The International Journal of Engineering and Information Technology (IJEIT)
ijeit.misuratau.edu.ly
Misurata University

Design Simulation Tool for Building Performance and Efficiency: The African Satellite Control Centre Case Study, Gharyan, Libya

Hatem A. Hadia[1,*], hahadia@elmergib.edu.ly
Department of Architecture, Faculty of Engineering, Elmergib University, Libya
*Corresponding author

Article History

Received 23 May, 2026
Revised 19 June, 2026
Accepted 20 June, 2026
Online 24 June, 2026

DOI: https://doi.org/10.36602/ijeit.v14i2.640

Index Terms

Building Performance Simulation, EnergyPlus, DesignBuilder, Climate Consultant, Energy Efficiency.

Abstract

Libya's built environment accounts for roughly 60% of national power demand, making the construction sector the largest contributor to CO_2 emissions and a persistent obstacle to energy security. Decades of unregulated development, an overstretched transmission network, and the absence of enforceable building energy standards have produced routine daily power cuts. Applying Building Performance Simulation (BPS) at the design stage represents a cost-efficient corrective lever. This study investigates the energy performance of the African Satellite Control Centre (ASCC) in Gharyan, Libya, a specialized public technical facility with high internal load density comparable to data centers, which consume 10 to 50 times the energy per unit area of conventional offices. A three-stage simulation sequence in DesignBuilder V7.1 with EnergyPlus addresses peak winter heating, peak summer cooling, and complete annual energy and carbon accounting. The 2,083.68 m² facility consumes 198,769.34 kWh annually (95.37 kWh/m²). Operational cooling is the dominant end-use at 78,472.74 kWh annually. Operational CO_2 emissions reach 120.45×10^3 kg per year; embodied carbon totals 489,558.50 $kgCO_2$ (549,212.20 $kgCO_2eq$). Against ASHRAE Standard 55-2004, 7,813.5 hours fall outside acceptable thermal comfort bounds. The East facade presents concentrated vulnerability with a 50.91% window-to-wall ratio. The paper's contribution is a fully documented, reproducible workflow integrating four analyses energy, thermal comfort, daylighting, and CFD for a high-load-density technical facility, a combination not previously reported for Libya or North Africa, offering a transferable decision-support framework for comparable facilities where simulation practice remains limited.

أداة محاكاة التصميم لتحسين أداء وكفاءة المباني: دراسة حالة مركز التحكم بالأقمار الصناعية الأفريقي، غريان، ليبيا

حاتم أحمد هدية
جامعة المرقب، كلية الهندسة، العمارة والتخطيط العمراني، الخمس، ليبيا، hahadia@elmergib.edu.ly
* المؤلف المراسل

الكلمات المفتاحية

محاكاة أداء المباني، EnergyPlus، DesignBuilder, Climate, Consultant، كفاءة الطاقة للمباني

الملخص

يستهلك قطاع البناء في ليبيا ما يقارب 60% من الطلب الوطني على الطاقة، مما يجعله المساهم الأكبر في انبعاثات ثاني أكسيد الكربون وعائقًا مستمرًا أمام أمن الطاقة. تشمل المشكلات الهيكلية عقودًا من التوسع العمراني غير المنظم، وشبكة نقل الطاقة المنهكة، وغياب معايير طاقة فعّالة للمباني. مما أفرز انقطاعات يومية في التيار الكهربائي. ويُعدّ استخدام محاكاة أداء المباني (BPS) في مرحلة التصميم أداةً فعّالة لرفع الكفاءة وخفض الهدر. تدرس هذه الورقة أداء الطاقة في مركز التحكم بالأقمار الصناعية الأفريقي (ASCC) في غريان، ليبيا، منشأة تقنية عامة متخصصة ذات كثافة أحمال داخلية عالية تُشبه مراكز البيانات، حيث تستهلك من 10 إلى 50 ضعف الطاقة لكل وحدة مساحة مقارنةً بالمكاتب التقليدية. تستخدم الدراسة تسلسل محاكاة من ثلاث مراحل في برنامج DesignBuilder V7.1 مع EnergyPlus: ذروة التدفئة الشتوية، وذروة التبريد الصيفية، وحساب كامل للطاقة والكربون سنويًا. يستهلك المبنى ذو المساحة 2083.68 م^2 الموزعة على ثلاثة طوابق 198,769.34 كيلوواط ساعة سنويًا (95.37 كيلوواط ساعة/م^2). يهيمن التبريد على الاستهلاك بمقدار 78,472.74 كيلوواط ساعة. وتصل انبعاثات ثاني أكسيد الكربون التشغيلية إلى 120.45×10^3 كيلوغرام/سنة والكربون المتضمن إلى 489558.50 كيلوغرام CO_2 (ما يعادل 549212.20 كيلوغرام CO_2eq). ووفقًا لمعيار ASHRAE 55-2004، فإن 7813.5 ساعة تتجاوز حدود الراحة الحرارية المقبولة. وتُظهر الواجهة الشرقية ضعفًا بنسبة نوافذ إلى جدران تبلغ 50.91%. تكمن مساهمة هذه الورقة في منهجية عمل موثقة وقابلة للتكرار تُدمج أربعة تحليلات للطاقة والراحة الحرارية والإضاءة الطبيعية وديناميكيات الموائع لمنشأة تقنية ذات أحمال داخلية عالية، وهو مزيج لم يُوثَّق سابقًا في ليبيا أو شمال إفريقيا، بما يوفر إطار دعم قرار قابلاً للتطبيق على منشآت مماثلة.

I. Aims and Objectives of the Study

At its broadest, this research seeks to demonstrate how a disciplined building performance simulation framework can be deployed to examine and improve the energy behavior of a complex technical facility in a climatically challenging location. Gharyan, Libya, provides both the geographic setting and the impetus: a climate that demands significant mechanical intervention for much of the year, and a local design culture that has historically underutilized quantitative performance tools. By grounding the investigation in a real, built case study, rather than a theoretical model, the work aims to speak directly to practitioners and policymakers confronting similar conditions elsewhere in the region.

More specifically, the study pursues the following objectives:

- Evaluate Simulation Platform Fidelity: Assess the capability of DesignBuilder V7.1 and EnergyPlus to simulate high internal load densities and thermal complexities within specialized technical facilities.
- Establish Microclimatic Boundary Conditions: Develop a comprehensive climate profile for the Gharyan region using Climate Consultant 6.0 to define the external thermal, solar, and aerodynamic loads acting on the building envelope.
- Quantify Peak Demands and Energy/Carbon Intensity: Determine mechanical heating and cooling capacities under peak design scenarios, while normalizing annual end-use energy consumption and estimating both operational and embodied carbon emissions against international sustainability benchmarks.
- Assess Daylighting Performance and Envelope Thermal Behavior: Map indoor daylight distribution via Radiance-based simulations to evaluate compliance with LEED EQ 8.1 criteria, and analyze how building geometry and the glazed East elevation influence overall heat balance.
- Resolve Indoor Aerodynamics and Thermal Stratification: Execute multi-planar Computational Fluid Dynamics (CFD) simulations to analyze internal airflow distribution and spatial temperature variations across the facility.

I. Introduction

Few aspects of Libya's built environment are as consequential, or as underexamined, as its energy performance. National electricity statistics gathered by the General Electric Company of Libya consistently show that buildings are responsible for approximately 60% of total electricity consumption, a proportion that stands well above the IEA's global average of around 40% [1]. The gap between supply and demand has widened steadily as rapid, largely unregulated urban expansion has outpaced both grid capacity and any meaningful regulatory framework for energy performance [2]. The result is a built stock that, for the most part, lacks adequate thermal insulation, solar control, or any evidence of performance-informed design.

