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Evaluation of thermal comfort in mixed-mode office buildings in hot and semi-arid climates: a case study from Burkina Faso

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ABSTRACT

The assessment of thermal comfort in mixed-mode office buildings located in hot dry climates remains insufficiently explored, particularly in West African contexts such as Burkina Faso, where no local comfort standards currently exist. This study aims to address thermal comfort conditions in office buildings in the warm semi-arid climate of Ouagadougou, by combining field measurements of indoor environmental parameters with thermal comfort surveys conducted across eight mixed-mode office buildings. The field protocol included simultaneous monitoring of indoor and outdoor conditions, along with more than 1,100 thermal comfort votes collected through structured questionnaires during hot, cold, and rainy seasons. The results indicate that occupants' thermal sensation and preference differ significantly between Natural Ventilation (NV) and Air-Conditioned (AC) operation modes. Neutral temperatures, estimated using the Griffiths method, ranged between 26.0 °C and 30.3 °C, while preferred temperatures ranged between 26.8 °C and 30.2 °C. A strong adaptive behavior was observed among occupants, particularly under NV mode, where comfort persisted at higher operative temperatures. Compared to international standards, the adaptive models of ASHRAE 55 (80 % acceptability limits) and EN 16798-1 (Category III) were found to be applicable under NV conditions but underestimated comfort limits during AC operation with an average exceedance from 0.5 °C to 0.7 °C, particularly during the peak hot season. These findings suggest the need for a context-specific adjustment of comfort temperature ranges in mixed-mode buildings within hot and dry climates. However, further studies are necessary to validate these results and support the development of regionally appropriate standards.

1. Introduction

Buildings are more than mere shelters; they are integral to ensuring safety, comfort, productivity, and socio-economic representation [1,2]. The sector has become one of the largest energy consumers worldwide, accounting for approximately 30–40 % of total final energy use and contributing to 26 % of global energy-related emissions [3]. In many developing countries, including those in sub-Saharan Africa, the rapid growth of urbanization, population, and economic activities has increased the demand for indoor environmental quality and thermal comfort in office and institutional buildings. According to ASHRAE Standard 55, thermal comfort is defined as "*that condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation*" [4]. However, achieving acceptable comfort in hot and semi-arid climates remains a challenge, as conventional air-conditioning (AC) systems require considerable electricity, leading to high operational costs and unsustainable energy demand [5,6]. In the context of Burkina Faso, cooling alone accounts for nearly 40 % of the total domestic electricity use [7] while in public buildings, it rises to 60–65 % of the total electricity use [6]. To maintain an indoor temperature of 25 °C in public buildings, projections indicate that annual energy consumption for cooling may need to increase by approximately 56 % between 2030 and 2049 and by up to 99 % between 2060 and 2079 compared to current levels [6].

At the same time, the global discourse on sustainable building design

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Nomenclature

Parameters	Definition
T_a	Air Temperature (°C)
T_g	Black Globe Temperature (°C)
T_{op}	Operative Temperature (°C)
Clo	Clothing Insulation
SD	Standard Deviation
RH	Relative humidity (%)
V_a	Air Velocity (m/s)
T_{mrt}	Mean Radiant Temperature (°C)
TSV	Thermal Sensation Vote
TPV	Thermal Preference Vote
T_n	Neutral Temperature (°C)
CS	Cold Season
RS	Rainy Season
HS	Hot Season
T_{pref}	Preferred Temperature (°C)
AC	Air-Conditioned
NV	Naturally Ventilated
MM	Mixed-Mode
Tpma(out)	Prevailing Mean Outdoor Air Temperature

has shifted toward low-energy, climate-responsive strategies that can provide comfortable indoor environments while minimizing energy consumption. Among these, mixed-mode (MM) ventilation systems, also called hybrid ventilation buildings, have attracted growing attention from researchers, designers, and policymakers [8–10]. These systems integrate both natural ventilation (NV) and mechanical cooling (AC), allowing buildings to dynamically switch between modes according to outdoor climate conditions and indoor comfort requirements. MM buildings have the potential to save 40 % HVAC energy by optimizing window operation schedules, and up to 75 % by alternating natural and mechanical ventilation [11].

In tropical and semi-arid regions, where large diurnal and seasonal temperature variations occur, mixed-mode operation offers a potentially effective strategy to enhance comfort and reduce cooling loads. Yet, the adoption of this approach in West Africa remains limited, mainly due to the lack of local empirical evidence on its performance and comfort implications. The present study contributes to filling this gap by evaluating thermal comfort in MM office buildings located in Ouagadougou, Burkina Faso, characterized by a hot semi-arid climate.

1.1. Literature review of mixed-mode buildings

Mixed-mode (MM) buildings are designed to combine passive natural ventilation, through operable windows, vents, or other openings—-with active mechanical systems, such as air conditioning or mechanical ventilation, to maintain comfortable indoor conditions while reducing energy use [12]. The MM approach with thermal adaptation enables significant energy saving [13], maintained thermal comfort at higher temperatures and climate-resilient building strategies for tropical regions [5–14]. Depending on their control logic and configuration, MM buildings are generally classified into three categories [12]. The first category is the "Concurrent MM buildings", where NV and AC operate simultaneously within the same space. Although concurrent MM operation is the most prevalent strategy in the current practice [12], running NV and AC systems at the same time is not energy-efficient. The second category is the "Change-over MM buildings", where NV and AC alternate automatically or manually based on a daily or seasonal basis. Based on the level of automation for MM control, change-over MM buildings can be classified into three types: automated, semi-manual and manual [15]. Each of these the three types have distinct pros and cons. Automated control uses smart sensors and predictive algorithms to manage indoor climates efficiently, but it limits occupants' adaptive behaviors and involves high installation and maintenance costs. Manual control gives users greater autonomy over their environment, yet it can lead to energy inefficiencies due to overcooling or overheating. Semi-manual control offers a balanced approach by integrating both automated and manual elements [15]. The last category is the "Zoned MM buildings", where NV and AC are used in different areas at the same time [10–16].

The rationale behind this hybrid approach is to exploit the natural cooling potential of outdoor air whenever possible, and to rely on mechanical systems only when environmental conditions exceed comfort thresholds. Such a "hybrid philosophy" can yield energy savings of 20–45 % compared with fully air-conditioned buildings [9], similar as what is found by YuzhenPeng et al. [17]. The potential for mixed-mode design also arises from its applicability in both new construction and existing building stock [13]. There is so a need of field implementation in real-world buildings [17]. Studies across different climates have demonstrated that MM operation improves both thermal comfort and indoor air quality, while offering occupants more adaptive opportunities [12–18]. However, despite these advantages, current comfort standards (ASHRAE 55, EN 16798-1, GB/T 50785) still provide limited or inconsistent guidance for evaluating MM buildings. They typically classify buildings as either naturally ventilated or mechanically conditioned, which restricts the application of the adaptive comfort model to purely NV environments [8]. This oversimplification does not reflect the dynamic and occupant-interactive nature of MM operation, especially in regions with strong seasonal variability.

1.2. Thermal comfort in mixed-mode buildings

Thermal comfort in MM buildings is complex because occupants experience different environmental stimuli depending on the operating mode. The adaptive comfort model—recognized in ASHRAE 55 and EN 16798-1 suggests that people can tolerate a wider range of indoor temperatures when they are free to interact with their environment, for example, by opening windows, adjusting clothing, or using fans [12]. Thermal comfort standards are divided into two distinct methodologies: steady-state approaches for mechanically conditioned buildings and adaptive approaches for naturally ventilated structures. The steady-state models, outlined in ISO 7730 [19], ASHRAE 55 [4], and EN 16798-1 [20], derive from Fanger's PMV-PPD framework [21]. These are chiefly employed in fully HVAC-regulated environments to assess average thermal perception and anticipated occupant dissatisfaction in thermally neutral conditions [22]. ISO 7730 introduces a three-tier classification (A, B, C) corresponding to varying satisfaction thresholds. EN 16798-1 [20] expands this further with four well-being-based categories: Category I (high-expectation spaces for sensitive occupants), Category II (standard expectations), Category III (reduced requirements), and Category IV (seasonally limited acceptability). The adaptive methodologies, incorporated in both ASHRAE 55 and EN 16798-1, are also detailed in **Table A- 1**. For naturally ventilated scenarios, the adaptive model of ASHRAE 55 prescribes two acceptability thresholds (80 % and 90 %), correlating permissible operative temperatures with outdoor mean temperatures.

Several field studies have investigated this adaptive behavior in MM contexts. Luo et al. [8] conducted one of the earliest comprehensive MM field studies in a subtropical climate, showing that occupants' comfort perception depended strongly on the operating mode and on their adaptive opportunities. Similarly, Rupp et al. [23] and Jia et al. [16] observed that the indoor comfort range during NV periods was broader than predicted by PMV/PPD models, and that the adaptive approach provided a better representation of occupants' real experiences.

Across Sub-Saharan Africa, numerous studies have explored thermal comfort in residential and educational buildings [24–26]. However, they primarily focus on residential or classroom settings, with limited attention to mixed-mode office environments and seasonal variations

[27]. Compared with office studies in Asia and Latin America, neutral temperatures in West Africa appear 2–4 °C higher, underscoring the climatic and cultural specificity of comfort perception in this region [28,29]. In Burkina Faso, as in many other African countries, there are no national regulations designed to dictate requirements and control thermal comfort in buildings based on knowledge of the local reality. Field studies across similar climates have demonstrated that applying non-contextualized standards can lead to the misrepresentation of occupants' comfort and energy needs [1,2,30].

Thermal Comfort studies in Burkina Faso have predominantly focused on passive cooling techniques and building materials [31–33]. However, it is essential to combine physical measurements and Post Occupancy Evaluation (POE) surveys for a comprehensive assessment of thermal comfort and energy management [17,34]. Based on Thermal Sensation Vote (TSV), Ouedraogo et al. [35] developed a numerical thermal comfort model and found a comfort temperature range from 25.5 ℃ to 28.3 ℃ in residential NV buildings. There are very few studies related on MM office buildings in Burkina Faso. The only known field study, conducted by Hema et al. [29], evaluated thermal comfort in Ouagadougou. Based on thermal preference vote (TSV), they found an average indoor temperature of 27.1 °C and a neutral range from 26.2 °C to 26.5 °C. Nevertheless, they have not considered occupants' thermal preferences vote (TPV) and have done the study during only the cold season. Since it is proved that even TSV is a key metric, it is not enough alone for thermal comfort prediction [36], it is essential to take into account occupants' TPV. Also, the seasonal variations significantly impact thermal sensation and adaptation strategies, yet existing research neglects the crucial role of culturally-influenced subjective preferences in comfort assessment. Surely defining a seasonally appropriate control could improve the energy efficiency [37]. The recent literature has sufficiently highlight that MM buildings can improve indoor thermal comfort and energy savings. This operational potential makes them ideal for thermal comfort research in hot and dry climates. However, there are still key challenges such as limited number of field studies in hot and semi-arid climates [5], particularly in West Africa region. Then there is insufficient seasonal coverage in the context of Burkina Faso and under-representation of TPV, which can complement TSV to identify comfort and preferred conditions. **Table A- 2** synthesizes recent studies on thermal comfort in mixed-mode office buildings across tropical [14,37], temperate [23], and arid regions [29,38]. While most confirm the validity of adaptive comfort models under NV conditions, they also expose the limited representativeness of ASHRAE 55 and EN 16798-1 for hot-dry contexts where occupants exhibit strong behavioral adaptation [39]. These findings justify the present study's focus on developing context-appropriate comfort ranges for office occupants in Burkina Faso's semi-arid climate.

1.3. Objectives of This study

Considering the above, the present study aims to advance the understanding of thermal comfort in mixed-mode office buildings in a hot semi-arid climate, focusing on Burkina Faso as a representative case in West Africa. The main objectives are:

1. To investigate occupant thermal comfort across multiple operating modes (natural ventilation vs. mechanical cooling) and across three characteristic seasons (cold, rainy, and hot) in office buildings.
2. To evaluate and compare thermal comfort indices using both TSV and TPV, identifying potential deviations between perceived and preferred neutrality.
3. To analyze the applicability of international comfort standards (ASHRAE 55, EN 16798-1) to MM buildings in hot, semi-arid climates and discuss the need for regional calibration.

Through these objectives, this study contributes new empirical data and critical insights to the limited body of knowledge on MM operation in hot and semi-arid regions, highlighting how climatic, cultural, and behavioral factors influence comfort perception and adaptive potential.

