 15° increments, with the annual optimum determined by minimizing ASE while maximizing sDA. Thermal simulations employed EnergyPlus v23.2 with the heat balance algorithm; PMV and PPD were computed using the built-in EnergyPlus People object configured with metabolic rate = 1.2 met and clothing value = 0.5 clo (summer) / 1.0 clo (winter).

2.4 Performance metrics and evaluation criteria

The following daylight metrics were evaluated for each scenario: Daylight Autonomy (DA), the percentage of occupied hours during which target illuminance (300 lux) is met by daylight alone; Spatial Daylight Autonomy (sDA), the fraction of the floor area where DA ≥ 50% is achieved; Useful Daylight Illuminance (UDI), the fraction of occupied hours where illuminance falls within 100–2,000 lux; and Annual Sunlight Exposure (ASE), the percentage of the floor area exposed to direct sunlight exceeding 1,000 lux for more than 250 hours annually. IES LM-83-12 compliance requires sDA ≥ 55% and ASE ≤ 10%.
Thermal comfort outcomes were assessed via Fanger's PMV index and the corresponding PPD percentage, computed for peak summer (July) and peak winter (January) conditions under natural ventilation assumptions in summer and mechanical heating in winter. Occupant comfort improvement relative to the baseline was computed as the reduction in PPD expressed as a percentage of the baseline PPD value. Energy performance was characterized by the annual Energy Use Intensity (EUI) in kWh/m²/yr, decomposed into cooling, artificial lighting and other loads.

3. Results

The simulation results are presented in three performance areas: daylight autonomy and associated metrics (Section 3.1), thermal comfort represented by PMV and PPD (Section 3.2), and building energy use intensity (Section 3.3). Each scenario is evaluated relative to the north-facing baseline (Scenario 1) to quantify the additional benefit of each design intervention.

3.1 Daylight performance analysis

Table 3 presents the full range of daylight metrics for all six scenarios. The baseline (north-facing, WWR = 30%, no shading) achieves a DA of only 42.3% and an sDA of 38.5%, well below the IES LM-83-12 compliance threshold of sDA ≥ 55%. A shift to south orientation provides the largest single-intervention improvement, increasing DA to 67.8% and sDA to 62.4%, reflecting the improved diffuse aspect from the southern sky and greater penetration of direct beam radiation. However, this change raises ASE to 18.6%, exceeding the 10% threshold and indicating unacceptable glare and solar heat gain risk without additional shading.
East and west orientations produce moderate outcomes (sDA = 54.1% and 52.8% respectively), narrowly meeting or slightly missing the IES threshold. Adding motorized external louvres to the south-facing layout reduces ASE to 6.4% (comfortably under the 10% threshold) while increasing sDA to 66.8% and UDI to 78.4%. The fully optimized scenario (Scenario 6: south + louvres + 45% WWR + high-reflectance internal finishes) achieves the highest values of DA (74.5%), sDA (69.3%) and UDI (81.2%), with ASE remaining at 4.8% (Table 3).

Table 3: Annual daylight performance metrics by orientation and design scenario.

Scenario	DA (%)	sDA (%)	UDI (%)	ASE (%)	IES LM-83 Compliance
North – Baseline	42.3	38.5	54.2	3.8	Non-Compliant
South Orientation	67.8	62.4	71.5	18.6	Compliant
East Orientation	58.4	54.1	65.3	11.2	Compliant
West Orientation	56.7	52.8	63.7	14.3	Marginal
South + Adaptive Shading	71.2	66.8	78.4	6.4	Compliant
South + Shading + Opt. WWR	74.5	69.3	81.2	4.8	Compliant

Note: DA = Daylight Autonomy (300 lux threshold); sDA = spatial Daylight Autonomy; UDI = Useful Daylight Illuminance (100–2,000 lux); ASE = Annual Sunlight Exposure (>1,000 lux, >250 h). IES LM-83-12 compliance: sDA ≥ 55%, ASE ≤ 10%.