Rolling power cuts, sometimes lasting the better part of a day during the summer peak, have become routine. Against this background, the adoption of Building Performance Simulation (BPS) in the design process represents one of the most practical interventions available. These tools now allow designers to test and compare building strategies in silico before construction begins, offering a form of evidence that was simply unavailable to earlier generations of practitioners [3, 4]. The value of this capability is amplified in extreme climates, where design missteps produce not merely aesthetic failures but measurable, long-term energy consequences.

Gharyan occupies a particularly demanding climatic position: a high-altitude inland plateau approximately 70 to 80 kilometers south of Tripoli, where summer dry-bulb temperatures have been recorded at 48°C and winter nights can bring temperatures close to freezing, occasionally accompanied by snow [5, 6]. Few locations in the region impose such a demanding thermal program on a building in both directions. These challenges intensify further when the building in question is a technical facility rather than a conventional office or residential structure. Satellite control centers share operational characteristics with data centers, a building type documented to consume between 10 and 50 times the energy of ordinary office space per square meter [7]. Equipment cooling alone can represent more than 40% of a facility's total energy draw [8]. Wherever that mechanical burden is allowed to develop in the absence of a coherent passive design strategy, the consequences for the national grid are disproportionate and the carbon cost is substantial [9].

This paper presents the results of a comprehensive simulation of the African Satellite Control Centre (ASCC) in Gharyan, conducted using DesignBuilder and the EnergyPlus calculation engine. A preliminary climate analysis using Climate Consultant 6.0 informed the passive design strategy assessment, after which three successive simulation stages (heating design, cooling design, and full annual performance) were used to generate an integrated picture of the building's energy, carbon, comfort, daylighting, and airflow behavior. Taken together, the outputs support a clear conclusion: rigorous pre-design simulation, even for a building of this scale and complexity, is both achievable and capable of informing significantly better outcomes. The contribution of this work is accordingly methodological rather than algorithmic: it establishes a fully documented, reproducible tripartite simulation workflow through which energy, thermal comfort, daylighting, and indoor airflow are assessed jointly for a high-internal-load technical facility of a type not previously analyzed in the Libyan or wider North African literature. In doing so, the study offers a transferable decision-support framework that designers, engineers, and policymakers can apply to comparable public and technical buildings across the region.

II. Literature Review

A. The Evolution of Building Performance Simulation

Computational thermal modelling began in earnest during the 1960s, driven initially by the aerospace and nuclear industries, and was progressively adapted to architectural applications over the following decades. What distinguishes contemporary BPS from those early efforts is the integration of multiple physical domains (thermal, optical, airflow, and electrical) within a single modelling environment capable of resolving interactions across the full 8,760-hour annual cycle. This multi-domain capability is what makes BPS genuinely useful as a decision-support tool rather than merely a post-design audit instrument [4, 9].

Among the available simulation engines, EnergyPlus has achieved something close to canonical status in academic research. Built on the accumulated expertise of six decades of U.S. Department of Energy work, the engine applies a detailed Heat Balance methodology to every surface and zone in the model, accounting simultaneously for conductive, convective, and radiative exchanges at each time step [10]. The limitation that practitioners most frequently cite is not computational accuracy but ease of use: EnergyPlus works through an input file interface that presupposes a relatively high level of technical fluency. DesignBuilder was designed specifically to remove this barrier, providing a parametric 3D geometric modeler that feeds directly into the EnergyPlus kernel while retaining the full range of simulation outputs. The combination has become one of the most widely used platforms in both academic and professional BPS work [11].

B. Energy Efficiency in Technical and Data Center Facilities

Technical buildings occupy a distinct position in the energy performance literature. Unlike offices or dwellings, their loads are dominated by equipment (servers, communications hardware, control systems) rather than by occupant behavior or solar exposure. The Power Usage Effectiveness (PUE) ratio, which expresses total facility energy relative to IT equipment energy, remains the industry's preferred summary metric; current industry-wide averages hover around 1.58, though exemplary facilities have demonstrated values approaching 1.2 [12]. Bridging that gap typically requires a combination of hot/cold aisle containment to manage internal airflows, carefully matched central plant to avoid part-load inefficiencies, and the exploitation of ambient free-cooling wherever the outdoor climate permits. Each of these strategies depends on building configuration decisions that ideally should be settled at the design stage rather than retrofitted [13].

C. Passive Design in Mediterranean and North African Contexts

The architecture of the Mediterranean basin and the North African interior have always had to grapple with climatic extremes. Recent research quantifying the potential of contemporary passive strategies in these contexts is, if anything, more optimistic than early work suggested. Rigorous envelope upgrades; combining high thermal mass, enhanced insulation, and solar control glazing, have been shown to reduce combined heating and cooling demand by as much as 87% in Mediterranean climates [14, 15]. Even targeted shading interventions alone, without envelope modifications, have yielded cooling load reductions of 17 to 40% in hot arid settings [16, 17]. The European Union's policy ambition for near-zero-energy buildings has helped to accelerate this research, though its direct uptake in Libya has been minimal [18].

Within Libya itself, the vernacular architectural tradition offers an instructive counterpoint to the energy-intensive modern stock. Gharyan's troglodyte dwellings partially or fully subterranean chambers cut into the plateau rock, exploited the thermal mass of the surrounding earth to maintain relatively stable interior temperatures across the diurnal and seasonal cycles, with lower humidity than the above-ground built fabric that replaced them [19]. Contemporary construction in the city has largely abandoned these principles, defaulting to lightweight concrete frames, minimal insulation, and large unshaded windows. Studies examining this shift quantitatively have found that correcting for orientation and adding insulation to such buildings can improve thermal performance by up to 60%, a figure that underlines how much has been lost in the transition [20].

D. Daylighting Standards and Occupant Well-being

Natural daylighting is increasingly treated not as a passive amenity but as a quantifiable contributor to both energy performance and occupant health. Reduced reliance on artificial lighting lowers electrical loads directly; the secondary effects on productivity, circadian regulation, and general well-being are also reasonably well documented, even if the causation is more difficult to isolate [21]. The LEED Credit EQ 8.1 framework operationalizes these concerns by requiring that computer simulation demonstrate illuminance levels between 300 and 3,000 lux across at least 75% of regularly occupied floor area under a standard overcast sky condition. Achieving this in hot climates is not straightforward. The same facade apertures that admit useful daylight also introduce direct solar radiation that raises cooling loads and risks glare; managing the trade-off typically demands dynamic shading elements such as external louvers, light shelves, or electrochromic glazing [22, 23].

Taken together, this body of work establishes what is known about BPS tools, technical-building loads, passive design potential, and daylighting standards individually, but leaves a specific gap unaddressed. Existing Libyan and North African studies have applied simulation or field assessment to conventional residential, office, or vernacular typologies rather than to high-internal-load technical facilities [19, 20, 26, 27], while the data-center and technical-facility literature that documents PUE-driven design strategies has developed almost entirely around temperate, developed-economy contexts [7, 12, 13]. No published study has yet combined dynamic energy simulation, thermal comfort, Radiance-based daylighting, and CFD airflow analysis for a high-load-density technical facility situated in a Libyan, or comparably hot and high-altitude North African, climate. The present study addresses that gap directly, using the ASCC as the vehicle through which this combined framework, and the design lessons it yields, can be documented and made available to practitioners working on similar facilities in the region.