2. Materials and methods

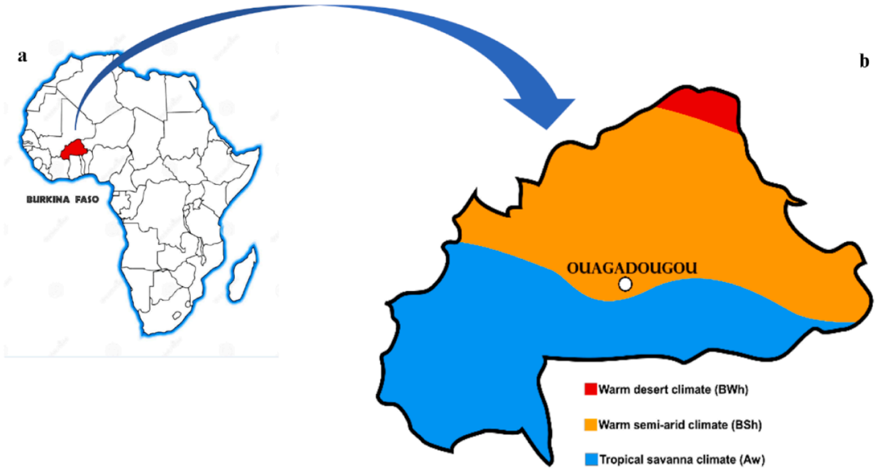
This study combined on-site physical measurements of indoor thermal parameters with occupant surveys to evaluate thermal comfort in eight office buildings located in Ouagadougou, Burkina Faso. The research design followed the methodological guidelines established by ASHRAE Standard 55 and ISO 7730, ensuring consistency and comparability with international studies on mixed-mode buildings.

2.1. Context

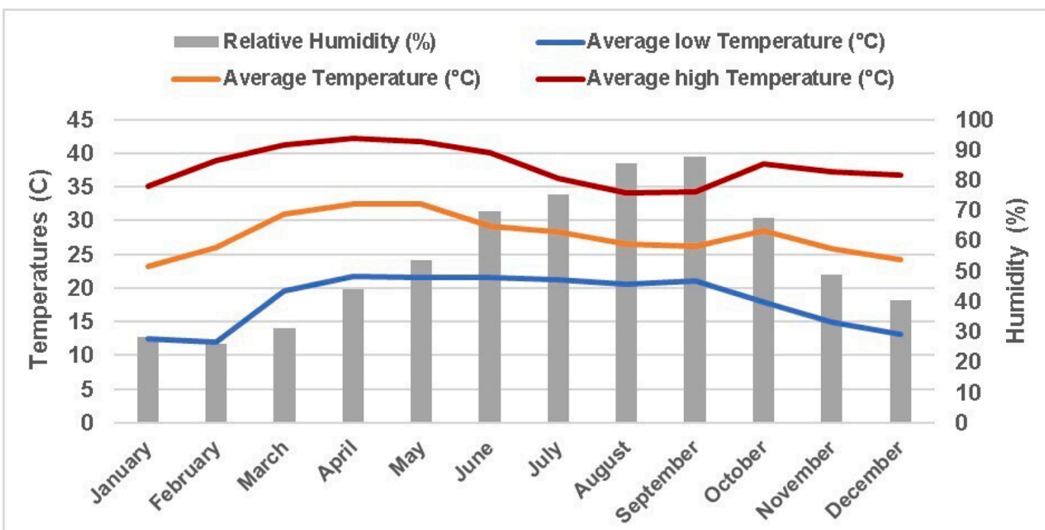
Burkina Faso, situated in West Africa (Fig. 1a), encounters diverse climatic patterns owing to its geographical location. It can be categorized into three main climatic regions: the dry Sahelian zone in the north, the semi-arid Sudano-Sahelian zone in the central area, and the Sudano-Guinean zone in the south. Ouagadougou (Coordinates: 12°22′07″N 01°31′39″W) is the country's political capital and has 2.8 million inhabitants in 2022 [40]. Consequently, it contains the highest number and most important office buildings. Ouagadougou's climate is warm semi-arid (BSh) under Köppen-Geiger classification (Fig. 1b), and closely borders on tropical hot and dry (Aw). Data from the "*Agence Nationale de la Météorologie du Burkina Faso (ANAM-BF)*" (Fig. 1c**)** shows that temperatures range from 11.9 °C during cold season to 42.2 °C during the hot one. The average temperature varies between 25——35 °C throughout the year, peaking in April-May. Relative humidity is lowest (20–30 %) in the dry November-March season and highest (70–90 %) during the rainy season (June-September period). This tropical climate is characterized by significant temperature variations between highs and lows as well as pronounced wet and dry seasons.

2.2. Field study protocol

The field study followed a standardized protocol designed to ensure representativeness, data reliability, and participant safety across all investigated office buildings. Prior to data collection, written consent was obtained from the competent authorities responsible for the buildings, and verbal consent was requested individually from each participant before the start of the survey. This ethical approach ensured transparency and participant cooperation throughout the study. On the first day of fieldwork in each building, *Waranet Solutions* sensors were installed outdoors in a shaded and ventilated location to continuously measure outdoor temperature and relative humidity throughout the survey period. For the indoor environment, two *Delta Ohm HD32.3* instruments were used to record key parameters such as air temperature, globe temperature, relative humidity, and air velocity. Before each interview session, the objective and context of the study were clearly explained to participants to ensure informed participation and guarantee the anonymity and confidentiality of responses. This procedure also encouraged participant engagement and accurate reporting of thermal perception. Two complementary questionnaires, labeled Form A and Form B (**Appendice: Survey Forms**), were used simultaneously. While occupants completed Form A, which collected data on thermal sensation, thermal preference, acceptability, and personal information (clothing, activity, etc.), the researchers team completed Form B, which documented contextual factors such as occupant behavior, window and door status, fan or air conditioner operation, and any other relevant behavioral observations. This process was repeated systematically across all accessible rooms in each building until completion. At the end of each survey period, all the instruments were retrieved. The recorded data were extracted, and instruments were reconfigured before redeployment in the next building. The same field protocol was replicated across all office buildings, ensuring comparability of results between buildings and across different climatic seasons.



a. Burkina Faso Location within Africa; **b.** Ouagadougou Location within Burkina Faso



c. Outdoor climate data for Ouagadougou [source: ANAM-BF]

Fig. 1. Geographical and Climatic Overview of Ouagadougou, Burkina Faso.

2.3. Case studies

The study involved eight mixed-mode (MM) office buildings (Fig. 2), selected based on representativeness in terms of construction materials, year of construction, and building typology, excluding spaces with functions other than work, called mixed-use constructions. An additional key criterion was the accessibility of the buildings and the availability and willingness of occupants to participate in the study. A selection of both recent and older buildings was made to ensure a representative sample of the national building stock. Each case study building is codified following capital letter from A to H (Table 1). All of them operated in change-over MM, combining natural ventilation from operable windows and mechanical cooling systems such as air-conditioner and fans. Windows are manually controlled by the users. During the fieldwork, the research team systematically recorded the operational mode (NV or AC) of each space at the time of measurement and survey. This was done through direct observation and confirmation with occupants. The mode was noted and later used in the analysis to correlate thermal sensation votes with ventilation mode. The Window-to-Wall Ratio (WWR) value is estimated for each case's glazed surface area. It can be observed that only cases A and B have more than 60 % of WWR, while the value of others cases is less than 30 %. Fieldwork was conducted between 2023 and 2024 across three seasons: Rainy Season (RS), Cold Season (CS), and Hot Season (HS). Each case study was monitored for one to four days depending on floors count and occupants' availability. Each case study was also evaluated once per season, focusing on the accessible floors in the building (Table 2).

2.4. Field measurements

The field measurements encompassed several variables such as dry-bulb temperature (T_a), globe temperature (T_g), relative humidity (RH) and air velocity (V_a). As depicted in Table 4, indoor temperature readings were obtained using Pt100 sensors of varying ranges. The measurements were carried out using a *Delta Ohm HD32.3* device (Fig. 3a), which recorded the variables once per minute. Relative humidity was gauged by employing a capacitive sensor, while air velocity was assessed utilizing a *10kOhm NTC* thermistor. Two Delta Ohm devices were used.

Fig. 2. Case studies: mixed-mode office buildings located in Ouagadougou.

Table 1
Case study information.

Code	Con. year	Fieldwork date (dd/mm/yyyy)			Floors Evaluated	WWR (%)	N. participants			N. votes
		Rainy	**Cold**	**Hot**			**Rainy**	**Cold**	**Hot**	
A	2017	12–15/06/2023	23/01/ 2024	24/04/2024	1,2,3,4 and 5	>70	46	47	48	141
B	2012	19–21/06/2023	20–21/11/2024	08/04/2024	1,2,3 and 4	>80	34	33	34	101
C	1998	27–29/06/2023	4–5/12/2024	12/4/2024	1, 2 and 3	<30	33	31	32	96
D	2010	25–27/07/2023	30–31/01/2024	2–3/05/2024	1,2,3 and 4	<30	83	87	85	255
E	1971	03–04/07/2023	08/01/2024	16/04/2024	1,2,3 and 4	<30	53	56	58	167
F	1971	06–07/07/2023	15/01/2024	17/04/2024	2,3 and 4	<30	46	45	47	138
G	1971	21–23/08/2023	11–12/01/2024	25–26/04/2024	1,2,3 and 4	<30	67	65	68	200
H	1971	17/07/2023	09/01/2024	18/04/2024	1 and 2	<30	23	22	23	68
TOTAL							**385**	**386**	**395**	**1166**

Code: Code assigned to each building; **Con. Year:** Year building was built; **WWR:** Window-to-Wall Ratio.

The first one was placed in a representative office and operated continuously during the entire survey period at 60 min step. The second device is used during working period (from 8:00 AM to 4:00 PM or to 6:00 PM depending to the building), to go from office to office to measure environmental conditions at 1 min step in real time while participants completed the questionnaire. The average completion time was approximately 10 min. Subsequently, during data processing, a mean value was calculated for each parameter over the corresponding response period. Each occupant surveyed was in proximity to a measuring device placed at a distance of approximately 1.5 m from the occupants and at 1.1 m above the floor. For outdoor Temperature and Humidity, *Waranet Solution* sensors are used at a step of 60 min. Fig. 3b shows the position of the sensor. All the devices were pre-calibrated as illustrated in Table 4. The external sensors were cross-checked with *Delta Ohm HD32.3* readings during a one-week test period to ensure coherence and stability.

2.5. Survey

In this study, a real-time survey in French was conducted alongside field measurements. Participants were recruited voluntarily among regular office workers, excluding visitors and temporary staff. Participation was anonymous and written consent is obtained from the administrative authorities, while verbal consent is obtained from each voluntary participant. Participants were interviewed once per season during three seasons (rainy, cold, and hot), and indoor thermal conditions were recorded simultaneously (Fig. 3a). Only those present during the measurement period were included. The researchers team conducted in-person surveys using printed questionnaires where participants marked their responses. The questionnaire Form A focused on assessing the Thermal Sensation Vote (TSV) and Thermal Preference vote (TPV) of individuals in office buildings. For TSV, the question "*How would you describe your current thermal sensation?*" was used, with responses based on the ASHRAE seven-point scale [4]. Since it has been proved that even TSV is a key metric, it is not enough alone for thermal comfort prediction We also considered TPV in this study [36]. So, the question "*How would*

Table 2
Characteristics of the measuring equipment.

Indoor environment Parameters	Probes	Measuring range	Resolution	Accuracy
Dry bulb temperature (T_a)	TP3207.2 Thin film Pt100	−40 to 100 ∘C	0.1 ∘C	±0.1 ∘C
Globe temperature (T_g) (globe therm Ø50mm)	TP3276.2 Pt100	−10 to 100 ∘C	0.1 ∘C	±0.1 ∘C
Relative air humidity (RH)	HP3217.2 Capacitive sensor	5 to 98 %	0.1 %	±2.5 %
Air velocity (V_a)	AP3203.2 NTC 10Kohm	0.05–5 m/s	0.01 m/s	±0.05 m/s (0–1 m/s) ±0.15 m/s (1–5 m/s)
Outdoor environment				
Dry bulb temperature (T_a)	TH	−20 to 85 ∘C	0.06 ∘C	
Relative air humidity (RH)	TH	0 to 100 %	0.12	

Table 3
Scales used in the thermal comfort survey.

	Thermal Sensation (TSV)		Thermal Preference (TPV)	
Categorization	**English**	**French**	**English**	**French**
−3	Cold	Très froid		
−2	Cool	Froid	Much cooler	Plus froid
−1	Slightly cool	Légèrement froid	A bit cooler	Un peu froid
0	Neutral	Neutre	No change	Pas de changement
+1	Slightly warm	Légèrement chaud	A bit warmer	Un peu chaud
+2	Warm	Chaud	Much warmer	Plus chaud
+3	Hot	Très chaud		

Table 4
Participants characteristics.