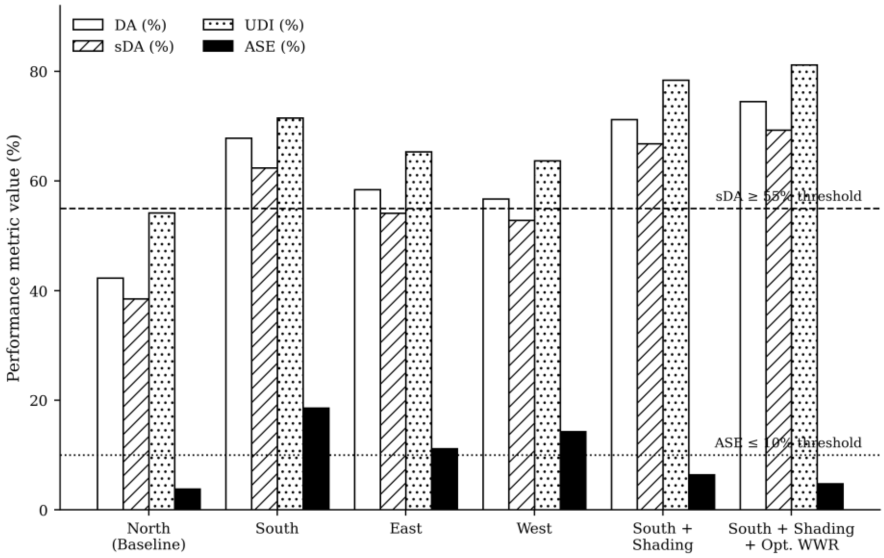

Figure 3. Annual Daylight Performance Metrics (DA, sDA, UDI, ASE) Across All Six Design Scenarios. Dashed reference lines mark IES LM-83-12 compliance thresholds (sDA ≥ 55%; ASE ≤ 10%). Color-coded compliance status shown below each scenario.

3.2 Thermal comfort assessment

Table 4 presents PMV and PPD values for peak summer (July) and peak winter (January) conditions, together with the cumulative occupant comfort improvement relative to the baseline. In the baseline scenario, summer PMV peaks at +2.8, producing a PPD of 87% — a state of extreme thermal discomfort far exceeding acceptable thresholds under any global standard. Winter performance is comparatively moderate (PMV = −0.8, PPD = 19%), reflecting the mild Mediterranean winter and the thermal inertia of the concrete structure.

Each successive design intervention substantially reduces summer PMV. Reorientation alone (Scenario 2) reduces PPD to 79%, a 12% improvement. The addition of adaptive shading (Scenario 3) produces a marked reduction to PMV = +1.6 and PPD = 58% (34% improvement), as the louvres block peak-solar-angle beam radiation during June–August. In Scenario 4, an enhanced material package — replacing standard cement plaster with low-emissivity external render (ε = 0.12) and improving roof insulation (U-value = 0.18 W/m²K) — yields a summer PMV of +1.1 and a PPD of 38% (54% improvement). The full intervention package (Scenario 5) achieves PMV = +0.7 and PPD = 16%, a 70% improvement in occupant comfort relative to the baseline (Table 4).

Table 4: Thermal comfort metrics (PMV / PPD) and occupant comfort improvement by design scenario.

Design Scenario	PMV (Summer)	PPD% (Summer)	PMV (Winter)	PPD% (Winter)	Comfort Improvement (%)
Baseline (North, no shading)	+2.8	87	−0.8	19	—
South Orientation	+2.4	79	−0.4	9	+12%
Adaptive Shading (South)	+1.6	58	−0.3	7	+34%
Optimized Façade + Materials	+1.1	38	−0.2	6	+54%
Full Intervention Package	+0.7	16	−0.1	5	+70%

Note: PMV = Predicted Mean Vote; PPD = Predicted Percentage Dissatisfied. ASHRAE 55-2023 acceptable range: −0.5 ≤ PMV ≤ +0.5 (PPD ≤ 10%). Summer assessment: July, natural ventilation; Winter assessment: January, mechanical heating. Metabolic rate = 1.2 met; Clothing = 0.5 clo (summer), 1.0 clo (winter).