III. Study Area: Gharyan, Libya

A. Geographic and Topographic Context

Gharyan sits near the spine of the Jebel Nafusa, the mountain range that curves across northwestern Libya roughly parallel to the Mediterranean coast. Its geographic coordinates place it at 32°10′N, 13°01′E, approximately 100 km south of Tripoli, at elevations that range between 700 and 900 m above sea level [24]. The altitude matters climatically, compared with the coastal belt, temperatures at this elevation run cooler in summer and considerably colder in winter, with far more pronounced diurnal swings. For a facility like the ASCC, the elevated plateau also provides the unobstructed sky-view and electromagnetic separation from urban infrastructure that satellite operations require.

B. Climatic Profile

Under the Köppen-Geiger classification, Gharyan sits in a zone of transition between Semi-Arid (BSh) and Mediterranean (Csa) conditions. What this means in practice is that the building has to be capable of managing both a hot, dry summer and a winter that, while relatively short, is cold enough to generate meaningful heating demand. The climatic analysis prepared using Climate Consultant 6.0, covering all 8,760 hours of the year in accordance with the ASHRAE Handbook of Fundamentals, reveals four characteristics that most directly shape building energy performance [25]:

- **Thermal range:** Peak summer dry-bulb temperatures reach 48°C. Winter temperatures at this altitude can drop to 1°C, and snowfall, while infrequent, has been recorded.
- **Diurnal swing:** Temperature differences between day and night regularly reach 20°C. This supports night-flush ventilation strategies to exploit cool nocturnal air.
- **Solar radiation:** Global horizontal irradiance is high year-round, making solar gain a major threat to cooling performance in summer, particularly through east- and south-facing glazing.
- **Wind:** The dominant airflow is from the north, supporting natural ventilation. The Ghibli, a hot, sand-laden desert wind from the south, arrives periodically, elevating infiltration rates [5, 26, 27].

Table 1 summarizes the monthly temperature extremes that define the outer limits of the thermal design problem for this site.

TABLE 1. CLIMATOLOGICAL EXTREMES FOR THE GHARYAN, LIBYA REGION (AUTHOR VIA DESIGN-BUILDER SIMULATION TOOL)

Month	Record High (°C)	Record Low (°C)	Climate Feature
January	32	8.9 (Avg Low)	Wet/Mild Winter [6]
May	43	—	Rising Heat [6]
June	48	—	Peak Solar Load [6]
July	33 (Avg High)	22 (Avg Low)	High Summer [6]
August	48	—	Extreme Heat [6]
December	31	1	Potential Snowfall [6]

Figure 1 translates these climatic data into spatial form, showing the annual solar path and seasonal wind roses overlaid on the plateau site plan. The diagram makes clear why the South and East facades carry the greatest solar exposure, and why northerly summer breezes offer a meaningful passive cooling resource.

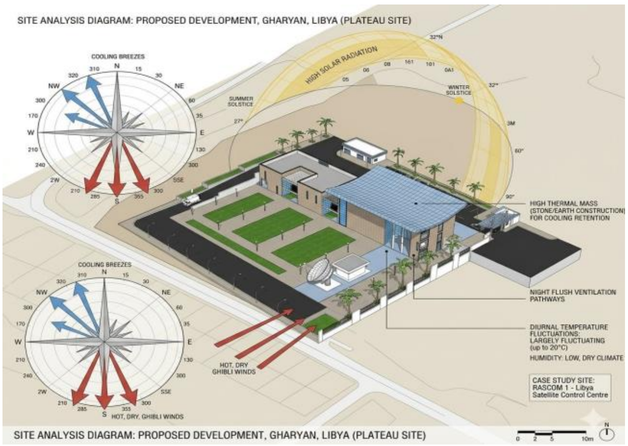


Figure 1. Site analysis diagram for the proposed development, Gharyan, Libya (Plateau Site), illustrating solar path, seasonal wind roses, passive design strategies, and thermal mass principles. (source: author via Gemini ai pro with nano banana ai simulation)

IV. Materials of the Study

A. Building Documentation and Zonal Configuration

The simulation draws on architectural and engineering documentation obtained from the consultant company (Günay Construction) and the supervising team for the African satellite control center project in Gharyan, Libya. The building covers a gross floor area of 2,083.68 m² across three levels, of which 1,558.65 m² is mechanically conditioned and 525.03 m² is unconditioned. Functionally, the facility encompasses offices, an operator’s room, maintenance workshops, corridors, and support spaces [28, 29]. Table 2 sets out the zone-by-zone breakdown of areas, volumes, conditioning status, and artificial lighting densities for all three floors.

TABLE 2. BUILDING ZONE SUMMARY AND FUNCTIONAL DISTRIBUTION

Zone Block	Area (m²)	Volume (m³)	Conditioned	Lighting (W/m²)
GROUND LEVEL				
Operators Room	176.28	731.55	No	6.80
Corridor	302.25	1,254.32	Yes	3.40
Office 6	359.78	1,493.11	Yes	17.00
Maintenance 3	53.99	224.06	Yes	5.10
WC 04	50.34	208.91	Yes	6.80
FIRST FLOOR				
Corridor	297.74	1,205.86	Yes	3.40
Office 03	163.46	662.01	Yes	17.00
Bedroom	36.48	147.73	Yes	2.72
Electric Room	109.21	442.28	No	3.40
SECOND FLOOR				
Corridor	34.41	139.36	Yes	3.40
Office	66.91	270.97	Yes	17.00

B. Envelope and Fenestration Specifications

Total gross wall area across the building amounts to 2,028.80 m². Of this, 566.73 m² consists of glazed openings, giving an overall window-to-wall ratio (WWR) of 27.93%. The East elevation carries a WWR of 50.91%, by some margin the most exposed facade in the building, subject to intense direct solar radiation during the morning hours. The directional breakdown is set out in Table 3.

TABLE 3. BUILDING ENVELOPE AND FENESTRATION SUMMARY BY ORIENTATION

Orientation	Gross Wall Area (m²)	Window Area (m²)	WWR (%)
North (315–45°)	644.25	58.03	9.01%
East (45–135°)	344.89	175.58	50.91%
South (135–225°)	679.53	202.92	29.86%
West (225–315°)	360.14	130.20	36.15%
TOTAL	**2,028.80**	**566.73**	**27.93%**

C. Equipment and Internal Load Parameters

Simulation zones were assigned Plug and Process loads consistent with high-intensity communications and computing equipment, reaching 15 W/m² in the main office and maintenance areas. These loads generate continuous sensible heat gains that the mechanical cooling system must manage throughout the year. The zone-by-zone load parameters are presented in Table 4.

TABLE 4. INTERNAL LOAD PARAMETERS PER REPRESENTATIVE ZONE

Zone	Plug & Process (W/m²)	Occupancy Density (m²/person)
Operators Room	3.00	9.09
Office 6	15.00	9.09
Maintenance 3	15.00	5.88
Entrance	2.00	5.71
Mech. Room 01	0.00	10.39

D. Climate Data and Simulation Weather File

All dynamic thermal calculations use an EnergyPlus Weather (EPW) file compiled for the Nafusa Mountains region of Libya [29]. Before the formal simulation sequence began, the data were processed through Climate Consultant 6.0 to extract graphical representations of the climate.

E. Construction Costs and Economic Context

The DesignBuilder cost estimation module places the total construction cost of the ASCC at USD 5,122,451.82. Superstructure construction is the largest single cost category, at USD 2,268,676.96 (44.29% of the total), reflecting the reinforced floor slabs, partitions, and finishes required for a facility of this type. Among the building services, HVAC plant is the largest line item at USD 1,298,947.55, roughly 25.36% of the total construction cost, a figure that reflects the scale of the mechanical challenge [11, 30]. Table 5 gives the full cost breakdown.