Variable	Category	Count	Percentage (%)
Gender	Male	710	61
	Female	456	39
Age (years)	[18 – 30]	156	13.4
	[31 – 40]	531	45.6
	[41 – 50]	416	35.7
	[51 – 60]	62	5.3
	> 60	1	0.1
Weight (kg)	< 60	115	9.9
	[60 – 70]	387	33.2
	[71 – 80]	347	29.7
	[81 – 90]	177	15.2
	> 90	140	12
Height (m)	< 1.60	126	10.8
	[1.61 – 1.70]	459	39.4
	[1.71 – 1.80]	446	38.2
	[1.81 – 1.90]	125	10.7
	> 1.90	10	0.9
Thermal sensitivity	Yes	114	9.8
	No	1047	89.8
	No_Answer	5	0.4
Time living in Burkina Faso (years)	< 1	2	0.2
	[1 – 5]	13	1.1
	> 5	1151	98.7
Time in current office (months)	< 6	344	29.5
	[6 – 12]	238	20.4
	> 12	584	50.1

you prefer your thermal sensation right now?" was employed, using the Nicol five-point thermal preference scale [41] (Table 3). Participants were also asked about their perception of thermal acceptability (Yes/No), their activities in the 30 min and 1 h before the survey, and their clothing. This information was used to calculate metabolism and Clo values according to ASHRAE 55 [4]. The operational mode—natural ventilation (NV) or air conditioning (AC)—was identified through direct observation and occupant confirmation, along with adaptive behaviors such as window opening, fan or AC use, and clothing adjustments. Observations of any transient changes in operation were noted on the Form B to accurately classify each data record and to characterize the adaptive opportunities associated with each mode.

2.6. Data analysis

Only correctly completed questionnaires were included in the analysis to ensure the reliability of results. All responses from the field surveys were recorded through Google Forms, then exported in Microsoft Excel format (.xlsx) for data processing. Similarly, the physical measurements of indoor thermal parameters (air temperature, globe temperature, relative humidity, and air velocity) were recorded using the *Delta OHM HD32.3* device. The measurement data were extracted via DeltaLog10 software, which allows the storage, visualization, and processing of time-series measurements before exporting them to Excel format. Subsequently, all field and survey data were compiled and harmonized in Microsoft Excel, and then analyzed using Python (pandas, numpy, and matplotlib) for statistical computations and graphical analysis.

Descriptive statistics, including mean, standard deviation, minimum, and maximum, were computed for all measured environmental parameters and survey responses. Thermal comfort evaluation was carried out by analysing TSV in relation to the corresponding measured operative temperature (T_{op}). Since it is proved that T_{op} and T_g are virtually indistinguishable [28], T_g is used in this study. The neutral temperature (T_n) was estimated using both the Griffiths method illustrated in Equation (1) and simple linear regression between TSV and T_{op}, to allow cross-validation of results.

$$T_n = T_{op} - \frac{TSV}{G} \tag{1}$$

where, T_n represents the neutral temperature using the Griffiths method, and G denotes the rate of change of thermal sensation with operative temperature, substituting the regression coefficient. T_{op} is used here since it is showed, that it has the most significant effect on the occupant's thermal sensation in MM buildings [42]. This method has been widely employed in other studies, consistently yielding valid results [28,43]. A constant value of 0.5 K was utilized for G, considering findings from various sources [27,28,43].

Thermal acceptability rates were calculated as the percentage of occupants reporting TSV values between − 1 and + 1, consistent with ASHRAE Standard 55 criteria. Furthermore, Thermal Preference Votes (TPV) were used to verify the direction of comfort adjustment (i.e., whether occupants preferred warmer or cooler conditions). All data were classified according to both the building operation mode (NV or AC) and the season (hot, cold, rainy) to identify behavioral and comfort differences under varying climatic conditions. Finally, comfort results were compared with existing standard such as ASHRAE 55 and EN 16798-1 to verify the applicability of these standards in the context of the study. Due to the non-normal distribution of indoor environmental variables, the spearman's test was employed to assess the relationship between TPV and TSV across ventilation modes and seasons. All measured and derived data were processed using the Python programming language. In applying the thermal adaptation model, it is essential to first determine the prevailing mean outdoor air temperature. This value is calculated using a weighted average of daily mean temperatures from the

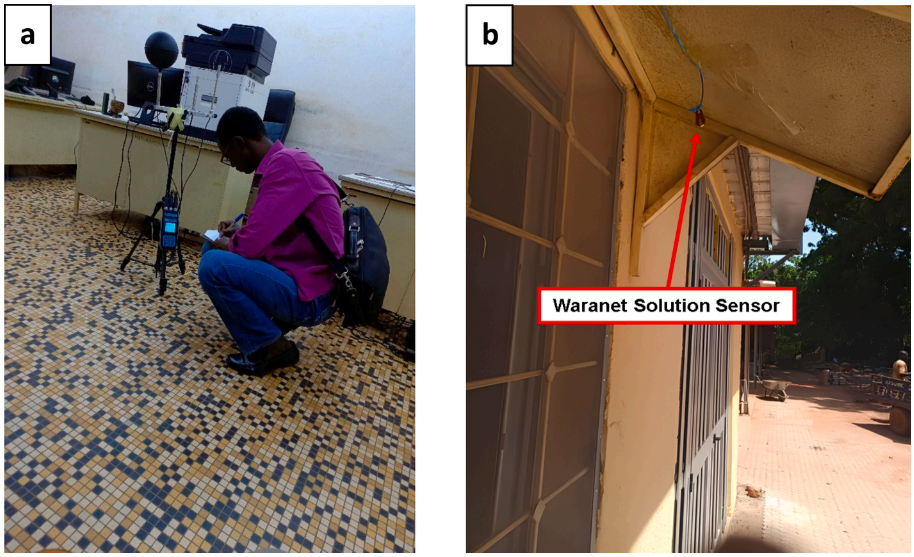


Fig. 3. Photographs of the survey process. a. Indoor parameters collection; b. *Waranet Solution* sensor for outdoor parameters collection.

preceding week. The weighting factor, denoted as α, significantly influences the outcome. According to ASHRAE Standard 55, recommended values for α range between 0.6 and 0.9. The value α = 0.8 is commonly used in adaptive comfort studies because it gives precedence to recent outdoor conditions, which is appropriate where occupant acclimatation and short-term behavioural adjustments dominate. For this study, α = 0.8 (seven days) is selected as it has been used by researchers in similar climates [43,44]. The prevailing mean outdoor temperature $t_{pma(out)}$ [4] is calculated using the following equation:

$$\overline{t_{pma(out)}} = (1-\alpha) \times \left[t_{e(d-1)} + \alpha \cdot t_{e(d-2)} + \alpha^2 \cdot t_{e(d-3)} + \alpha^3 \cdot t_{e(d-4)} + \alpha^4 \cdot t_{e(d-5)} + \alpha^5 \cdot t_{e(d-6)} + \alpha^6 \cdot t_{e(d-7)}\right] \quad (2)$$

where $\overline{t_{pma(out)}}$ is the prevailing mean outdoor temperature (°C), $t_{e(d-1)}$ is the daily mean outdoor temperature for the previous day (°C), $t_{e(d-2)}$ is the daily mean outdoor temperature for the day before the previous day, etc.

3. Results

3.1. Participants characteristics

Before analyzing thermal comfort responses, we present the demographic and contextual characteristics of the study participants. A total of 553 participants contribute to 1,166 thermal responses across three seasons. The sample consisted of 61 % of male and 39 % of female, with the majority of participants aged 18–50 years (94 %), while older age groups were less represented. Regarding body weight, most individuals fell within the 60–70 kg (33.20 %) and 71–80 kg (29.69 %) ranges. Regarding height, participants were predominantly within the 1 m61–1 m70 (39.40 %) and 1 m71–1 m80 (38.19 %) categories. Additionally, 89.80 % of respondents reported no particular medical sensitivity to thermal conditions. Most respondents (98.7 %) had lived in Burkina Faso for more than five years, indicating strong local acclimatization, while about half (50.1 %) had occupied their current office for over a year, reflecting stable workplace exposure and familiarity with the indoor environment. These findings provide a demographic and anthropometric overview of the surveyed population, serving as a basis for further analysis of thermal perception and comfort responses. Table 4 summarizes the distribution of participants across these categories.

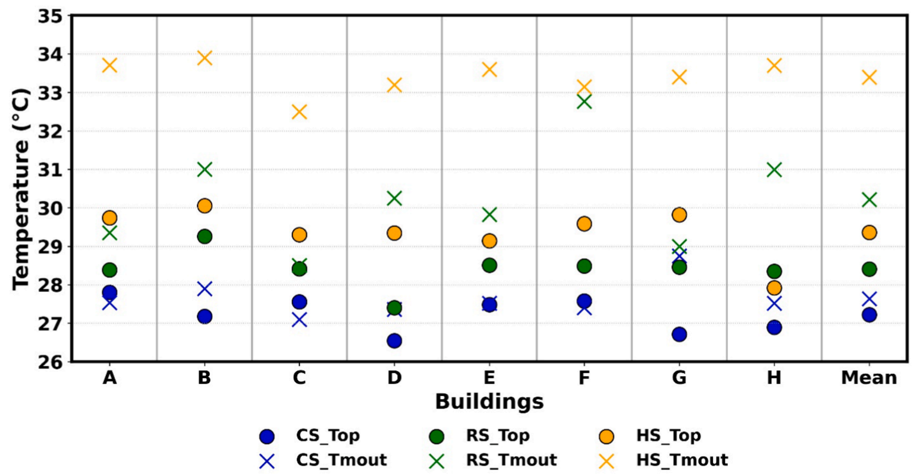
3.2. Measurements

Table 5 shows variables collected statistics during the study. In total 11,056 data points were recorded with 6357 points in air-conditioned (AC) mode, while 4699 points in Naturally Ventilated (NV) mode. Indoor air temperature averaged 28.9 °C in NV spaces and 27.3 °C in AC spaces, while globe temperature followed a similar pattern (28.8 °C NV vs. 28.0 °C AC), indicating warmer indoor conditions under NV operation. Relative humidity was lower and more variable in NV mode (30.0 ± 18.29 %) compared to AC (39.93 ± 15.48 %), while air velocity was higher in NV (0.32 m/s) than in AC (0.21 m/s), confirming the influence of natural airflow. Despite these environmental contrasts, the mean

Table 5
Statistics of collected variables.

Parameters	Mode	N	Mean	SD	Min	Max
Air Temperature (T_a), °C	NV	4699	28.9	2.1	24.1	35.1
	AC	6357	27.3	1.98	21.5	30.2
Globe Temperature (T_g), °C	NV	4699	28.8	2.3	22.0	35.6
	AC	6357	28.0	1.53	24.5	31.2
Relative Humidity (RH), %	NV	4699	30.0	18.29	9.7	72.7
	AC	6357	39.9	15.48	10.88	78.2
Air Velocity (V_a), m/s	NV	4699	0.32	0.2	0.05	1.66
	AC	6357	0.21	0.23	0.01	0.51
Thermal Sensation Vote	NV	496	−0.11	0.89	−3	3
(TSV)	AC	670	−0.28	0.93	−2	2
Thermal Preference Vote	NV	496	−0.28	0.64	−2	1
(TPV)	AC	670	−0.33	0.58	−2	1
Clothing Insulation, Clo	NV	496	0.60	0.11	0.43	1.14
	AC	670	0.63	0.13	0.43	1.14

SD: Standard Deviation; **Min:** Minimum; **Max:** Maximum; **NV:** Natural Ventilation; **AC:** Air conditioning; **N:** Number of Data points.



CS_Top: Mean Operative Temperature in Cold Season; **RS_Top:** Mean Operative Temperature in Rainy Season; **HS_Top:** Mean Operative Temperature in hot season; **CS_Tmout:** Mean Outdoor Temperature in Cold Season; **RS_Tmout:** Mean Outdoor Temperature in Rainy Season; **HS_Tmout:** Mean Outdoor Temperature in Hot Season.

Fig. 4. Average operative during seasons: Cold Season (CS, Blue), Rainy Season (RS, Green), Hot Season (HS, Orange) **CS_Top:** Mean Operative Temperature in Cold Season; **RS_Top:** Mean Operative Temperature in Rainy Season; **HS_Top:** Mean Operative Temperature in hot season; **CS_Tmout:** Mean Outdoor Temperature in Cold Season; **RS_Tmout:** Mean Outdoor Temperature in Rainy Season; **HS_Tmout:** Mean Outdoor Temperature in Hot Season.

