JSACE 2/38

Assessment of Indoor Thermal Comfort Criteria and Challenges Across the African continent

Received 2025/01/29

Accepted after revision 2025/09/17

Assessment of Indoor Thermal Comfort Criteria and Challenges Across the African continent

Aleksejs Prozuments*, Anatolijs Borodinecs

Riga Technical University, Faculty of Civil and Mechanical Engineering, Institute of Sustainable Building Materials and Engineering Systems, Riga, Latvia

Adamah Messan, Kokouvi Edem N'tsoukpoe, Philbert Nshimiyimana, Césaire Hema, Daniel Yamegueu Nguewo

Institut International d'Ingénierie de l'Eau et de l'Environnement (Institut 2iE), Laboratoire Eco-Matériaux et Habitats Durables (LEMHaD), Ouagadougou, Burkina Faso

Mohamed Tariq Kahn, Efe Orumwense

Department of Electrical, Electronic and Computer Engineering, Cape Peninsula University of Technology, Bellville, Cape Town, South Africa

Christophe Ménézo

Universté Savoie Mont Blanc, Laboratoire proCédés énergle bâtimEnt – LOCIE, Institut National de l'Energie Solaire – INES Le Bourget-du-Lac, France

Adey Feleke Desta

College of Natural Sciences, Addis Ababa University, Addis Ababa, Ethiopia

*Corresponding author: **aleksejs.prozuments@rtu.lv**

https://doi.org/10.5755/j01.sace.38.2.40349

Abstract

The assessment of indoor thermal comfort across Africa reveals significant challenges arising from the continent's diverse climatic conditions, infrastructural disparities, and socio-economic limitations. The absence of unified thermal comfort standards further complicates efforts to ensure adequate indoor environments, as existing regulations vary widely between countries. While some nations reference international standards like ASHRAE and ISO, many lack locally adapted guidelines that account for regional climate variations and construction practices. This study examines the current landscape of thermal comfort standards in Africa, identifies key challenges—including increasing urbanization, rising temperatures due to climate change, and inadequate building codes—and evaluates the effectiveness of existing regulations. The findings indicate that many African buildings, particularly in low-income and informal settlements, are highly susceptible to overheating, with indoor temperatures frequently exceeding comfort thresholds. To address these challenges, this study highlights the need for climate-responsive building codes, improved policy frameworks, and enhanced professional expertise in thermal comfort assessment. Strengthening regulatory guidelines, incorporating passive cooling strategies, and promoting further research on localized thermal comfort thresholds are essential steps toward creating healthier indoor environments. A comprehensive, region-specific approach is crucial to improving indoor thermal comfort, public health, and sustainable building practices across Africa.

Journal of Sustainable Architecture and Civil Engineering
Vol. 2 / No. 38 / 2025
pp. 161-176
DOI 10.5755/j01.sace.38.2.40349

Keywords: recycled rubber crumb (RRC); mechanical performance and pavement durability; environmental impact mitigation through RRC; sustainable pavements; modified asphalt mixtures.