TABLE 5. ESTIMATED CONSTRUCTION COST BREAKDOWN FOR ASCC, GHARYAN, LIBYA

Cost Category	Floor Area (m²)	Cost (USD)
Structure Costs	2,084.2	681,947.46
Sub-Structure Costs	1,015.1	173,979.56
Super-Structure Costs	7,656.5	2,268,676.96
HVAC Systems	2,084.2	1,298,947.55
Lighting Systems	2,084.2	324,736.89
Glazing	595.4	167,718.19
Surface Finishes	—	206,445.22
TOTAL BUILDING COST	**—**	**5,122,451.82**

VI. Methodology of the Study

A. Overall Simulation Framework

DesignBuilder V7.1 serves as the modelling environment, with EnergyPlus providing the computational engine beneath it. Climate Consultant 6.0 was used to analyze the weather file and establish bioclimatic strategies.

B. Tripartite Simulation Sequence

The simulation sequence was divided into three stages: Stage 1 established steady-state peak winter heating capacity requirement (176.72 kW across the facility); Stage 2 determined peak summer cooling capacity (223.26 kW facility total); Stage 3 executed a full 8,760-hour dynamic annual run tracking disaggregated end-uses and operational carbon outputs.

C. Daylighting Simulation

Daylighting metrics were evaluated using the Radiance-based calculation engine. Daylight Factor (DF) and Spatial Daylight Autonomy (sDA) were quantified across regularly occupied zones against the LEED EQ 8.1 baseline.

D. Computational Fluid Dynamics (CFD) Analysis

CFD simulations resolved air velocity fields (0.00 to 0.47 m/s) and internal temperature fields (13.92 to 18.97°C) across three orthogonal section planes.

E. Thermal Comfort and Environmental Evaluation Standards

Thermal comfort was modeled using the ASHRAE Standard 55-2004 Simple Comfort Model. Embodied carbon calculations used the Bath ICE database embedded within DesignBuilder.

VII. Discussion of the Results

A. Annual Energy Consumption and Environmental Performance

Total site energy consumption evaluated to 198,769.34 kWh, giving a normalized intensity of 95.37 kWh/m². Source energy totals reached 431,389.10 kWh (206.98 kWh/m²), which aligns closely with Mediterranean public infrastructure benchmarks. The headline figures are summarized in Table 6.

TABLE 6. ANNUAL BUILDING UTILITY PERFORMANCE SUMMARY (SOURCE: ENERGYPLUS, 2012)

Metric	Total Energy (kWh)	Intensity (kWh/m²)
Total Site Energy	198,769.34	95.37
Total Source Energy	431,389.10	206.98

The end-use breakdown, presented in Table 7, reveals the extent to which cooling dominates the facility's energy budget. District cooling accounts for 78,472.74 kWh (39.48% of total site energy) reflecting both the severity of Gharyan's summer conditions and the continuous heat generated by the building's communications equipment. Interior equipment loads contribute a further 23,601.31 kWh of direct electricity demand, while interior lighting adds 27,989.25 kWh. District heating for the winter period totals 41,935.06 kWh, a smaller but non-trivial share that underlines the dual-season character of the thermal challenge.

TABLE 7. ANNUAL ENERGY CONSUMPTION BY END-USE CATEGORY

End-Use Category	Electricity Component (kWh)	Percentage Allocation (%)
Cooling (Electricity)	78,472.74	39.48%
Heating (Electricity)	41,935.06	21.10%
Interior Lighting	27,989.25	14.08%
Room Electricity (Equipment)	23,601.31	11.87%
Auxiliary Energy	26,332.83	13.25%
Domestic Hot Water (DHW)	438.15	0.22%
TOTAL	**198,769.34**	**100.00%**

Figure 2 places these patterns in a temporal context, plotting daily energy consumption and indoor temperatures against the external dry-bulb temperature across the full year. The bimodal structure is clear: a winter heating peak from December through February, driven primarily by fabric heat loss and ventilation loads, and a protracted summer cooling peak from May through September with a sharp maximum in July. The bottom panel further shows that mechanical ventilation air-change rates increase substantially during the occupied hours of the warmer months.

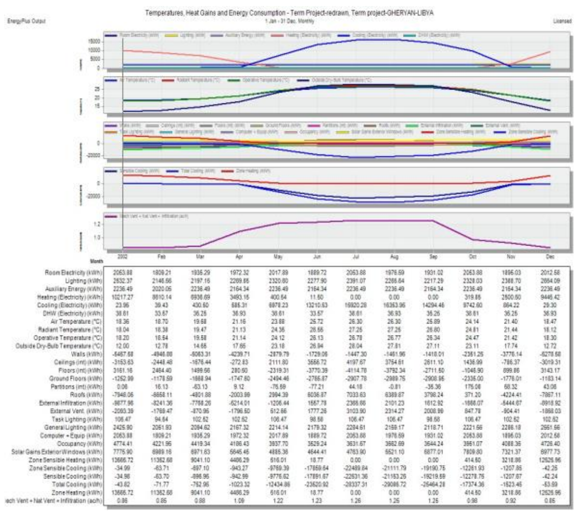


Figure 2. Annual temperatures, heat gains, and energy consumption profile for the ASCC, Gharyan, Libya (1 Jan – 31 Dec, Daily). Source: EnergyPlus (2012).

B. Heating Design Simulation Results

Under peak winter conditions (external dry-bulb 4.60°C), fabric and ventilation thermal paths account for significant losses: ventilation at −49.65 kW, roof assembly at −34.93 kW, and infiltration at −27.39 kW (Fig. 3). Total design heating capacity requirements reached 176.72 kW. Fig. 4 gives the full zone-by-zone breakdown.

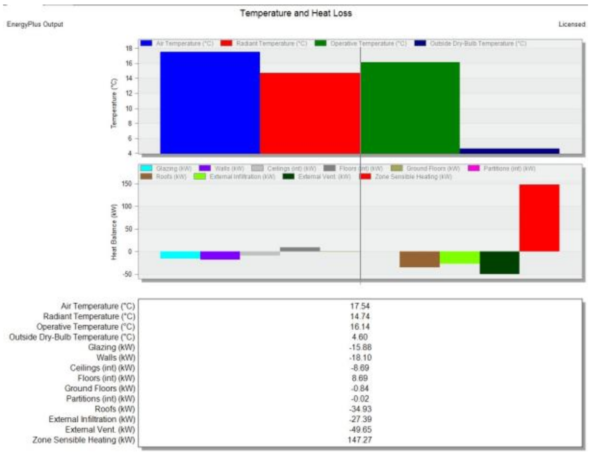
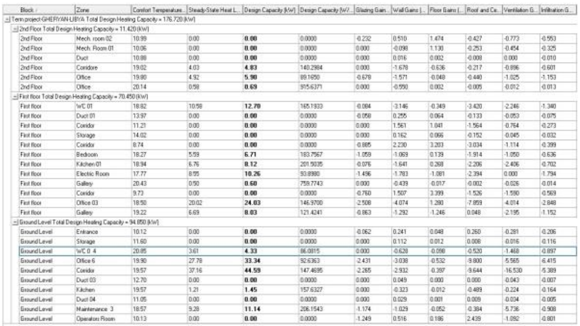


Figure 3. Heating design simulation: temperature and heat loss breakdown for the ASCC facility, Gharyan, Libya.