Thermal Sensation Vote (TSV) remained near neutrality (−0.11 NV; −0.28 AC), and Thermal Preference Vote (TPV) values (−0.28 NV; −0.33 AC) indicated that most occupants were thermally comfortable, highlighting their adaptive capacity across ventilation modes. Fig. 4 shows the average operative temperatures (T_{op}) for each case study in each season, together with the average daily outdoor temperatures (T_{mout}) at the time of the fieldwork. The operative temperature was obtained from the globe temperature (T_g), as they are virtually indistinguishable [28,45], and varied by season. It can be seen that all measurements are within a range of 26.0 °C – 30.5 °C. These results are higher than those found by Trebilcock et al. [28] in the Chile context (20.0 °C–25.0 °C) maybe due to the fact that Chile has Mediterranean climate while our context is warm semi-arid. Results are also higher and wider than those found by Hema et al. [29] (26.3 °C–26.5 °C) during cold season, likely due to the varied building types versus their single concrete building. But they align with Efeoma et al. [46] in Enugu, Nigeria (26.2 °C–32.0 °C; 28.1 °C–31.9 °C). The average T_{op} in Cold Season (CS) was 27.2 °C. This value increased to 28.4 °C in Rainy Season (RS) and 29. 6 °C in Hot Season (HS). It is noted a difference of approximately 1 °C between each season. The T_{op} also varied consistently between the different building modes with lower temperatures in AC mode (average 27.5 °C) that increased in NV mode (average 29.2 °C). In the context of Ghana, Mohammad et al.[43] reported that 83.3 % of occupants in NV spaces found a mean T_{op} of 30.6 ± 1.8 °C acceptable, while 86.7 % of those in AC spaces accepted a mean T_{op} of 27.5 ± 0.7 °C. These high acceptability rates may reflect psychological adaptation to the prevailing thermal conditions. All these results indicate that external climate conditions strongly influence indoor environments, especially in buildings running in NV mode.

3.3. Thermal sensation

As shown in Table 5, the average Thermal Sensation Vote (TSV) was − 0.11 ± 0.89 under naturally ventilated (NV) conditions and − 0.28 ± 0.93 under air-conditioned (AC) mode. These results indicate that occupants generally perceived the indoor environments as slightly cooler

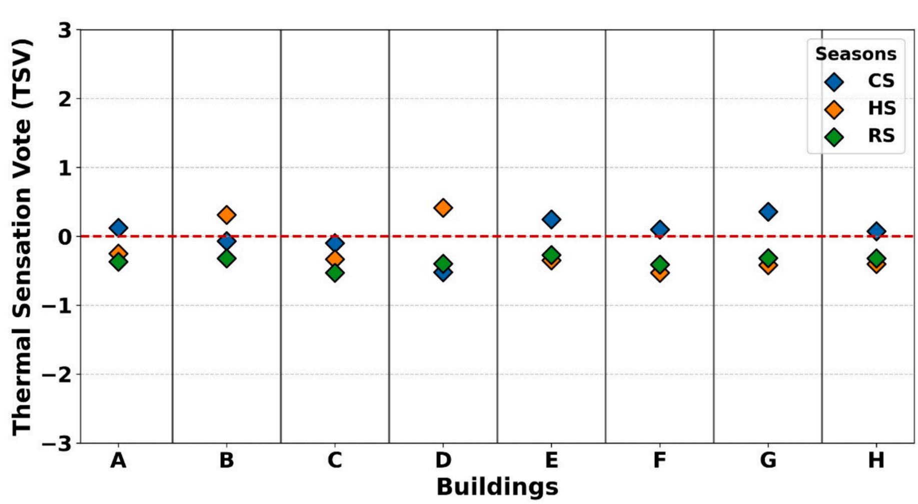


Fig. 5. Mean thermal sensation vote by case study for Cold Season (CS, Blue), Rainy Season (RS, Green) and Hot Season (HS, Orange).

than neutral in both modes, with greater variability observed in the AC mode. The wider standard deviation during AC operation suggests a more heterogeneous thermal perception, possibly reflecting individual differences in sensitivity to mechanically controlled cooling and limited opportunities for personal adjustment. Similar findings were reported by Mohammad et al. [43] who noted that in AC mode, the cooling setpoint may not reflect local thermal preferences, leading to discomfort despite mechanical cooling. The average TSV for each case study, illustrated in Fig. 5 indicate that all mean values fall within the range of –1 (slightly cool) to + 1 (slightly warm). It can also be noted that in CS, the thermal sensation is warmer than in RS, with the exception of a few specific cases such as case B and D. The average TSV are 0.03 in CS, −0.37 in RS and −0.19 in HS, thus indicating that thermal sensation becomes warmer throughout the year. These findings are relatively higher than those found by Muhammad et al. [27] (−1.07 during the rainy season) in the context of Abuja, Nigeria (Fig. 6).

Table 6 shows the distribution of TSV according to those within and outside the comfort range of −1, 0, and + 1, across seasons. Overall, more than 25 % of the votes fall outside the specified range, with this tendency being most evident in HS, where the proportion exceeds 31 %. These results are consistent with those reported by [28], which found values between 31.2 % and 33.5 %, and are higher than in other studies where over 80 % of the responses across all surveyed locations were within the TSV range of –1, 0, and 1 [29].

The Clo values in Table 5 and Table 7 exhibit a consistent variation across building ventilation modes and seasons. They tend to be slightly higher in AC mode compared to NV mode, indicating that occupants adapt their clothing to the operating mode. Similarly, values are higher in CS than in RS and HS, which corresponds to the colder conditions in CS. These values are generally lower than those in temperate climates like Chile, where Trebilcock et al. [28] observed higher seasonal variations (e.g., 0.95 *Clo* in winter) [28]. But align with findings in tropical climates [27]. The Clo value in AC mode is higher than in NV mode. The same trend is noted by Mohammad et al. [43] who found 0.57 ± 0.1 Clo and 0.55 ± 0.11 respectively in AC and NV modes, but still lower than values in this study. While no significant correlation was observed between Clo values and TSV ($R^2 = 0.016$), a strong correlation was found with outdoor temperature T_{mout} (R2 = 0.57). The relationship is negative, suggesting that occupants increase clothing insulation as an adaptive response to lower outdoor temperatures. Behavioral adaptation strategies were observed, including clothing adjustments (e.g., lighter fabrics, short sleeves) during HS, and window opening during NV mode. In contrast during CS and RS, occupants clothing's tend to be heavier. In Burkina Faso, traditional garments like "*Faso Dan Fani*" or "*Koko Dunda*" promoted by the government within the public administration and adopted by occupants may explain clothing patterns [47] illustrated in **Fig. B- 1**. However, the frequency and effectiveness of these actions varied depending on cultural norms, building layout, and individual preferences. For instance, some occupants expressed reluctance to open windows due to noise or dust, while others preferred natural airflow over mechanical cooling. These behaviors reflect not only thermal needs but also cultural expectations and workplace habits, which significantly shape comfort perception in the local context.

Table 6
Thermal Sensation Vote (TSV) ranges.

Seasons	Within the comfort range (TSV = −1, 0, +1)		Outside the comfort range (TS = −3, −2, +2, +3)	
	Number of votes	**Percentage (%)**	**Number of votes**	**Percentage (%)**
Rainy	287	74.35	99	25.65
Cold	281	72.99	104	27.01
Hot	269	68.10	126	31.90

Table 7
Average Clo values.

Buildings	N (data points)	Cold Season (Clo)	Rainy Season (Clo)	Hot Season (Clo)
AC	670	0.71	0.60	0.57
NV	496	0.68	0.59	0.55

3.4. Thermal preference

Traditionally, field studies assessing comfort temperatures in office buildings have focused on determining the neutral temperature based on indoor environmental measurements and thermal sensation vote (TSV) data. However, some researchers have challenged the notion that the 0 (neutral) value represents the ideal or desired condition for building occupants [28]. Instead, they hypothesize that, depending on the environmental characteristics as well as the personal, cultural, and psychological attributes of the occupants, individuals may prefer a thermal sensation other than neutral as the optimum [28,48,49]. The Fig. 7 displays both TPV = 0 (no change) and Thermal Sensation votes, TSV = 0 (neutral), across the three seasons for all buildings. It's noteworthy that the number of individuals indicating a preference for no change in their thermal environment (TPV = 0) is significantly higher than those who report their thermal sensation as neutral (TSV = 0). It can also be noted that the number of neutral TSV was slightly higher in CS (34.97 %)

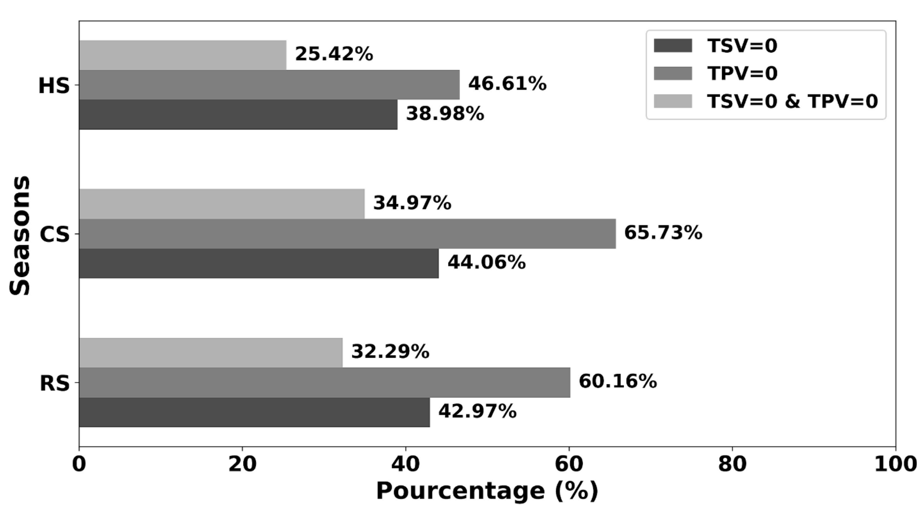


Fig. 6. Relationship between TSV neutral and TPV no change votes.

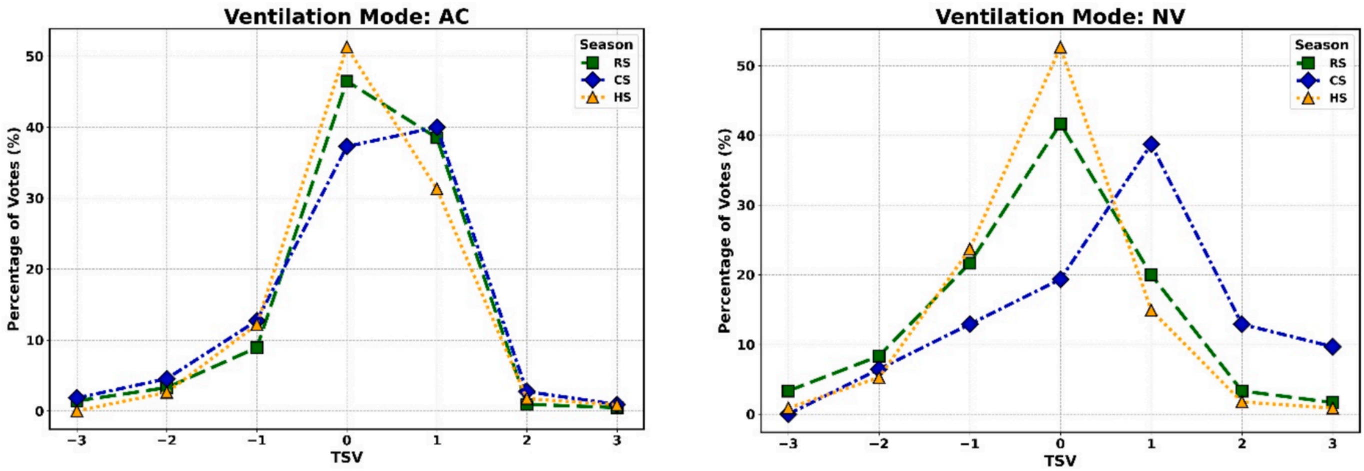


Fig. 7. Relationship between the number of votes for each thermal sensation in AC and NV mode for Cold Season (CS, Blue), Rainy Season (RS, Green) and Hot Season (HS, Orange).

Table 8
Cross tabulation of thermal sensation and preference.

Preferred Sensation (TPV)	Actual thermal sensation (TSV) −3	−2	−1	0	1	2	3	Total
2	**15**	13	8	3	3	0	2	44
1	11	22	36	12	14	11	6	112
0	8	**28**	**88**	**290**	**206**	15	8	643
−1	9	18	93	94	29	**34**	12	289
−2	1	9	13	11	15	11	**18**	78
Total	44	90	238	410	267	71	46	**1166**

and decreased throughout the year until the HS (25.42 %), when a lower number of occupants claimed to have a neutral thermal sensation. Of the 1166 total votes obtained for the three periods, 410 correspond to a neutral thermal sensation (TSV = 0). Of those 410 votes, 290 indicated a thermal preference for no change (TSV = 0/TPV = 0). Hence, the remaining 120 votes (29.27 % of respondents) would have preferred a different environment despite having a neutral thermal sensation.