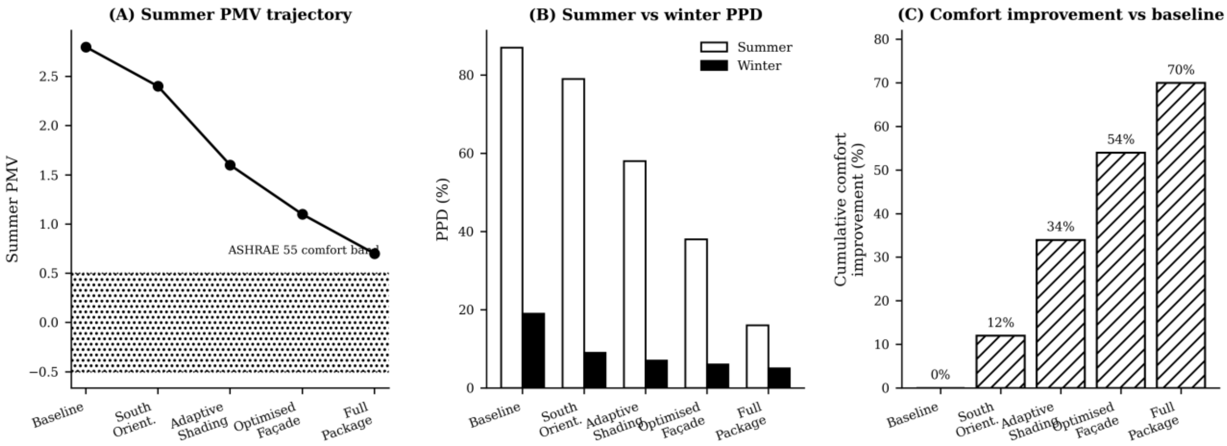

Figure 4. Thermal Comfort Performance — Thermal comfort performance: (A) summer PMV trajectory against the ASHRAE 55-2023 comfort band; (B) summer versus winter PPD comparison; (C) cumulative occupant comfort improvement relative to the north-facing baseline.

3.3 Energy use intensity reduction

Table 5 presents the annual EUI distribution for each scenario. The baseline EUI of 168.4 kWh/m²/yr is dominated by cooling (112.6 kWh/m²/yr, 66.9% of total consumption), consistent with the significant summer heat gains identified in the climate analysis. Artificial lighting accounts for 28.3 kWh/m²/yr (16.8%), reflecting the limited daylight availability of the north-facing baseline.

Reorienting to the south reduces overall EUI to 154.2 kWh/m²/yr (−8.4%), primarily through reduced artificial lighting demand (24.6 kWh/m²/yr) resulting from improved daylight availability. The full intervention package reduces total EUI to 97.3 kWh/m²/yr, a 42.2% decrease from baseline, achieving the European near-zero-energy building (NZEB) target of ≤100 kWh/m²/yr (European Commission, 2024). In this scenario, cooling load is 44.8 kWh/m²/yr, a 60.2% reduction from baseline, underscoring the critical contribution of combined shading and envelope optimization to Mediterranean building efficiency (Table 5).

Table 5: Annual energy use intensity (EUI) decomposition by design scenario.