Block	Zone	Comfort Temperature...	Steady-State Heat L...	Design Capacity (kW)	Design Capacity (W/...	Glazing Gain...	Wall Gains (...	Floor Gains (...	Roof and Ce...	Ventilation G...	Infiltration G...
Term project-GHERYAN-LIBYA Total Design Heating Capacity = 176.720 (kW)											
2nd Floor Total Design Heating Capacity = 11.420 (kW)											
2nd Floor	Mech. room 02	10.99	0.00	**0.00**	0.0000	-0.232	0.510	1.474	-0.427	-0.773	-0.553
2nd Floor	Mech. Room 01	10.06	0.00	**0.00**	0.0000	0.000	-0.098	1.130	-0.253	-0.454	-0.325
2nd Floor	Duct	10.88	0.00	**0.00**	0.0000	0.000	0.016	0.002	-0.008	0.000	-0.010
2nd Floor	Coridore	19.02	4.03	**4.83**	140.2984	0.000	-1.678	-0.636	-0.217	-0.896	-0.601
2nd Floor	Office	19.80	4.92	**5.90**	89.1650	-0.678	-1.571	-0.048	-0.440	-1.025	-1.153
2nd Floor	Office	20.14	0.58	**0.69**	915.6371	0.000	-0.550	0.002	-0.005	-0.012	-0.013
First floor Total Design Heating Capacity = 70.450 (kW)											
First floor	WC 01	18.82	10.58	**12.70**	165.1933	-0.084	-3.146	-0.349	-3.420	-2.246	-1.340
First floor	Duct 01	13.97	0.00	**0.00**	0.0000	-0.058	0.255	0.064	-0.133	-0.053	-0.075
First floor	Coridor	11.21	0.00	**0.00**	0.0000	0.000	1.561	1.041	-1.564	-0.764	-0.273
First floor	Storage	14.02	0.00	**0.00**	0.0000	0.000	0.162	0.066	-0.152	-0.045	-0.032
First floor	Coridor	8.74	0.00	**0.00**	0.0000	-0.885	2.230	3.203	-3.034	-1.114	-0.399
First floor	Bedroom	18.27	5.59	**6.71**	183.7567	-1.059	-1.069	0.139	-1.914	-1.050	-0.636
First floor	Kitchen 01	18.94	6.76	**8.12**	201.5035	-0.076	-1.641	0.268	-2.206	-2.406	-0.702
First floor	Electric Room	17.77	8.55	**10.26**	93.8980	-1.496	-1.783	-1.081	-2.394	0.000	-1.794
First floor	Galley	20.43	0.50	**0.60**	759.7743	0.000	-0.439	-0.017	-0.002	-0.026	-0.014
First floor	Coridor	9.73	0.00	**0.00**	0.0000	-0.760	1.507	3.399	-1.526	-1.590	-0.569
First floor	Office 03	18.50	20.02	**24.03**	146.9700	-2.508	-4.074	1.280	-7.859	-4.014	-2.848
First floor	Galley	19.22	6.69	**8.03**	121.4241	-0.863	-1.292	-1.246	0.048	-2.195	-1.152
Ground Level Total Design Heating Capacity = 94.850 (kW)											
Ground Level	Entrance	10.12	0.00	**0.00**	0.0000	-0.062	0.241	0.048	0.260	-0.281	-0.206
Ground Level	Storage	11.60	0.00	**0.00**	0.0000	0.000	0.112	0.012	0.008	-0.016	-0.116
Ground Level	WC 0 4	20.85	3.61	**4.33**	86.0815	0.000	-0.628	-0.098	-0.520	-1.468	-0.897
Ground Level	Office 6	19.90	27.78	**33.34**	92.6363	-2.431	-3.038	-0.532	-9.800	-5.565	-6.415
Ground Level	Coridor	19.57	37.16	**44.59**	147.4695	-2.265	-2.932	-0.397	-9.644	-16.530	-5.389
Ground Level	Duct 03	12.70	0.00	**0.00**	0.0000	0.000	0.049	0.000	0.000	-0.043	-0.007
Ground Level	Kitchen	19.57	1.21	**1.45**	157.6327	0.000	-0.323	-0.012	-0.489	-0.224	-0.164
Ground Level	Duct 04	11.05	0.00	**0.00**	0.0000	0.000	0.029	0.001	0.009	-0.034	-0.005
Ground Level	Maintenance 3	18.57	9.28	**11.14**	206.1543	-1.174	-1.029	-0.052	-0.384	-5.736	-0.908
Ground Level	Operators Room	10.13	0.00	**0.00**	0.0000	-1.249	0.516	0.186	2.439	-1.092	-0.801

Figure 4. Heating design simulation summary report: zone-by-zone design heating capacities for the ASCC, Gharyan, Libya.

C. Cooling Design Simulation Results

Peak sensible load reached 159.42 kW, and total cooling design capacity required was 223.26 kW. Peak cooling stress occurs during mid-afternoon in July when intense solar radiation through East glazing matches high equipment internal gains. Without cooling, the main Operators Room climbs to an operative peak of 35.5°C. The sub-hourly heat gain profile for 15 July is shown in Fig 5 and Fig 6 presents the full zone-by-zone cooling capacity data.

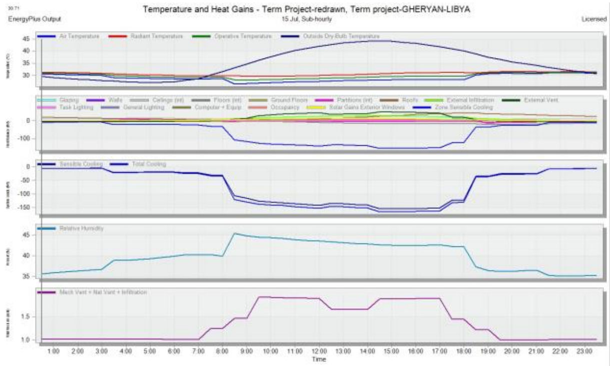
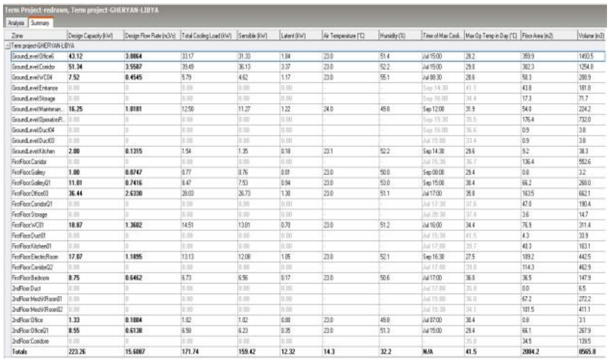


Figure 5. Cooling design simulation: temperature and heat gains profile for the ASCC, 15 July (Sub-hourly). (source: author via DesignBuilder V7.1 simulation tool)