Introduction

As the global climate change and its associated impact is becoming more pronounced worldwide, with 2024 being the hottest year on record (the recorded temperature anomaly of 1.17oC) and four of the hottest years recorded occurring within the last five years (Lindsey & Dahlman, 2024), urban scholars have increasingly directed their attention towards regions in the developing world, in large part driven by substantial economic and population growth occurring within these regions (Kelly & Ngo Nguéda Radler, 2024). Over the past decades there has been an undisputed evidence of rising temperatures across the world, that has led to a growing concern of more extreme weather patterns and regular seasonal heat waves globally (Lindsey & Dahlman, 2024; Marcotullio et al., 2021; Yadav et al., 2023). As such, building occupants are at an ever increasing risk to overheating exposure which is already emerging as an existing issue in many buildings (Laouadi et al., 2020; Murtagh et al., 2019; Pathan et al., 2017). With an advent of higher temperature patterns in both winter and summer seasons, it is suggested that the building cooling requirement will be continuously increasing with respect to heating/cooling energy consumption per floor area (Khourchid et al., 2022). While with regards to the population density and quality of life much attention has been set on Asian continent, projections indicate a shift towards Africa, which is anticipated to undergo substantial population growth and urbanization (Akinsola et al., 2022; Gutu Sakketa, 2023). Africa is one of the continents most vulnerable to climate change (Kelly & Ngo Nguéda Radler, 2024). By the end of the twenty-first century, Africa's total population is projected to exceed 4.4 billion, comprising over 90% of Asia's population (Güneralp et al., 2017; Iyakaremye et al., 2021; UN, 2018). Despite these demographic changes, uncertainties persist regarding the potential economic outcomes of urbanization in African nations, where more than half of the global extremely poor currently reside, and the World Bank projections suggest that by 2030, nine out of ten extremely poor will be in the African continent (World Bank, 2015, 2018). In parallel, climate analysts project increased climate change impacts driven by human activities. Among the various climate risks, high temperature events pose a significant threat to urban residents, with projections indicating increases in frequency, intensity, and duration of heat waves (Marcotullio et al., 2021). Recent studies suggest that the number of high-temperature events has already increased globally, including in urban areas (Matthews et al., 2017). While research has projected these trends globally, there remains a lack of understanding regarding the specific impacts on African cities, particularly in terms of urban heat wave vulnerability and the scale of potential impacts (Mora et al., 2017). This study aims to assess these aspects by providing estimates of urban population exposure to heat events across Africa, offering insights into the potential challenges and vulnerabilities faced by urban populations in the region. In addressing these challenges, the importance of ensuring indoor thermal comfort emerges as a crucial aspect of human health and well-being. With rising temperatures and an increase in extreme weather events, establishing and maintaining optimal indoor environmental conditions becomes essential to mitigate adverse health effects associated with temperature extremes (Arriazu-Ramos et al., 2023). However, the continent's diverse climates and varying levels of infrastructure development present certain challenges in establishing unified standards for indoor thermal comfort (Verma, 2020). As temperatures rise and heatwaves become more frequent and prolonged, the risk of heat-related illnesses and mortality escalates (Yadav et al., 2023). Conversely, inadequate indoor heating in regions susceptible to cold extremes can lead to increased susceptibility, particularly among vulnerable population groups such as the elderly and infants (Iyakaremye et al., 2021; Su et al., 2024). In this context, it is necessary to establish and maintain optimal indoor environmental conditions. Africa's extensive geographical range and climatic variability pose significant challenges in achieving this goal. The continent encompasses a wide range of climates, from equatorial rainforests to Mediterranean coastlines and high-altitude plateaus. Within these diverse climatic zones lie distinct challenges and considerations for indoor thermal comfort regulation (Hugo et al., 2021). Moreover, the level of infrastructure development and access to resources vary widely across African countries. While urban centers may have modern, climate-controlled buildings, rural communities often contend with inadequate housing stock, limited access to electricity, and reliance on traditional building materials and construction techniques (Emodi et al., 2022). Bridging this urban-rural divide in terms of thermal comfort infrastructure represents a pressing challenge for policymakers and stakeholders (Ye & Koch, 2023). Additionally, it is crucial to address global environmental concerns related not only to the energy consumption for achieving thermal comfort but also to the widespread use of cement in concrete buildings, particularly in urban areas across Africa. The thermal properties of cementitious concretes are basically not appropriate for achieving thermal comfort. Research by Farhan et al. (2020) highlights that the world produces an average of 4 billion tons of Portland cement annually, with an annual growth rate of 4%, emphasizing the urgent need for sustainable alternatives (Farhan et al., 2020). Provided this complexity and diversity, developing unified standards for indoor thermal comfort in Africa presents a significant challenge. While international standards, such as those established by ASHRAE, offer valuable guidance, they must be contextualized and adapted to the climatic, socio-economic, and cultural realities of the African context (S. Chen et al., 2020; Földváry Ličina et al., 2018; Wang et al., 2020). Local building codes and regulations play a crucial role in this regard, serving as the primary mechanism through which indoor environmental quality is regulated and enforced. However, significant gaps and challenges persist in the current landscape of indoor thermal comfort regulation across Africa. Insufficient research and data on local climatic conditions, coupled with limited capacity and resources for implementation and enforcement, hinder progress towards comprehensive and effective unified standard development (O. Efeoma & Uduku, 2014). Moreover, the rapid pace of urbanization and infrastructure development exacerbates these challenges, with many buildings inadequately equipped to endure the challenges posed by a changing climate (Naicker et al., 2017).

Considering these challenges, a streamlined approach is needed to develop and implement standards and guidelines for indoor thermal comfort across the African continent. This requires a multi-disciplinary approach that encompasses research, policy formulation, capacity-building, and stakeholder engagement. This study examines the current landscape of thermal comfort standards in Africa, identifies key challenges including increasing urbanization, rising temperatures due to climate change, and inadequate building codes—and evaluates the effectiveness of existing regulations.

This review study selected countries and standards based on their representation of Africa's diverse climatic zones, socio-economic contexts, and documented presence of building regulations or practices addressing indoor thermal comfort. Sources were drawn primarily from peer-reviewed academic journals, regulatory documents, and global climate databases, ensuring a comprehensive and regionally diverse perspective.

Current landscape of indoor thermal comfort standards

Across the African continent, a diverse array of standards, guidelines, and regulations govern indoor thermal comfort. Some countries adhere to internationally recognized benchmarks such as those set by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), while others have developed local building codes designed to accommodate their environmental, socio-economic, and climatic contexts and infrastructural capacities (Rincón et al., 2019). For instance, South Africa's National Building Regulations incorporate aspects of indoor environmental quality, including lighting and ventilation, although the specific focus on thermal comfort remains relatively limited. Some of the standards and guidelines used in African countries are highlighted in Table 1 and might include:

- **ASHRAE standards –** some African countries refer to standards published by ASHRAE, such as ASHRAE 55 and ASHRAE 62.1, which provide guidance on thermal comfort and indoor air quality (e.g., Ghana, Burkina Faso) (Dodoo & Ayarkwa, 2019; B. I. Ouedraogo et al., 2012)
- **Local building codes / regulations –** some African countries have their own building codes and regulations that address various aspects of construction, including indoor environmental quality. These codes might include provisions related to thermal comfort, ventilation, and heating/cooling systems (e.g., South Africa, Nigeria, Morocco).