Table 8 presents a cross-tabulation of TSV and TPV, which shows that as thermal sensation becomes colder, preference shifts to warmer temperatures. The opposite occurs when TSV becomes warmer, which is to be expected. It is interesting to note that more than 54 % of the respondents who reported a thermal preference for no change (TPV = 0) at the same time indicated a thermal sensation different from "neutral" (TSV = −2, −1, 1, and 2), which suggests that the sensation of comfort could occurs at a different point other than neutral. This has also been observed in other studies, such as Mohammadpourkarbasi et al. [43] who found that 47.1 % of respondents preferred a "slightly cooler" temperature, even though 45.7 % felt neutral at 30.4 °C. Similar to findings of Trebilcock et al. [28] in Chile, Shahzad & Rijal in Japan, Norway, and the UK [49], and Humphreys and Hancock in the UK [48], from which it can be inferred that people do not necessarily prefer a neutral thermal sensation.

3.4.1. Thermal sensation and thermal preference according to operating mode

Fig. 7 shows a detailed analysis of the number of votes obtained for each of the options on the ASHRAE thermal sensation scale when the thermal preference is "no change" (TPV = 0), differentiated according to each case 'study's operating mode. In the Air Conditioned (AC) mode buildings graph, there is a clear trend towards TSV = 0 in the HS, with 51.30 % of votes. It decreases during RS (46.48 %) is always around TSV = 0, but with a regular dispersion. In CS, the maximum of votes is divided between TSV = 0 with 37.27 % and TSV = +1 with 40 % of votes. This indicates that a large portion of the AC mode occupants prefer to feel neutral, except in CS, where there is a division between individuals who prefer a neutral sensation and those who prefer a bit warmer. In the case of NV mode buildings, the dispersion of TSV varies notably across seasons. In the HS and RS, TSV responses are more narrowly distributed around neutrality (TSV = 0), with 52.63 % and 41.67 % of the votes, respectively. This suggests a high alignment between thermal sensation and preference, indicating adaptive satisfaction with the indoor environment during these periods. Conversely, in the CS, the peak is around TSV = 1 with 38.71 % of votes, while TSV = 0 was 19.35 %. A somewhat irregular vote dispersion can still be seen, with varied user sensations when indicating a preference for "no change". In general, it can be seen that the less active a building's climate control system is, the greater the tendency for users to prefer warm sensations in CS and cool sensations in HS. Meanwhile, in AC mode, where there is greater control of the indoor environment and therefore less influence from outdoor conditions, users tend to prefer neutral temperatures. Similar findings were reported by Rupp et al. [23] and Khoshbakht et al. [18], who observed that occupants in warm climates often prefer slightly higher indoor temperatures even in cooler periods. This may result from long-term adaptation to high ambient temperatures and clothing behavior adapted for comfort rather than warmth. Conversely, studies such as Kim et al. [37] in subtropical climates found that occupants in AC spaces can experience cool discomfort due to overcooling, which could explain the preference for slightly warmer conditions in this study.

Spearman's rank correlation was used to assess the relationship between thermal preference vote (TPV) and thermal sensation vote (TSV) across ventilation modes and seasons (Fig. 8). The results show a strong and statistically significant negative correlation in both AC ($\rho = -0.855$, $p < 0.001$) and NV ($\rho = -0.765$, $p < 0.001$) modes when all seasons are considered. This indicates that, overall, occupants tend to prefer cooler thermal conditions as their thermal sensation increases. Seasonal analysis revealed consistently strong negative correlations in AC mode, with coefficients ranging from –0.729 in the cold season (CS, $p = 0.003$) to –0.90 in the hot season (HS, $p < 0.001$). This suggests a robust and

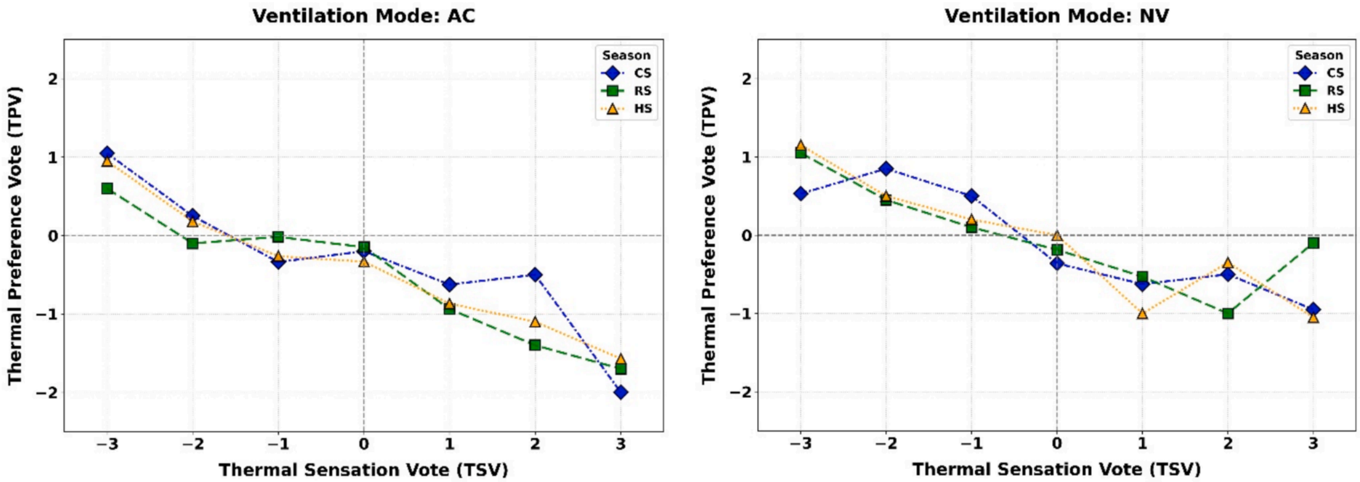


Fig. 8. Dependence of mean preferred thermal sensation upon actual thermal sensation for Cold Season (CS, Blue), Rainy Season (RS, Green) and Hot Season (HS, Orange).

Table 9
Neutral temperature for each case study.

Buildings	Cold Season (CS)			Rainy Season (RS)			Hot Season (HS)		
	T_{nreg}(°C)	R^2	T_n(°C)	T_{nreg}(°C)	R^2	T_n(°C)	T_{nreg}(°C)	R^2	T_n(°C)
A	29.4	0.21	27.8	29.1	0.18	28.7	30.6	0.11	29.8
B	29.2	0.15	27.8	29.2	0.11	28.6	28.8	0.21	29.3
C	28.5	0.17	26.8	29.2	0.23	27.8	30.7	0.16	29.9
D	31.0	0.02	27.5	N/A	0.01	29.1	28.7	0.05	30.3
E	25.3	0.01	27.9	31.0	0.01	28.9	29.0	0.06	29.2
F	32.6	0.03	26.3	N/A	0	28.8	25.1	0.01	28.0
G	29.6	0.07	26.2	30.0	0.14	28.8	N/A	0	29.0
H	29.9	0.01	26.1	19.3	0	28.7	28.1	0.15	28.0
Average	**29.4**	**0.08**	**27.0**	**28.0**	**0.12**	**28.7**	**28.7**	**0.21**	**29.2**
Reg. Eq.	y = 0.1339x −4.0051 R^2 = 0.0514			y = 0.1704x −5.1791 R^2 = 0.0876			y = 0.1761x −5.0989 R^2 = 0.1016		

N/A*:** The value given is not coherent; T_{nreg}**:** Neutral temperature using the simple regression method; R^2**:** Coefficient of determination using the simple regression method; T_n**:** Neutral temperature using Griffiths method; ***Reg. Eq: Regression equation.

increasing preference for cooler environments as thermal discomfort rises, particularly in warmer seasons. In NV buildings, significant negative correlations were also observed in CS (ρ = –0.764, p < 0.001) and RS (ρ = –0.586, p = 0.036), confirming a similar trend. The HS also showed a strong correlation (ρ = –0.864, p < 0.001), indicating that even in naturally ventilated mode, occupants express a clear preference for cooler conditions as thermal sensation intensifies. This behavioral trend reflects an adaptive response aimed at restoring comfort when thermal neutrality is exceeded. Similar patterns have been widely reported in mixed-mode and naturally ventilated buildings, where users can actively modify their environment through window opening, fan use, or clothing adjustments [8,50]. In warm climates, this preference for cooler conditions at higher thermal sensations is also consistent with findings by Rupp et al. [51] and Kim et al. [37], who observed that occupants' adaptive capacity plays a key role in maintaining comfort under elevated temperatures.

3.5. Neutral temperature

The neutral temperature for each case study can be seen in Table 9. This temperature was obtained using two different methods: a simple regression analysis that relates the thermal sensation of occupants to the indoor operative temperature, and the Griffiths method. With the simple regression method, the neutral temperature (T_{nreg}) is the point at which the trendline corresponding to each case study crosses the point where the TSV is neutral (TSV = 0). This was done separately for each measurement period. There are three cases: D and F in RS and G in HS, for which the T_{nreg} could not be calculated because the excessive dispersion of the votes resulted in imprecise trendlines. These points are indicated in the table as N/A and are not considered in the average T_{nreg} values. One fact that should be taken into account is that the dispersion of the points is quite wide, and therefore, the multiple correlation coefficients or coefficients of determination with the simple regression method (R^2) are in nearly all cases less than 0.2. In addition to the T_{nreg}, neutral temperature was calculated using Griffith's method (T_n) [27,28,48], which evaluates the comparison between the average operative temperature and the average TSV based on the perception of the occupants. This method provides an alternative option to linear regression when the regression coefficient is too low and it is not possible to calculate neutral temperature in some cases, as in this study.

The average T_n consistently increases from Cold Season (CS) to Hot Season (HS). It is by more than 1 °C from CS to Rainy Season (RS) and by 0.5 °C from RS to HS. Of the two methods used, the Griffiths method was selected for the next step in the analysis due to the low coefficient of determination and the lack of results obtained in some cases with the simple regression method. T_n clearly varies during a given season: in CS

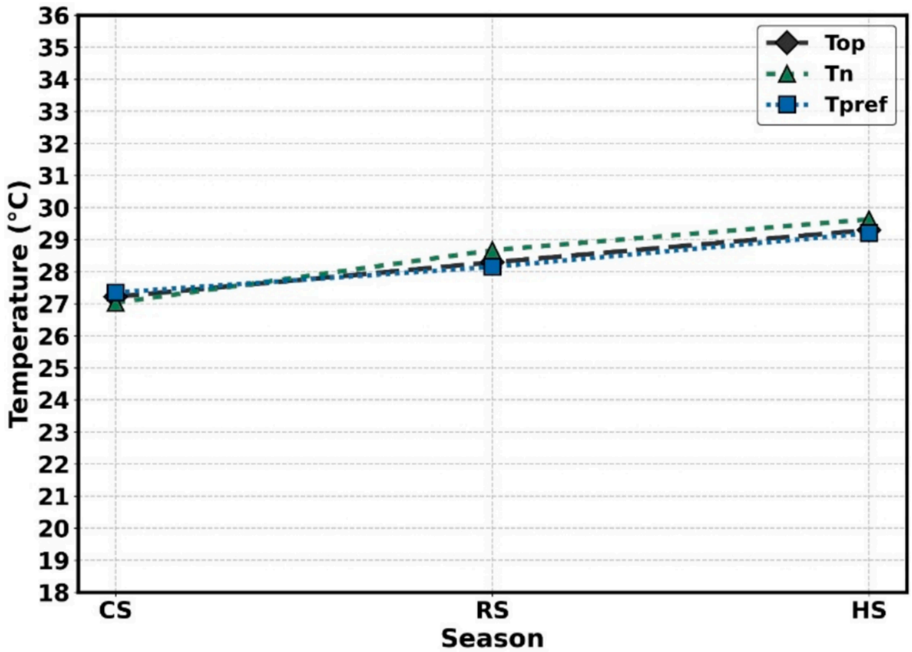


Fig. 9. Comparison of operative, neutral and preference temperatures for Cold Season (CS), Rainy Season (RS) and Hot Season (HS).