Term Project-redrawn, Term project-GHERYAN-LIBYA

Analysis | Summary

Zone	Design Capacity (kW)	Design Flow Rate (m3/s)	Total Cooling Load (kW)	Sensible (kW)	Latent (kW)	Air Temperature (°C)	Humidity (%)	Time of Max Cool...	Max Op Temp in Day (°C)	Floor Area (m2)	Volume (m3)
Term project-GHERYAN-LIBYA											
GroundLevelOffice6	**43.12**	**3.0864**	33.17	31.33	1.84	23.0	51.4	Jul 15:00	28.2	359.9	1493.5
GroundLevelCoridor	**51.34**	**3.5587**	39.49	36.13	3.37	23.0	52.2	Jul 15:00	29.0	382.3	1254.8
GroundLevelWC04	**7.52**	**0.4545**	5.79	4.62	1.17	23.0	55.1	Jul 08:30	28.6	58.3	208.9
GroundLevelEntrance	0.00	0	0.00	0.00	0.00	-	-	Sep 14:30	41.1	43.8	181.8
GroundLevelStorage	0.00	0	0.00	0.00	0.00	-	-	Sep 16:00	34.4	17.3	71.7
GroundLevelMaintenan...	**16.25**	**1.0181**	12.50	11.27	1.22	24.0	49.8	Sep 12:00	31.9	54.0	224.2
GroundLevelOperatorsR...	0.00	0	0.00	0.00	0.00	-	-	Sep 15:30	35.5	176.4	732.0
GroundLevelDuct04	0.00	0	0.00	0.00	0.00	-	-	Sep 16:00	36.6	0.9	3.8
GroundLevelDuct03	0.00	0	0.00	0.00	0.00	-	-	Jul 15:00	33.4	0.9	3.8
GroundLevelKitchen	**2.00**	**0.1315**	1.54	1.35	0.18	23.1	52.2	Sep 14:30	29.6	9.2	38.3
FirstFloorCoridor	0.00	0	0.00	0.00	0.00	-	-	Jul 15:30	36.7	136.4	552.6
FirstFloorGalley	**1.00**	**0.0747**	0.77	0.76	0.01	23.0	50.0	Sep 08:00	29.4	0.8	3.2
FirstFloorGalley01	**11.01**	**0.7416**	8.47	7.53	0.94	23.0	53.0	Sep 15:00	30.4	66.2	268.0
FirstFloorOffice03	**36.44**	**2.6330**	28.03	26.73	1.30	23.0	51.1	Jul 17:00	35.8	163.5	662.1
FirstFloorCoridor01	0.00	0	0.00	0.00	0.00	-	-	Jul 17:30	37.6	47.0	190.4
FirstFloorStorage	0.00	0	0.00	0.00	0.00	-	-	Jul 20:30	37.4	3.6	14.7
FirstFloorWC01	**18.07**	**1.3602**	14.51	13.81	0.70	23.0	51.2	Jul 16:00	34.4	76.9	311.4
FirstFloorDuct01	0.00	0	0.00	0.00	0.00	-	-	Jul 15:30	41.5	4.3	30.9
FirstFloorKitchen01	0.00	0	0.00	0.00	0.00	-	-	Jul 17:00	33.7	40.3	163.1
FirstFloorElectricRoom	**17.07**	**1.1895**	13.13	12.08	1.05	23.0	52.1	Sep 16:30	27.5	109.2	442.5
FirstFloorCoridor02	0.00	0	0.00	0.00	0.00	-	-	Jul 17:00	39.0	114.3	462.9
FirstFloorBedroom	**8.75**	**0.6462**	6.73	6.56	0.17	23.0	50.6	Jul 17:00	36.0	36.5	147.9
2ndFloorDuct	0.00	0	0.00	0.00	0.00	-	-	Jul 17:00	35.0	0.0	6.5
2ndFloorMechXRoom01	0.00	0	0.00	0.00	0.00	-	-	Jul 15:00	36.0	67.2	272.2
2ndFloorMechXRoom02	0.00	0	0.00	0.00	0.00	-	-	Jul 15:30	34.1	101.5	411.1
2ndFloorOffice	**1.33**	**0.1004**	1.02	1.02	0.00	23.0	49.8	Jul 07:00	30.4	0.8	3.1
2ndFloorOffice01	**8.55**	**0.6138**	6.58	6.23	0.35	23.0	51.3	Jul 15:00	29.4	66.1	267.9
2ndFloorCoridore	0.00	0	0.00	0.00	0.00	-	-		35.0	34.5	139.5
Totals	223.26	15.6087	171.74	159.42	12.32	14.3	32.2	N/A	41.5	2084.2	8565.8

Figure 6. Cooling design simulation summary report: zone-by-zone cooling capacities and temperatures for the ASCC, Gharyan, Libya. (source: author via DesignBuilder V7.1 simulation tool)

D. Thermal Comfort Analysis

The thermal comfort results indicate a substantial performance shortfall. Assessed against the ASHRAE Standard 55-2004 Simple Comfort Model (ASHRAE, 2005), a total of 7,813.5 hours of the year, representing 89.2% of all annual hours, fall outside the acceptable comfort envelope. The principal explanation lies in the significant unconditioned or under-conditioned floor area, where passive performance is insufficient to bridge the gap between external conditions and human comfort thresholds. Within the zones that are mechanically conditioned, the results are better but still imperfect: 133.00 occupied hours fail to meet the heating setpoint and 210.50 fail to meet the cooling setpoint, pointing to seasonal capacity constraints or scheduling gaps in the mechanical systems. These metrics are consolidated in Table 8.

TABLE 8. THERMAL COMFORT AND SETPOINT PERFORMANCE SUMMARY.

Metric	Facility Hours
Time Setpoint Not Met — Occupied Heating	133.00
Time Setpoint Not Met — Occupied Cooling	210.50
Time Not Comfortable (ASHRAE 55-2004)	7,813.50

E. Carbon Footprint and Environmental Impact

Libya's electricity grid carries a relatively high carbon intensity, and this is reflected in the facility's operational emissions. Annual CO_2 production from electricity and district energy use reaches 120.45×10^3 kg, derived from a total fuel consumption equivalent of 198.77 MWh. When the analysis is extended to include the embodied carbon locked into the building's construction materials, the cumulative environmental cost grows considerably: 489,558.50 $kgCO_2$ of direct embodied carbon and 549,212.20 $kgCO_2eq$ when expressed in CO_2-equivalent terms to capture the global warming potential of other greenhouse gases. The dominant material contributor is Foam Slag insulation at 268,384.8 $kgCO_2$, followed by Cast Concrete (Dense) at 54,662.5 $kgCO_2$. These figures illustrate that embodied-carbon decisions, among the most difficult to reverse once construction begins, are also those most frequently made without quantitative guidance in the Libyan context. Table 9 summarizes the full environmental performance picture.

TABLE 9. ANNUAL CARBON AND ENVIRONMENTAL PERFORMANCE SUMMARY.

Parameter	Annual Value
Total Fuel Consumption (Electricity)	198.77 MWh
Total CO_2 Production (Operational)	120.45×10^3 kg CO_2
Embodied Carbon (Building Materials)	489,558.50 $kgCO_2$
Equivalent CO_2 (Building Materials)	549,212.20 $kgCO_2eq$

F. Daylighting Performance Analysis

The Radiance-based daylighting simulation reveals a strongly polarized distribution of natural light across the ground floor plan. Perimeter zones, particularly those adjacent to the East façade, record Daylight Factor values approaching the simulation maximum of 43.79%, corresponding to approximately 4,380 lux under the reference overcast sky. Beyond roughly five meters from the facade, however, DF values drop sharply toward zero. The Central Corridor, the Operators Room, and much of the deep-plan office area receive so little natural light as to be effectively dependent on artificial illumination throughout the day.

The Spatial Daylight Autonomy analysis tells a more nuanced finding. Office 13 and the Operators Room both show sDA values approaching 100% in their perimeter zones, suggesting comfortable daylighting conditions for much of the year in these locations. The Central Corridor and Office 8, by contrast, exhibit the blue-to-green gradients that indicate only marginal compliance or outright failure to meet the 300 lux / 50% annual occupancy threshold at depth. The critical qualification here is that the strong sDA performance near the East facade is achieved at a cost, the same glazing area that delivers daylight autonomy also admits the largest solar gain in the building, particularly in the morning hours. Resolving this tension, capturing daylight while controlling heat, is one of the central design challenges that external shading or high-performance glazing would need to address (USGBC, 2009; Green Exam Academy, 2008). The sDA distribution across the floor plan is shown in Fig 7, while the corresponding DF and illuminance (lux) distributions appear in Fig 8.