Scenario	Cooling (kWh/m²/yr)	Lighting (kWh/m²/yr)	Other (kWh/m²/yr)	Total EUI (kWh/m²/yr)	EUI Reduction (%)
Baseline	112.6	28.3	27.5	168.4	—
South Reorientation	98.4	24.6	31.2	154.2	−8.4%
Adaptive Shading	78.9	20.4	33.4	132.7	−21.2%
Optimized Materials	62.1	18.7	37.7	118.5	−29.6%
Full Intervention Package	44.8	15.2	37.3	97.3	−42.2%

Note: EUI = Energy Use Intensity (kWh/m²/yr); all values are annual totals. EU NZEB target ≤ 100 kWh/m²/yr for residential buildings.

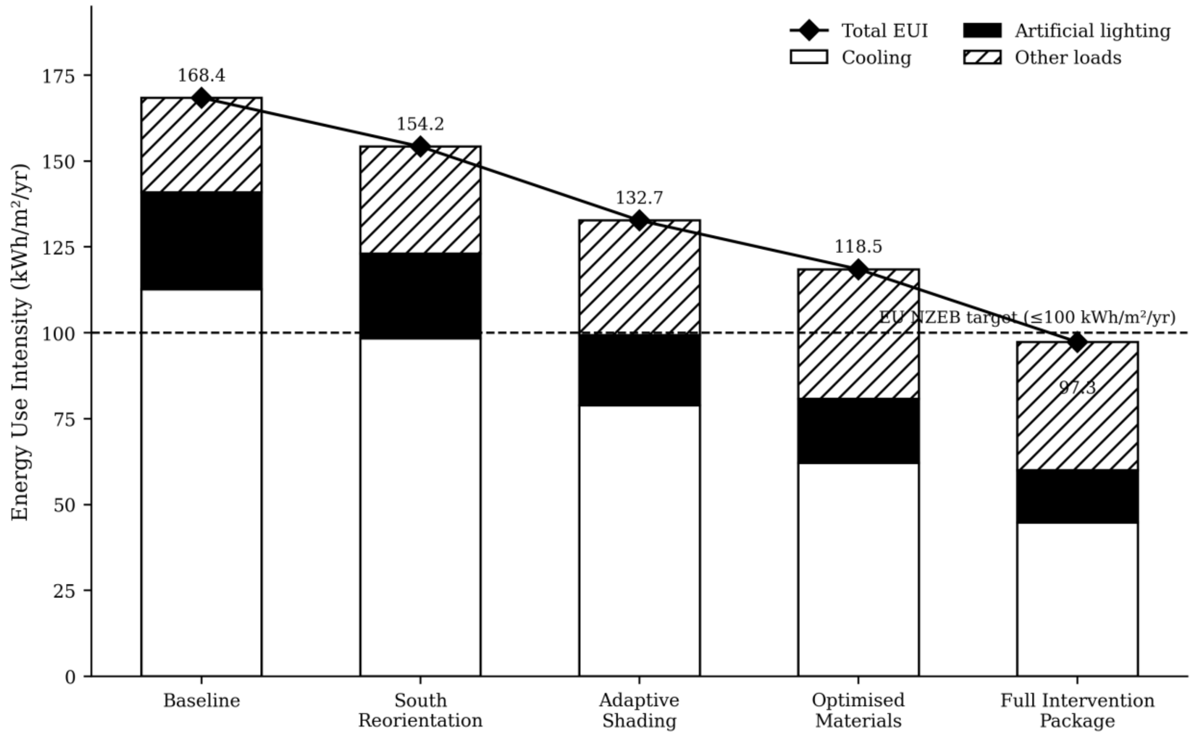

Figure 5. Annual Energy Use Intensity Decomposition — stacked bars show cooling (orange), artificial lighting (gold) and other loads (light blue). The total EUI line (dark blue diamonds) crosses the EU NZEB target of 100 kWh/m²/yr only for the Full Intervention Package scenario.