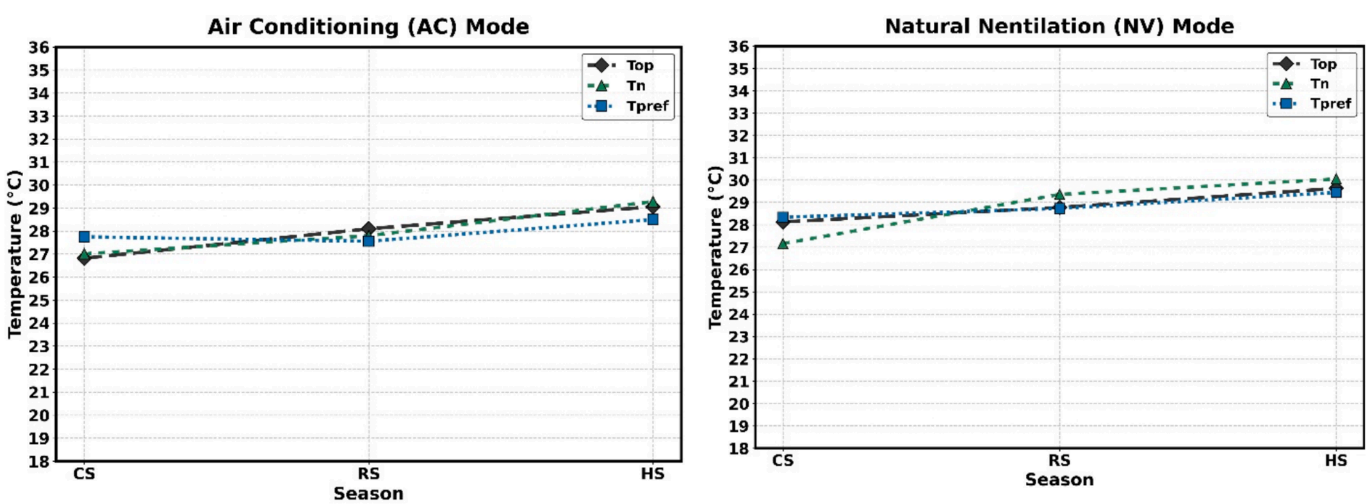


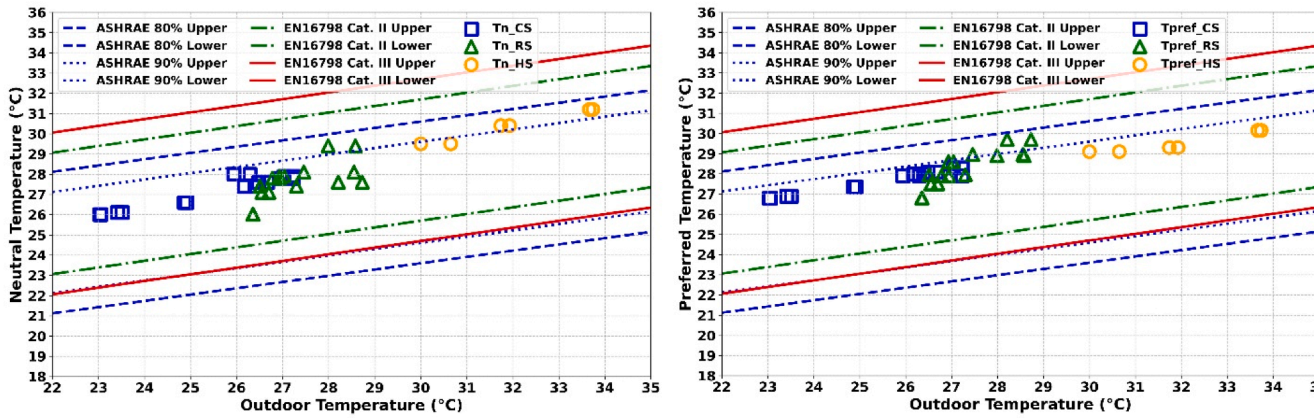
Fig. 10. Comparison of neutral, preferred, and operative temperatures for Cold Season (CS), Rainy Season (RS) and Hot Season (HS).

between 26.1 °C and 27.9 °C amongst the different cases, in RS between 27.8 °C and 29.1 °C, and in HS between 27.9 °C and 30.3 °C. These values remain higher than those found by Hema et al. [29] (26.2 °C – 26.5 °C) in their study during the CS, but align with the study of Mohammadpourkarbasi et al. [43], who found the range of 27.4 °C – 30.3 °C in Ghana mixed-mode office building. Also, in the hot and humid tropical, Yue Lei et al. [14] found that Occupants, initially accustomed to temperatures of 23.0–25.0 °C, gradually accepted temperatures of up to 30.0 °C.

3.6. Preferred temperature

Fig. 9 and Fig. 10 compare the comfort and preference temperatures obtained with the average operative temperature (T_{op}) at the time of the surveys. Preferred Temperature (T_{pref}) is the average T_{op} considering only the TPV = 0, and T_n is the neutral temperature obtained using the Griffiths method. Fig. 9 shows a progressive increase in T_{op}, T_n, and T_{pref} across seasons, reflecting occupants' thermal adaptation. In Cold Season (CS), T_n remains lower than both T_{op} and T_{pref}, suggesting that thermal neutrality is perceived at lower temperatures than those measured or preferred. T_n rises in line with T_{op}, T_{pref} remains consistently lower than both, particularly during the HS, where the gap between T_{op} (29.6 °C) and T_{pref} (28.9 °C) is most pronounced. It is important to highlight that in all cases, the T_{pref} is quite similar to the T_{op}, with the only difference being a decrease in the T_{pref} in HS. Despite showing differences, the T_n can also be considered similar to the T_{op} and T_{pref} throughout the year, which could indicate that the office building users adapt more than expected to the operative temperature of the building. Overall, it is found that the preferred temperature range is from 26.8 °C to 30.2 °C. These findings are within the estimated comfort range of two studies from West Africa. Ali et al.[44] found a preferred temperature of 25.9 °C, 29.3 °C and 33.1 °C respectively during winter, mid-season and summer in NV buildings of Nigeria, while [43]. Accordingly, more studies in the region are required to understand the adaptive model in Burkina Faso and West Africa.

Fig. 10 shows a similar comparison but differentiates the two



Tn_CS: Neutral Temperature in Cold Season (Square, Blue); **Tn_RS:** Neutral Temperature in Rainy Season (Triangle, Green); **Tn_HS:** Neutral Temperature in Cold Season (Circle, Orange). **Tpref_CS:** Preferred Temperature in Cold Season (Square, Blue); **Tpref_RS:** Preferred Temperature in Rainy Season (Triangle, Green); **Tpref_HS:** Preferred Temperature in Cold Season (Circle, Orange).

Fig. 11. Relationship between neutral and preferred temperature and comfort standards with the adaptive method. **Tn_CS:** Neutral Temperature in Cold Season (Square, Blue); **Tn_RS:** Neutral Temperature in Rainy Season (Triangle, Green); **Tn_HS:** Neutral Temperature in Cold Season (Circle, Orange). **Tpref_CS:** Preferred Temperature in Cold Season (Square, Blue); **Tpref_RS:** Preferred Temperature in Rainy Season (Triangle, Green); **Tpref_HS:** Preferred Temperature in Cold Season (Circle, Orange).

operating modes (AC and NV) of the case studies. Spearman correlation analysis revealed strong associations between T_{op}, T_n, and T_{pref}. Overall, T_{op} was strongly correlated with T_n ($\rho = 0.81$) and T_{pref} ($\rho = 0.80$), while T_n and T_{pref} were also closely related ($\rho = 0.75$). Under NV mode, the correlation was stronger between T_{pref} and T_{op} than between T_{pref} and T_n, thereby corroborating 'occupants' adaptability to the T_{op} in terms of thermal preference. Under AC mode conditions, T_{op} and T_n showed a very strong correlation ($\rho = 0.97$), with $T_n - T_{pref}$ at $\rho = 0.86$ and $T_{op} - T_{pref}$ at $\rho = 0.70$. In NV mode spaces, $T_n - T_{pref}$ ($\rho = 0.95$) and $T_{op} - T_{pref}$ ($\rho = 0.87$) were highly correlated, while $T_{op} - T_n$ was lower ($\rho = 0.67$). Overall, the correlation was stronger between T_{pref} and T_{op} in NV than in AC mode, where a stronger correlation was found between T_{op} and T_n. This corroborates the occupants' adaptability to the Top in terms of thermal preference. These results suggest that thermal preferences are more directly influenced by operative temperature in NV mode, whereas in AC mode, the operative and neutral temperatures are more tightly coupled. These findings align with findings from [28].

3.7. Results in relation to standards

Fig. 11 and Fig. 12 compare the average T_n and T_{pref} obtained in each of the case studies for each of the seasons with the comfort ranges defined in the ASHRAE 55 and the EN 16798-1, which are the reference standards. Fig. 11 shows the results compared with the adaptive method, and Fig. 12 shows them in comparison to the steady-state method defined in both standards. The adaptive method applies to NV mode when occupants use the adaptive opportunity to open windows and enable natural ventilation to occur; while the steady-state method applies to AC mode, when windows are closed, and air-conditioners are used in buildings. The average T_n values in the CS are entirely within the 90 % acceptability comfort range defined by both ASHRAE 55 and EN 16798-1 standards. During RS and HS, some of the values are outside the 90 % acceptability comfort range, but are entirely within the 80 % acceptability comfort range, suggesting that the adaptive method applies to the data derived from the field studies in all cases, possibly driven by acclimatization or cultural habits. Overall, both standards capture the seasonal variations, but EN 16798-1 provides a wider acceptable range accommodating more of the observed values, while ASHRAE's narrower 90 % acceptability limits flag higher exceedances. These results are also supported by Attia et al. [52], who confirm that adaptive models such as ASHRAE 55 and EN 16798-1 are more suitable for hot climates, particularly in naturally ventilated or hybrid buildings. Also, Efeoma et al. [46] found provides insight as to why the ASHRAE 55 adaptive model is more suitable for thermal comfort assessment of office buildings in the tropical West African climate. The comfort equations derived from the data are:

$$T_n = 0.2815\ T_{out} + 20.863 \text{ with } R^2 = 0.331 \quad (3)$$

$$T_{pref} = 0.1848\ T_{out} + 23.128 \text{ with } R^2 = 0.2575 \quad (4)$$

Theses regression models reveal a moderate adaptive relationship between outdoor and indoor comfort temperatures, indicating that occupants adjust their thermal expectations to outdoor conditions. The relatively low coefficients of determination ($R^2 = 0.331$ and 0.2575) indicate that outdoor temperature alone explains roughly 25–33 % of the variability in comfort responses. A large range of percentage was found by Trebilcock et al. [28] with $T_n = 0.28\ T_{out} + 18.5$ ($R^2 = 0.427$) and $T_{pref} = 0.2\ T_{out} + 19.6$ ($R^2 = 0.237$) in the Mediterranean climate of Chile. In the context of tropical climate of Ghana, Mohammadpourkarbasi et al., found $T_{comf} = 0.41 \times T_{out} + 18.21$ in NV mode. However, their study was focused only during dry season. Findings also align with Lei et al. [14] and Kim et al. [53], who observed that adaptive comfort in mixed-mode buildings depends not only on climatic context but also on building operation mode (NV or AC).

Fig. 12 reveals significant seasonal variations in both neutral (T_n) and preferred (T_{pref}) temperatures, with higher values observed during the HS compared to the CS, reflecting occupants' thermal acclimatization. Notably, during HS, T_n and T_{pref} frequently exceed the upper limits of static standards (ASHRAE 55 at 0.5 Clo and EN 16798-1 Category III), suggesting these norms underestimate thermal comfort requirements in hot climates. In contrast, in CS, values align more closely with standard thresholds. In CS, all the values of T_n and T_{pref} adjust well to the range defined by ASHRAE 55 for 0.5 Clo. These findings highlight a fundamental limitation of steady-state comfort models, which fail to fully