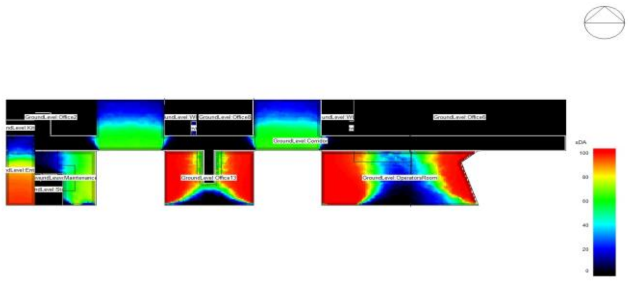


Figure 7. Annual daylighting simulation: Spatial Daylight Autonomy (sDA) distribution across ground floor zones of the ASCC.

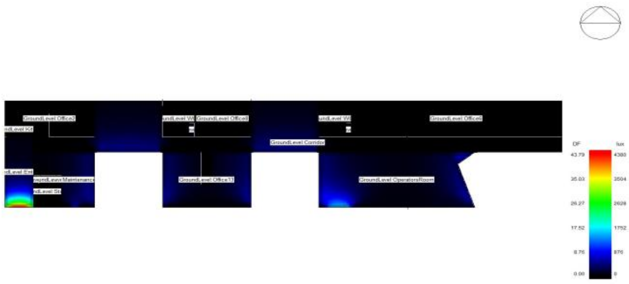


Figure 8. Annual daylighting simulation: Daylight Factor (DF) and illuminance (lux) distribution across ground floor zones of the ASCC.

G. Computational Fluid Dynamics (CFD) Analysis

Three orthogonal section planes were used to reconstruct the three-dimensional behavior of indoor air under mechanical ventilation conditions, as illustrated in Figures 9 through 11. The longitudinal across-X section (Fig 9) shows air velocities in the occupied zone predominantly falling between 0.17 and 0.25 m/s the yellow-orange band in the color scale; which is consistent with moderate forced convection from supply registers positioned along the ceiling. Corresponding temperatures in this zone range from 15.76 to 18.51°C, confirming that mechanical conditioning is reaching the central core of the building. The localized blue patches of near-zero velocity visible between supply register positions suggest dead zones where air mixing is incomplete; these areas are worth addressing in detailed HVAC design.

Figure 9. CFD analysis across X-axis (longitudinal section): internal air velocity and temperature distribution, ASCC.

The transverse across-X-Y section (Fig 10) reveals a more troubling picture, pronounced vertical thermal stratification, with the upper zone reaching 18.51 to 18.97°C while the occupied floor zone maintains 15.30 to 16.67°C. The 3.97 m floor-to-ceiling height of the primary occupancy zone is evident in this section. The stratification itself is a natural consequence of buoyancy, warm air rising to the ceiling, and is not unusual in mechanically ventilated spaces, but it does represent a reservoir of heat that may complicate night-flush cooling strategies.

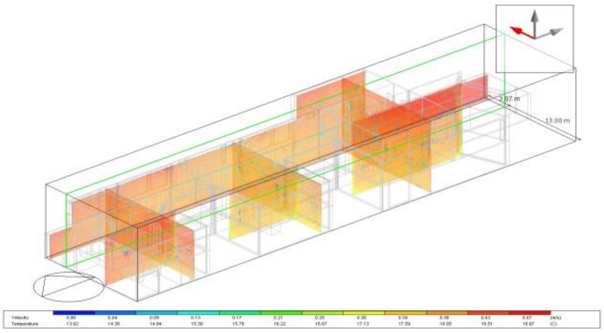


Figure 10. CFD analysis across X-Y plane (transverse section, 13.88 m width): internal air velocity and temperature stratification, ASCC.

The horizontal across-Z section at 11.97 m elevation (Fig 11) captures conditions at roof level and confirms that the roof assembly is carrying the highest temperatures in the model, uniformly 18.05 to 18.97°C across its full extent. This is consistent with the heating design results that identified the roof as the source of −33.27 kW of fabric heat loss in winter, and by implication a comparable source of summer heat gain. Air velocities at this elevation are low (0.13 to 0.21 m/s), suggesting that airflow near the ceiling is governed primarily by thermal buoyancy rather than the mechanical supply system

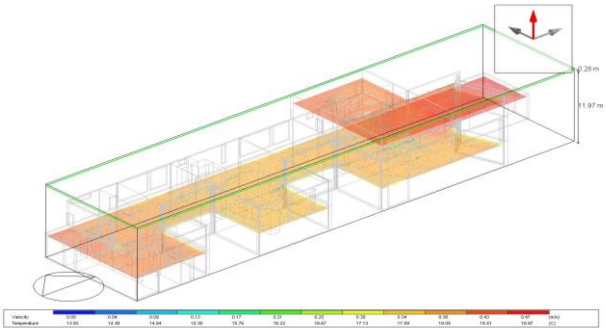


Figure 11. CFD analysis across Z-axis (horizontal section at 11.97 m elevation): roof-level thermal conditions and air velocity distribution, ASCC.

H. Implications for the Libyan Building Sector

The ASCC reflects broader regional trends: building cooling loads consume up to 60% of national power infrastructure output, yet mandatory envelope performance thresholds do not exist [1, 2]. The scale of the envelope-driven cooling load documented here is consistent with, though more moderate than, the reductions reported for comprehensive Mediterranean envelope retrofits (up to 87% of combined heating and cooling demand) [14, 15] and for shading-only interventions in hot-arid settings (17 to 40% of cooling load) [16, 17], and it falls within the range reported for orientation and insulation corrections to conventional Libyan buildings (up to 60% improvement) [20]. That cooling still dominates 39.48% of the ASCC's site energy despite these documented gains elsewhere suggests that passive strategies calibrated for ordinary residential and office occupancies are unlikely, on their own, to be sufficient for high-internal-load technical buildings; equipment-driven internal gains constrain how far envelope measures alone can reduce mechanical demand.

For practice and policy in Libya and comparable North African settings, three implications follow. First, the absence of enforceable envelope performance standards [2, 26] leaves designers of technical and public buildings without a regulatory floor comparable to the U-value or glazing limits underpinning the Mediterranean and EU results cited above; codifying region-specific thresholds informed by simulation studies such as this one would give that floor practical effect. Second, because the ASCC's cooling load concentrates on the East and South facades, orientation-based glazing and shading requirements are likely to deliver a larger return per unit of regulatory or capital effort than uniform, orientation-blind envelope rules. Third, sequencing matters: investing in envelope and shading measures before sizing the HVAC plant allows the mechanical system to be sized to a well-shaded, well-insulated envelope, avoiding the outsized capital and operating costs of a plant sized to compensate for a poorly performing envelope after construction.

VIII. Conclusion

The evidence assembled through this simulation study makes a clear case that the ASCC in Gharyan is a technically sound building facing a preventable performance crisis. The facility consumes 198,769.34 kWh of site energy annually (95.37 kWh/m²), equivalent to 431,389.10 kWh of source energy (206.98 kWh/m²), and is responsible for 120.45 metric tons of CO_2 annually, figures directly traceable to design decisions that simulation could have improved before construction began. What the tripartite simulation sequence adds, beyond these headline numbers, is a structured disaggregation of where, when, and why the performance shortfalls occur.

The Heating Design Simulation establishes that the highland climate imposes a genuine winter demand of 176.72 kW, a figure that is frequently underestimated in North African practice. The Cooling Design Simulation ties the peak summer load of 223.26 kW directly to the solar exposure of the East and South facades, with peak demand concentrated in the July afternoon window. The Full Annual Simulation then shows that cooling represents 39.48% of all site energy consumed across the year, making envelope and shading decisions (not mechanical system efficiency) the most productive area for improvement.