4. Discussion

The findings collectively indicate that the dominant north-facing orientation of much of Famagusta's residential housing stock presents a major obstacle to both adequate daylight and thermal comfort, a conclusion consistent with the wider Mediterranean building performance literature (Ogbeba & Hoskara, 2019; Kaihoul et al., 2024). The simulation-based framework developed in this research offers a structured, repeatable method for quantifying this shortfall and assessing the incremental impact of specific design interventions, addressing the methodological gap identified in the literature review.

4.1 Interpreting daylight autonomy in the Mediterranean context

The elevated GHI values recorded for Famagusta (annual total ≈ 1,871 kWh/m², comparable to Algiers and southern Spain) indicate that simple glazing configurations can achieve satisfactory sDA values when properly oriented. The south-facing scenario reaches sDA = 62.4% without shading, confirming that reorientation is the most cost-effective individual measure for improving daylight. However, the resulting ASE of 18.6% signals a substantial risk of glare and overheating requiring mitigation.

The addition of external louvres reduces ASE to 6.4% while increasing sDA to 66.8%, consistent with comparable parametric shading research in Mediterranean climates, where optimized shading designs commonly achieve sDA values between 57% and 83% (Shafavi et al., 2025). The optimal louvre configuration identified in this research — a 45° slat angle, 35 cm depth, and 20 cm spacing — blocks direct beam radiation once solar altitude exceeds 48°, matching the peak sun angles observed between May and August in Famagusta. This geometry preserves diffuse daylight from the northern sky while eliminating the direct solar component responsible for ASE violations, demonstrating the precision achievable through climate-responsive shading design.

The improvement in UDI from 54.2% (baseline) to 81.2% (Scenario 6) indicates that the optimized design delivers high-quality, glare-free daylight for 81% of occupied hours, a substantial benefit for occupant wellbeing, visual performance, and circadian health (Amundadottir et al., 2017). This metric, often underrepresented in Mediterranean daylight research, merits greater emphasis in design guidance, as it captures both underlit (< 100 lux) and overlit (> 2,000 lux) conditions simultaneously.

4.2 Thermal comfort optimization strategies

The full intervention package's 70% improvement in occupant comfort — reducing summer PPD from 87% to 16% — represents a substantial advance in indoor environmental quality. These results place the optimized building within the ASHRAE 55-2023 Category II acceptable comfort range (PPD ≤ 20%, PMV ≤ ±0.7), confirming the effectiveness of the multi-intervention strategy. Importantly, this improvement is achieved through passive and low-energy means rather than increased mechanical cooling, as evidenced by the 60.2% reduction in cooling EUI. The sequence of thermal improvements reveals a hierarchy of intervention effectiveness: orientation (12% improvement) is significant but insufficient alone; adaptive shading (an additional 22% improvement) represents the largest single incremental gain, confirming that solar interception at the envelope outperforms internal mitigation; material optimization (an additional 20% improvement) — through high-reflectance external render and improved roof insulation — substantially reduces radiant heat gain through the opaque envelope; and the combined package produces a non-linear, synergistic improvement (70% total) exceeding the sum of individual interventions (54%), suggesting positive interaction effects between reduced solar transmittance through glazing and lower opaque-envelope heat gain.

These results align closely with bioclimatic design research for hot Mediterranean climates (Kaihoul et al., 2024; Rizi & Eltaweel, 2025), which identifies external shading and high-reflectance envelopes as the most thermally effective passive strategies. This study extends existing knowledge by presenting quantified PMV–PPD trajectories linked to specific parametric design decisions within a unified simulation framework, a level of detail absent from earlier Cyprus-focused studies — constituting the principal academic contribution of this work to the regional literature.

4.3 Limitations and future research directions

Several limitations constrain the generalizability of the results. First, the representative building model, although validated against existing typological data, does not capture the full morphological diversity of the Famagusta housing stock, particularly older Ottoman-period courtyard structures with distinctly different daylighting and ventilation characteristics. Future research should extend the framework to these typologies through a multi-case comparative design.