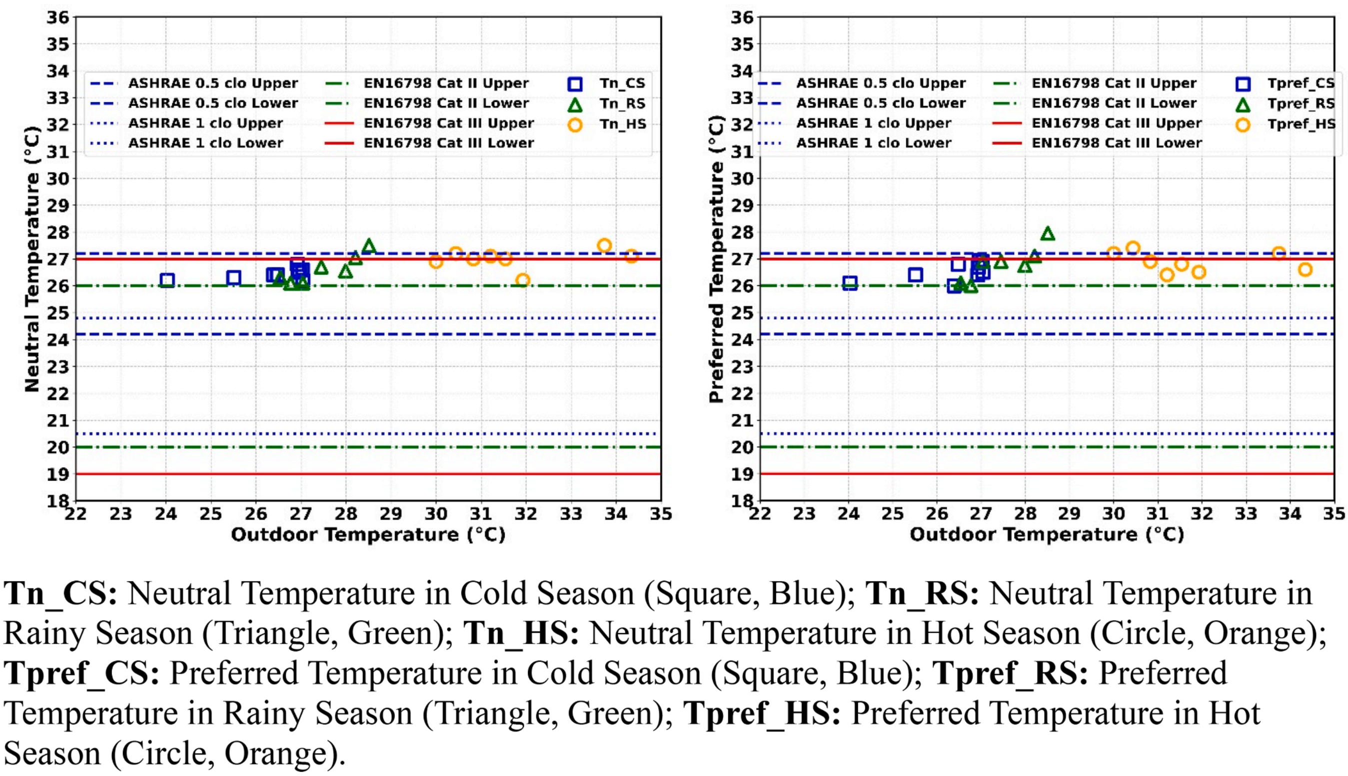


Fig. 12. Relationship between neutral and preferred temperature and comfort standards with the steady-state method. **Tn_CS:** Neutral Temperature in Cold Season (Square, Blue); **Tn_RS:** Neutral Temperature in Rainy Season (Triangle, Green); **Tn_HS:** Neutral Temperature in Hot Season (Circle, Orange); **Tpref_CS:** Preferred Temperature in Cold Season (Square, Blue); **Tpref_RS:** Preferred Temperature in Rainy Season (Triangle, Green); **Tpref_HS:** Preferred Temperature in Hot Season (Circle, Orange).

capture seasonal adaptive behaviors, particularly in HS, where occupants demonstrate higher heat tolerance. From a practical perspective, the results advocate for revising current standards to incorporate climate-specific adaptive approaches, emphasizing flexible thermal thresholds and passive cooling strategies that account for observed seasonal variations and local comfort behaviors in building design and operation. These findings align with other studies such as [43] in the tropical climate in Ghana, and study from Maohui Luo et al. [8] in the subtropical climate context of Shenzen, China, who found that compared to the steady state comfort model, the adaptive model was found to be more applicable to MM buildings, especially when NV was being utilized. In the Australia context, Jungsoo Kim et al. [53] found that occupants were more tolerant of, or adaptive to indoor temperature variations during the NV operation period than the AC period.

To evaluate how the occupants' neutral and preferred temperatures compared with the international thermal comfort thresholds, the measured values were contrasted with the upper limit of the ASHRAE 55 (0.5 Clo) and EN16798-1 (Cat. III) comfort bands. The analysis revealed that most neutral and preferred temperatures remained below this threshold, with only a few cases exceeding it by during Hot Season. Specifically, neutral temperatures (T_n) exceeded the ASHRAE limit with a maximum difference of + 0.3 °C, while preferred temperatures (T_{pref}) were reaching up to + 0.7 °C. For EN 16798-1 (Cat. III), the exceedance is respectively + 0.5 °C and + 0.9 °C. The average difference between measured comfort temperatures and the standard's upper bound was approximately in the range [0.5 – 0.7] °C. These findings indicate that although current international standards comfort range adequately captures most of the observed conditions, occupants in mixed-mode office buildings in Ouagadougou appear to tolerate slightly warmer indoor environments. An average difference of 2.1 °C in AC mode were estimated when Mohammad et al. [43] compare their proposed model with those international standards. Consequently, a modest upward adjustment of the upper comfort limit could better reflect local adaptive behaviour and comfort expectations under semi-arid climatic conditions. This finding consistent with previous study of Khoshbakht et al. [18] in Australia who found neutral temperature to be about 0.5 °C higher than the predicted neutral temperature by ASHRAE 55 under both modes of operation.

3.7.0.1. Implications for standards, design, and energy frameworks

Field measurements in Burkina Faso show that neutral (T_n) and preferred (T_{pref}) temperatures range from 26.1 °C to 30.3 °C across seasons, often exceeding the upper limits of ASHRAE 55 and EN 16798-1 steady-state models, particularly during the hot season. Strong negative correlations between thermal sensation (TSV) and thermal preference (TPV), ρ = -0.855 in AC mode and, 0.765 in NV mode, confirm significant adaptive behavior among occupants. These findings suggest that current international comfort thresholds are restrictive for this context. Occupants in semi-arid tropical climates exhibit higher heat tolerance than those in temperate regions on which the international standards are based. Similar conclusions were reported in previous studies conducted in warm and humid regions of India [54], the Middle East [55], and Sub-Saharan Africa [56], all indicating that comfort temperatures can reach or exceed 31–33 °C without significant decreases in acceptability. However, this study supports the extension of the upper limits beyond the current international standard thresholds in AC mode. Burkina Faso should consider developing adaptive national standards based on local data, accounting for seasonal variation and behavioral patterns such as clothing and ventilation use. In terms of design, passive cooling strategies and natural ventilation should be prioritized, especially as T_n increases by approximately 2 °C from the cold to the hot season. Energy certification frameworks must also recalibrate comfort assumptions to avoid overestimating cooling needs, particularly in NV buildings where T_{pref} aligns more closely with operative temperature (T_{op}). Nonetheless, further studies across other cities and building types in Burkina Faso and West Africa are necessary to validate these results and support the development of regionally appropriate standards.

4. The study limitations

While this study provides valuable insights into thermal comfort in office buildings in Burkina Faso, some limitations must be acknowledged. The data were collected from a limited number of mixed-mode office buildings in a single urban area (Ouagadougou). Results may not fully represent other climatic regions of Burkina Faso or Sub-Saharan Africa such as Bobo Dioulasso (warm desert climate, BWh) and Dori (tropical savanna climate, Aw), as illustrated in Fig. 1.b, also with different microclimates or building typologies. Additionally, although seasonal variation was captured, the number of case studies and occupants per mode (AC/NV) remains limited. Broader sampling across building types and socio-professional profiles is needed to generalize findings. Studies have shown that thermal sensitivity—and thus the appropriate Griffiths coefficient—can vary significantly depending on whether the space is naturally ventilated, air-conditioned, or mixed-mode, as well as by age, gender, and region [51]. Using a fixed value of 0.5 K can therefore introduce estimation errors in neutral temperature [57]. For example, Mohammadpourkarbasi et al. [43] performed a sensitivity analysis to obtain the appropriate value of the α-coefficient. These limitations highlight the need for expanded field studies to validate the observed comfort ranges and correlations, and to support the development of regionally adapted thermal comfort standards.

5. Conclusion

Focusing on eight mixed-mode office buildings in Ouagadougou, Burkina Faso's capital city, this investigation evaluated workspace thermal comfort using both neutral temperature (T_n) and preferred temperature (T_{pref}) parameters. The results provide valuable insights into the actual thermal conditions experienced by office workers, with significant findings indicating that:

- Occupants' actual thermal sensation and thermal preference varied when the building switched between air-conditioned (AC) and naturally ventilated (NV) modes, as found in other studies [8]. Occupants in MM are more adaptive in NV mode [37].
- Analysis shows that despite 71 % of subjects experiencing thermally neutral conditions (between −1 and + 1 on the sensation scale) and more than half expressing no desire for environmental changes, the overall comfort levels remain significantly lower than those observed in other thermal comfort studies [29,43].
- More than 54 % of the respondents who reported a thermal preference for no change (TPV = 0) at the same time indicated a thermal sensation different from "neutral" (TSV = −2, −1, 1, and 2), which suggests that the sensation of comfort could occurs at a different point other than neutral.
- Analysis revealed neutral temperatures between 26.1 °C and 30.3 °C and preferred temperatures spanning 26.8 °C and 30.3 °C across all observed cases. Seasonal fluctuations demonstrated statistically significant variation.

- The observed congruence between preferred and operative temperatures reinforces existing thermal adaptation theory. As shown in similar studies, occupants naturally adapt to indoor conditions through behavioral modifications, including window adjustments [28,49,58].
- Contrary to operative temperature, neutral thermal sensation demonstrates a more pronounced relationship with outdoor temperature, consistent with the adaptive model framework. Furthermore, a significant inverse correlation exists between clothing insulation (Clo) and outdoor temperature, indicating substantial seasonal adaptation through clothing adjustments. These observations align with existing literature on thermal adaptation in office environments [28].
- Field measurements reveal that ASHRAE 55′s 80 % acceptability limits and EN 16798-1 Category III criteria remain valid for mixed-mode buildings operating in NV mode, where occupants can adjust openings for ventilation. These conventional standards prove inadequate for AC operation in mixed-mode structures, especially during peak hot season conditions with an average exceedance from 0.5 °C to 0.7 °C. However, further studies are necessary to validate these results and support the development of regionally appropriate standards.

CRediT authorship contribution statement

Alphonse Bouda: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Césaire Hema:** Writing – review & editing, Supervision, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Louis Arnaud Louis Sountong-Noma Ouédraogo:** Visualization, Methodology, Data curation. **Philbert Nshimiyimana:** Writing – review & editing. **Shady Attia:** Writing – review & editing, Visualization, Validation, Methodology. **Tizane Daho:** Project administration, Methodology, Formal analysis. **Adamah Messan:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Ethics statement

This study was conducted with the prior knowledge and approval of institutional supervisors. All participants were informed about the purpose of the study and gave their verbal consent. The data were anonymized and handled in accordance with ethical research standards.

Appendix

Table A1
International Thermal Comforts Standards.

Standards	Steady-state method (AC mode)	Adaptive method (NV mode)
ISO 7730	Category A: $-0.2 < PMV < 0.2$ Category B: $-0.5 < PMV < 0.5$ Category C: $-0.7 < PMV < 0.7$	N/A
ASHRAE 55	$-0.5 < PMV < +0.5$ (PPD > 10)	Upper 80 % Accept: $T_{op} = 0.31\ T_{pma} + 21.3$ Lower 80 % Accept: $T_{op} = 0.31\ T_{pma} + 14.3$ Upper 90 % Accept: $T_{op} = 0.31\ T_{pma} + 20.3$ Lower 90 % Accept: $T_{op} = 0.31\ T_{pma} + 15.3$
EN 16798-1	Category I: $-0.2 < PMV < 0.2$	Category I Upper: $T_{op} = 0.33\ T_{rm} + 20.8$ Category I Lower: $T_{op} = 0.33\ T_{rm} + 16.8$
	Category II: $-0.5 < PMV < 0.5$	Category II Upper: $T_{op} = 0.33\ T_{rm} + 21.8$ Category II Lower: $T_{op} = 0.33\ T_{rm} + 15.8$
	Category III: $-0.7 < PMV < 0.7$	Category III Upper: $T_{op} = 0.33\ T_{rm} + 22.8$ Category III Lower: $T_{op} = 0.33\ T_{rm} + 14.8$

PMV: Predicted Mean vote; **N/A:** Does not define an adaptive method; **PPD:** Predicted Percentage of Dissatisfied; Accept: Acceptability of the method; $\mathbf{T_{op}}$: Acceptable operative temperature (∘C); $\mathbf{T_{pma}}$: prevailing mean outdoor temperature (∘C); $\mathbf{T_{rm}}$: running mean temperature (∘C).

Table A2
Summary of Thermal Comfort Field Study in Mixed-mode Buildings.