Beyond these facility-specific findings, the study's principal contribution is methodological: it demonstrates a reproducible workflow for integrating dynamic energy simulation, thermal comfort assessment, daylighting analysis, and CFD airflow resolution within a single investigation of a high-internal-load technical building, a combination not previously documented for the Libyan or wider North African context. Applied here to the ASCC, the same workflow constitutes a transferable decision-support framework for designers, engineers, and policymakers addressing similar public and technical facilities across the region, and it provides a concrete evidentiary basis for the orientation- and typology-specific design standards that Libya currently lacks.

These conclusions should be read within the study's scope. The analysis rests on a single case study and on simulated rather than field-monitored performance data, so the specific magnitudes reported here, while internally consistent, should be validated against metered energy use and on-site comfort surveys before being generalized to other facilities. The recommendations that follow outline how this framework can be extended, through regional code development, material-specific field testing, and empirical comfort studies, to build the broader evidence base such validation would require.

IX. Recommendation For Further Studies

- Developing Regional Building Codes: Using simulation results to establish U-values tailored to each climatic region in Libya (coastal, mountainous, and desert).
- Expanding Bio-Insulation: Conducting field simulation experiments with local materials to measure their stability and calibrate them as standard insulators.
- Net Zero Energy Buildings (nZEB): A feasibility study to convert public administrative buildings in Libya into energy-generating facilities by integrating photovoltaic systems into their facades.
- Adaptive Comfort Study: Conducting field research to compare digital PMV results with employees' actual comfort perceptions in different regions to develop local comfort models.

Acknowledgment

I would like to extend my sincere thanks to all my colleagues in the field who generously provided invaluable information to support the completion of this study and contributed to creating a conducive environment for interactive research. I also want to express my deep appreciation to my former supervisor Prof. Dr. Soofia Tahira Elias Ozkan for her unwavering support and for facilitating communication with other researchers in the field to stay abreast of the latest studies related to this topic. It is impossible to list all those who have lent me a helping hand, but I want to say that without their support, this work would not have been possible. Thank you all.

References

[1] General Electric Company of Libya, "Energy consumption statistics," GECOL, n.d.
[2] International Energy Agency, "Clean energy transitions in North Africa," IEA Publications, 2020.
[3] Y. Han, J. E. Taylor, and A. L. Pisello, "A critical review on building performance simulation tools: A focus on energy, thermal comfort, daylight and natural ventilation," Applied Sciences, vol. 8, no. 12, p. 2392, 2018.
[4] S. Attia, L. Beltrán, A. De Herde, and J. Hensen, "Architect friendly: A comparison of ten different building performance simulation tools," in Proc. 11th Int. IBPSA Conf., Glasgow, Scotland, 2009.
[5] World Meteorological Organization, "Weather information for Tripoli, Libya," WMO Climate Data Publications, 2011.
[6] H. M. M. Bakoosh, H. Arslangazi, and B. Asilsoy, "Comparison of temperature and humidity among traditional underground and modern house in Gharyan, Libya," Int. J. Adv. Appl. Sci., vol. 8, no. 3, pp. 1–11, 2021.
[7] U.S. Department of Energy, "Data centers and servers: Energy-intensive building types," DOE Building Technologies Office, 2025.
[8] Siemens Simcenter, "Top tips for energy-efficient data center design," Siemens Technical Publications, 2025.
[9] A. Ndiaye and N. Gabriel, "State of the art of residential building energy retrofits in Libya," Energy and Buildings, 2025.
[10] M. Royapoor, "EnergyPlus as the authoritative research tool: Validation and review," ResearchGate Technical Reports, 2015.
[11] DesignBuilder Software Ltd., "DesignBuilder V6 technical specifications: Heat balance method and EnergyPlus integration," DesignBuilder Documentation, 2024.
[12] Airsys North America, "Data center energy efficiency: PUE and CUE metrics," Airsys Technical Publications, 2025.
[13] Keentel Engineering, "Best practices in energy-efficient data center design," Keentel Engineering Technical Papers, 2025.
[14] L. M. López-Ochoa, J. Las-Heras-Casas, L. M. López-González, and P. Olasolo-Alonso, "Towards nearly zero-energy buildings in Mediterranean climates: A review," Sustainability, vol. 15, no. 8, 2023.

[15] A. Al-Habaibeh, M. Al-Amoudi, M. Arif, and A. Aizat, "Digital twins and model calibration in DesignBuilder for Libyan housing," Buildings, vol. 14, no. 2, 2024.
[16] AIP Conference Proceedings, "Passive cooling strategies in hot semi-arid climates," AIP Publishing, 2022.
[17] MDPI, "Primary energy consumption and shading systems in window elements," MDPI Energies, 2025.
[18] European Union, "Directive 2009/28/EC on the promotion of the use of energy from renewable sources," Official Journal of the European Union, 2009.
[19] N. M. S. Gabril, M. Wilson, and C. Gleeson, "Thermal comfort in Libya: Field study," University of Westminster, 2012.
[20] N. Aboud, "Analysis on thermal performance for increasing energy efficiency: A case study for Tripoli-Libya, using Ecotect®," Solar Energy and Sustainable Development Journal, vol. 10, no. 1, pp. 20–33, 2021.
[21] Kingspan, "Daylighting in LEED and BREEAM standards," Kingspan Daylight Technical Guide, 2025.
[22] U.S. Green Building Council, "LEED NC 2.2 reference guide: Indoor environmental quality credit EQ 8.1 — Daylighting and views," USGBC, 2009.
[23] Green Exam Academy, "LEED NC 2.2 indoor environmental quality credit 8.1: Daylighting and views," Green Exam Academy Publications, 2008.
[24] A. M. El-Tantawi, "Climate change in Libya and desertification of Jefara Plain: Using geographical information systems and remote sensing techniques," Johannes Gutenberg-Universität Mainz, 2005.
[25] American Society of Heating, Refrigerating and Air-Conditioning Engineers, "ASHRAE Handbook of Fundamentals," ASHRAE, 2005.
[26] M. Ekhlat, R. Hokoma, and D. Kreama, "The current and desired state of building regulation and energy efficiency in Libya," in Proc. 2nd PALENC Conf., Crete, Greece, 2007.
[27] M. S. Saleh, "Libyan traditional architecture: The Ghibli wind and vernacular adaptation strategies," International Journal of Architectural Heritage, 2006.
[28] Middle East Technical University, "Term Project: Final simulation report data, African Satellite Control Centre – Gharyan, Libya," METU Department of Architecture, Unpublished simulation report, 2012.
[29] EnergyPlus, "Annual building utility performance summary: Entire facility [Simulation output report]," U.S. Department of Energy, Lawrence Berkeley National Laboratory, 2012.
[30] DesignBuilder Software Ltd., "DesignBuilder V6 technical specifications," DesignBuilder Documentation, 2026.

BIOGRAPHIES

Assist. Prof. Dr. Hatem Hadia was born in Benghazi / Libya. He received BSc degree in Architecture and Urban planning from University of Benghazi, in 1998-99. He also received his MSc degree in Architecture from iku-Istanbul Kultur University /Turkey in 2005. Moreover, he received PhD degree in Architecture & Building Science from the Middle East Technical University-METU/Turkey in 2015. He is currently Assistant Professor in Department of Architecture, Faculty of Engineering, Elmergib University, Libya. His research field is building performance simulation and design efficiency in architecture.