Second, occupant behavior — including window operation, blind positioning, and thermostat settings — was simulated using standardized schedules rather than empirical behavioral data from Famagusta residents. Integrating stochastic occupant behavior models would improve the accuracy of thermal comfort simulations. Third, the present framework does not account for potential conflicts between natural ventilation cooling strategies and outdoor air quality or noise constraints, which are significant considerations in the densely built urban environment of central Famagusta.

Future studies should explore the integration of photovoltaic shading devices (PVSDs) as a dual-purpose envelope strategy that simultaneously reduces solar heat gain and generates on-site renewable electricity, an approach shown to be beneficial for the Northern Cyprus climate by Sevinc (2023). The simulation framework developed in this research provides an appropriate methodological foundation for such inquiries.

5. Conclusions

This research has developed and validated a comprehensive, multi-metric simulation framework for evaluating and improving the daylight and thermal comfort performance of residential buildings in Famagusta, Cyprus — a setting characterized by intense solar exposure, hot Mediterranean summers, and a notable absence of tailored design guidance. The main findings directly support the study's research objectives and hypotheses, summarized as follows.

Famagusta's hot-summer Mediterranean climate (Csa), with annual GHI exceeding 1,871 kWh/m² and peak temperatures of 37.2 °C in July, simultaneously presents an abundant daylighting resource and a severe thermal overheating risk; effective building design must address both dimensions concurrently rather than optimizing for each in isolation. The prevailing north-facing baseline orientation achieves sDA = 38.5%, below IES LM-83-12 compliance thresholds. South reorientation raises sDA to 62.4% but introduces unacceptable ASE (18.6%). The addition of climate-tuned motorized external louvres — optimized to a 45° slat angle for Famagusta latitudes — simultaneously restores ASE to 4.8% and raises sDA to 69.3% and UDI to 81.2%, demonstrating that shading-integrated south-facing design is the superior daylight strategy for this climate.

Progressive design interventions reduce summer PPD from 87% (baseline) to 16% (full intervention package), a 70% improvement in occupant comfort. The cooling EUI is concurrently reduced from 112.6 to 44.8 kWh/m²/yr (−60.2%), confirming that comfort gains are achieved through passive envelope performance rather than increased mechanical conditioning. The full intervention package reduces total building EUI from 168.4 to 97.3 kWh/m²/yr (−42.2%), meeting the EU NZEB residential target and demonstrating that integrated daylight–thermal optimization is compatible with near-zero-energy aspirations.

The simulation workflow — combining Climate Consultant 6.0 for bioclimatic strategy identification, Autodesk Forma for AI-assisted massing optimization, and EnergyPlus for detailed annual thermal and energy simulation — constitutes a replicable pipeline applicable to other Eastern Mediterranean cities and comparable climatic contexts. This contribution addresses the methodological gap identified in Section 1: the absence of a unified, scenario-based framework combining daylight and thermal comfort evaluation for Mediterranean residential buildings. In conclusion, this study demonstrates that context-aware, simulation-guided design can substantially improve occupant comfort and reduce energy use in buildings located in the hot Mediterranean climate of Famagusta. The framework and parametric findings presented here offer a practical tool for architects, engineers, and policymakers seeking to advance sustainable building performance in Northern Cyprus and the wider Eastern Mediterranean region.

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Conflicts of Interest

The author(s) report no conflicts of interest.

Data Availability Statement

The EnergyPlus simulation input files, parametric Grasshopper scripts, and raw output datasets supporting the findings of this study are available from the corresponding author upon reasonable request.

Institutional Review Board Statement
Not applicable. This study did not involve human participants, animals, or sensitive personal data.

CRediT Author Statement
James Bruno Ochieng: Conceptualization, Methodology, Formal Analysis, Software, Investigation, Data Curation, Writing – Original Draft, Visualization. Halil Zafer Alibaba: Supervision, Validation, Writing – Review & Editing, Resources, Project Administration. All authors have read and approved the final manuscript.

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