Reference (Author, Year)	Climate Type/ Location	Building Type / Ventilation Mode	Method & Metrics Used	Seasons / Sample Size	Main results
Yue Lei et al., 2025 [14]	Hot and humid tropical rainforest / Singapore	Office buildings / Mixed-mode	Field study over 20 weeks; TSV, TPV, TAV, T_{op}, SET*	Warm season; 28 participants (tropically acclimatized); Thousands of data points collected	Comfort thresholds met ASHRAE 55–2023, ISO 7730, and WELL v2 Study supports adaptive comfort models and incremental cooling strategies for tropical climates

(*continued on next page*)

Table A2 (*continued*)

Reference (Author, Year)	Climate Type/ Location	Building Type / Ventilation Mode	Method & Metrics Used	Seasons / Sample Size	Main results
Maohui Luo et al., 2015 [8]	Hot and humid subtropical / Shenzhen, China	Office / Mixed-mode office	Field study; TSV, TPV, TCV, PMV, Thermal acceptance, T_{op}	Full year; Over 50 occupants; 834 questionnaires	Showed mode-dependent comfort; adaptive model often better than PMV in NV; evidence of different neutral temps by mode.
Xinyu Jia et al., 2020 [16]	Cold zone, monsoon climate (Köppen Dwa) / Tianjin China	Office / Mixed-mode office	Field study; TSV, TPV, TCV, TAC, AVS, SET, PMV	Spring, Summer, Autumn, Winter; 47 occupants; AC-C: 157; AC-H: 270; NV: 156; Over 100,000 indoor environmental measurements during occupied hours	ASHRAE Standard 55: Adaptive model not officially applicable to MM buildings, but study shows it performs well in both NV and AC-C modes. PMV-PPD model: Overestimates thermal sensation, especially in warm conditions.
Rupp F.R. et al., 2018 [23]	Temperate and humid subtropical climate / Florianópolis, Southern Brazil	Office / Mixed-mode office	Field study; TSV, TPV, TA, TC, T_{op}, T_{comf}, T_n, SET, PMV.	Summer, winter, autumn, spring; 5470 questionnaires; ~9200 votes across NV and AC modes	Adaptive model fit NV periods well; AC periods less correlated with outdoor climate. Comfort temperatures were higher in AC mode (~24.2–24.6 °C) than NV (~22.6–23.9 °C). Study supports separate adaptive models for NV and AC modes in MM buildings.
Khoshbakht M. et al., 2023 [18]	Humid subtropical (Köppen Cfa) / Brisbane and Gold Coast, Australia	Office building / Mixed-mode ventilation	Field study; TSV, TPV, T_{op}, T_n, T_{comf}	Summer, Autumn, Winter; 884 valid responses.	ASHRAE 55′s adaptive model accurately predicts comfort in NV mode. Less accurate in AC mode due to overcooling and narrower comfort expectations.
Kim, J. et al., 2019 [37]	Humid subtropical (Köppen Cfa) / Wollongong, Australia	Offices building / Mixed-mode	Field study; TSV, TPV, TAV, T_{op}, PMV, T_n	Winter, swing seasons, summer; 909 survey responses from 31 participants; Over 140,000 data points collected during occupied hours	Adaptive comfort standards should be extended to mixed-mode buildings, especially during NV operation.
Hema C. et al., 2023 [29]	Hot-dry, Sudano-Sahelian / Ouagadougou, Burkina Faso	Offices building / Mixed-mode	Field study; TSV, T_n, T_{op},	Cold season; 93 participants; 54 offices surveyed	Findings suggest local adaptation is necessary: occupants in Burkina Faso may feel cold at 24 °C, a common design temperature in international standards. Study supports context-specific comfort models for hot-dry climates
De Vecchi, R. et al., 2017 [59]	Humid subtropical / Florianópolis, Brazil	Offices building / Mixed-mode	Field study; TSV, TPV, TAV, T_{op}, SET*, T_n, T_{comf}	Summer, Autumn, Winter, Spring; 617 occupants; 2688 questionnaires; 87 field measurement sessions.	AC: 26.9–28.9 °C NV: 29.4–31.5 °C. Occupants in Kumasi tolerate and prefer higher temperatures than those recommended by international standards.
Mohammadpourkarbasi H. et al., 2022 [43]	Tropical wet and dry (Aw) / Kumasi, Ghana	University library buildings / Mixed-mode	Field study; TSV, TPV, PMV, PMVe, T_{op}, T_{comf}	Dry season, 54 workers; 257 valid responses.	Adaptive comfort model aligned with EN15251 and ASHRAE 55 Validated the use of adaptive algorithms for MM buildings in Mediterranean climates
Yousra Rashad et al., 2024 [38]	Hot arid desert climate (Köppen classification) / Cairo, Egypt	Offices building / Mixed-mode	Field measurements and simulation	Winter; T_{comf}: not explicitly calculated. Simulations run for full-year scenarios.	Comfort range aligned with Olgyay's thermal comfort zone (21–26 °C). No direct use of ASHRAE 55 or EN15251.

TAV: Thermal Acceptability Vote; **TCV:** Thermal Comfort Vote; **SET*:** Standard Effective Temperature; $\mathbf{T_{comf}}$: Thermal Comfort.

Fig. B1. Traditional Garments illustration

Fiche A

ETUDE DE LA SENSATION THERMIQUE

N.B. : Toutes les réponses inscrites dans ce questionnaire resteront strictement confidentielles.
Veuillez ne pas en discuter avec l'un de vos collègues participant également à cette étude. Une fois le questionnaire rempli, veuillez le retourner directement à l'enquêteur SVP.
Merci pour la franche collaboration !

A. INFORMATIONS GENERALES (Réservée à la personne enquêtée)

1. **Genre :** Masculin ○ Féminin ○
2. **Âge (ans) :** 18-30 ○ 31-40 ○ 41-50 ○ 51-60 ○ Plus de 60 ○
3. **Poids (kg):** Moins de 60 ○ 61-70 ○ 71-80 ○ 81-90 ○ Plus de 90 ○
4. **Taille :** - de 1m60 ○ 1m61-1m70 ○ 1m71-1m80 ○ 1m81-1m90 ○ + de 1 m 90 ○
5. **Souffrez-vous d'un mal qui vous fait éviter la fraicheur ou la chaleur ?** Oui ○ Non ○
6. **Depuis combien de mois (ou années) vivez-vous au Burkina Faso ? :** ……………..
7. **Depuis combien de mois (ou années) occupez-vous ce bureau ? :** …………………

B. AMBIANCE THERMIQUE

N.B : Ici, nous souhaitons recueillir vos sensations thermiques. Veuillez répondre simplement en cochant.

8. **Comment vous sentez-vous actuellement ? (*Un seul choix possible*)**

Très Froid ○	Froid ○	Légèrement Froid ○	Neutre (ni froid ni chaud) ○	Légèrement chaud ○	Chaud ○	Très chaud ○

9. **Comment trouvez-vous cela ? (*Un seul choix possible*)**

Acceptable ○	Légèrement acceptable ○	Inacceptable ○	Légèrement inacceptable ○

10. **Quel état thermique préférez-vous actuellement ? (*Un seul choix possible*)**

Plus froid ○	Un peu plus froid ○	Sans changement ○	Un peu plus chaud ○	Plus chaud ○

Êtes-vous frappé par un courant d'air (climatiseur, ventilateur, air naturel) actuellement ? Oui ○ Non ○

11. **Comment trouvez-vous le mouvement d'air dans le local actuellement ? (*Un seul choix possible*)**

Très acceptable ○	Acceptable ○	Légèrement acceptable ○	Légèrement inacceptable ○	Inacceptable ○	Très inacceptable ○

12. **Que préférez-vous avoir en termes de mouvement d'air actuellement ? (*Un seul choix possible*)**

Plus de mouvement d'air ○	Pas de changement ○	Moins de mouvement ○

13. **Comment trouvez-vous le local en termes de confort thermique actuellement ? (*Un seul choix possible*)**

Très confortable ○	Confortable ○	Légèrement confortable ○	Légèrement inconfortable ○	Inconfortable ○	Très inconfortable ○

14. **Êtes-vous satisfait(e)s du niveau de confort thermique de manière générale ?** Oui ○ Non ○

C. ACTIVITÉ (ASHRAE55-2017)

15. Quelle était votre activité pendant les périodes suivantes ? (*Cochez une case par ligne***)**

Activités / Période	Assis - repos	Assis - lecture	Assis - écriture	Travail - ordinateur	Débout - repos	Débout - activité	Marché	Conduite (moto-voiture)
Il y a 1 h								
Il y a 30 min								

16. Qu'avez-vous consommé au cours de la dernière heure ? (*Plusieurs choix possibles***)**

Une boisson fraîche ○ | Une boisson chaude ○ | Une cigarette ○ | Nourriture ○ | De l'eau ○ | Rien ○

D. VÊTEMENTS (ASHRAE55-2017)

17. Qu'est ce qui correspond mieux à votre habillement actuel ? (*Un seul choix possible***)**

Vêtements (clo)	
Pantalon + Chemise manches courtes = 0,57	
Pantalon + Chemise manches longues = 0,61	
Pantalon + Chemise manches longues + plus veste de costume = 0,96	
Pantalon + Chemise manches longues + veste de costume, gilet, t-shirt = 1,14	
Pantalon + Chemise manches longues + pull à manches longues, t-shirt = 1,01	
Ensemble boubou, manches courtes = 0,60	
Ensemble boubou manches longues = 0,64	
Jupe mi-longue, chemise à manches courtes = 0,57	
Jupe longue, chemise à manches courtes, pull à manches longues = 1	
Jupe mi-longue, chemise à manches longues, demi-jupon, veste de costume = 1,04	
Jupe longue, chemise à manches longues, t-shirt = 0,61	
Robe longue à manches longues = 0,63	
Robe longue à manches courtes = 0,62	
Autres, décrire brièvement :	

18. Avez-vous tenu compte de la chaleur ou de la fraicheur pour vous habiller ? : Oui ○ Non ○

E. ACTIONS

19. Lequel (lesquels) disposez-vous dans le local ? (*Plusieurs choix sont possibles***)**

Ventilateur ○ | Climatiseur ○ | Fenêtres ouvrables ○ | Aucun ○

20. Que faites-vous lorsque vous avez chaud ou froid dans ce local ? (*Plusieurs choix possibles***)**

Réadapter mon habillement ○ | Ouvrir ou fermer les fenêtres ○ | Allumer ou éteindre le ventilateur ○ | Allumer ou éteindre le climatiseur ○ | Une combinaison des méthodes ○

21. Estimez votre temps d'utilisation du ventilateur, si applicable (*Une seule réponse possible***)**

Saison Chaude : | Jamais ○ | Moins de 3h ○ | 3h - 6h ○ | Plus de 6h ○

22. Estimez votre temps d'utilisation du climatiseur, si applicable (*Une seule réponse possible***)**

Saison Chaude : | Jamais ○ | Moins de 3h ○ | 3h - 6h ○ | Plus de 6h ○

23. Autres commentaires libres

Partie B (À remplir par l'enquêteur)

Nom et Prénom(s) – Enquêteur	Code Bâtiment – Bureau (*Ex : B_Aneree - 1*)	Date et heure de début (*Ex : 26/10/2022 - 08h25min*)	Fichier enregistré dans HD32.3

24. L'occupant a-t-il pris part à l'une des précédentes phases de l'étude ? : Oui ○ Non ○

25. Type de bureau : Bureau individuel : ○ Bureau à plusieurs : ………○

26. Enveloppe bâtiment : Bâtiments BTC ○ Bâtiments BLT ○ Bâtiments Parpaing ○

27. Façade : Vitrage Simple ○ Vitrage double ○ Briques ○

28. Le toit est-il exposé ? : Oui ○ Non ○

29. Y a-t-il des arbres aux alentours du bâtiment ? : Oui ○ Non ○

30. Conditions de contrôle pendant l'enquête :

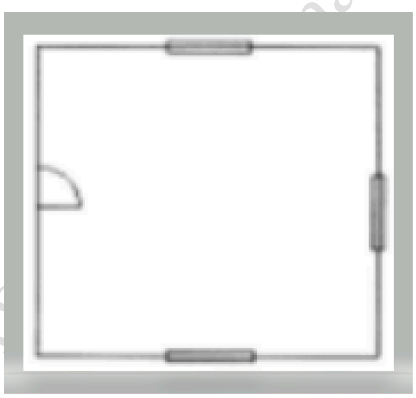
	Ouvert(e)	Fermé(e)			Allumé(e)	Éteint(e)
Porte extérieure				**Ventilateur**		
Porte du balcon				**Climatiseur**		
Fenêtre				**Lumière**		
Store/Rideau						

31. Période d'enquête : Saison chaude ○ Saison Froide ○ Saison Pluies ○

32. Visibilité du ciel : Clair ○ Nuageux ○ Ni l'un ni l'autre ○

33. Marquer sur la figure ci-dessous, la position des éléments suivants : Personne (X) ; Ventilateur (V) ; Climatiseur (C) ; Autre source de chaleur (H) ; Mur exposé (E) ; Mur non exposé (NE).

Marquer le Nord !



34. Autres commentaires :

35. Paramètres Environnementaux :

Conditions Extérieures			Conditions Extérieures							
Tn (°C)	Ta (°C)	Va (m/s)	Hr (%)	Tg (°C)	Tr (°C)	$WBGT_{in}$(°C)	$WBGT_{out}$(°C)	Ta_{ext}(°C)	Hr_{ext} (%)	Va_{ext} (m/s)

Heure de fin : ………………………

Data availability

The datasets collected and analysed during the current study are not publicly available but are available from the corresponding author upon reasonable request.

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