South Africa: In South Africa, for instance, the National Building Regulations provide guidelines and requirements for various aspects of construction, including indoor environmental quality. Part O: Lighting and Ventilation of the South African National Building Regulations (NBR) specifically deals with environmental sustainability, including thermal comfort. While not exclusively focused on thermal comfort, the regulations do encompass aspects related to energy efficiency and indoor environmental quality, which includes considerations for thermal conditions (Matandirotya et al., 2021).

Morocco: According to the General Building Regulations of Morocco (NM ISO 7730 2010), the annual heating and cooling requirements for the building need to meet the adapted reference temperature values fixed at 20 °C in winter and 26 °C in summer (Lamrani Alaoui et al., 2023).

Nigeria: Due to the differences in temperatures in the different regions of Nigeria, there are no accepted thermal requirements and regulations that cover the whole country. However, research done in this area has developed adaptable reference temperatures for areas in the North, East, West and the South of the country (Adunola, 2014).

Ethiopia: According to the code of practice for mechanical ventilation and air-conditioning of buildings (ES-EBCS 11, 2003), the operative temperature should be maintained in the ranges of 23 to 25 degree Celsius and the air movement should not exceed 0.3 m/s, at 1.5 meters from the floor (Ethiopian Standards Agency, 2003).

Kenya: The first building code standard in Kenya was established with the Local Government Order and was operationalized in 1968 (Kenya, Ministry of Local Government, 1968) and has long been applicable for the ventilation of buildings in Kenya. Although the optimal temperature for cooling is not specified, the code elaborates the need for openable windows sufficient enough for air circulation in rooms with specific services (living rooms, kitchen, pantries, etc.). Additionally, the Kenya Bureau of Standards (KEBS) has published a more comprehensive building code, with the ventilation codes unchanged (Kenya Bureau of Standards (KEBS), 2009). Since 2019, Kenya has begun implementing the Eurocodes and an incoming code, which aims to revolutionize the construction sector of Kenya, is underway (Lagat et al., 2024).

Rwanda: The first building code in Rwanda was the Rwanda Building Control Regulations, which was issued by the Rwandan Ministry of Infrastructure in 2009 and was updated in 2012 by the Rwanda Housing Authority to reflect the current needs and to be in harmony with other major legal tools. According to both versions, buildings are required to have effective ventilation in coherence with the size of the room (Rwanda Housing Authority, 2012).

- **International standards –** some African countries adopt international standards from organizations such as the International Organization for Standardization (ISO), such as Morocco and Senegal. ISO 7730, for example, provides guidelines for the evaluation of thermal environments and is often referenced for indoor thermal comfort assessments (Lamrani Alaoui et al., 2023).
- **Regional guidelines and practices –** guidelines provided by a group of experts gathered by the Institute of Energy and Environment of La Francophonie (IEPF), who provided guidelines and recommendations based on local climate conditions, cultural preferences, and available resources. The proposed approach is widely adopted in tropical countries, especially in West and Central Africa. (IEPF, 2010)

- **Local guidelines and practices** - in some cases, countries develop their own guidelines or recommendations based on local climate conditions, cultural preferences, and available resources.

Table 1

The overview of the standards, regulatory norms and guidelines with regards to indoor thermal environment across African countries

Country / region	Standards referenced	Key regulations
South Africa	ASHRAE 55, 62.1	No specific national thermal comfort standard
Morocco	ISO 7730	20°C (winter) / 26°C (summer)
Nigeria	None	Regional reference temperatures exist but not standardized
Ethiopia	Local code	23–25°C indoor operative temperature
Kenya	Local building codes	Natural ventilation required, no specific temperature thresholds
Rwanda	Local building codes	Effective ventilation required, no temperature guidelines
UEMOA (Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal, Togo)	Energy Efficiency Directives	Min. EER for AC units, 7 sub-climatic zones defined
ECOWAS (Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo)	ECOSTAND 071-2	Regional energy performance standards for AC systems
IEPF (Francophone Africa: Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Mali, Niger, Senegal, Chad, Togo)	IEPF Guidelines	Recommendations for air conditioning design and indoor temperatures

A critical review of the regulatory landscape reveals substantial disparities in adaptation to local climatic realities. For instance, Morocco has adopted and localized ISO 7730 by fixing operative indoor temperatures at 20°C for winter and 26°C for summer, aligning well with its regions which lies within the Mediterranean climate. In contrast, South Africa, despite having National Building Regulations addressing lighting and ventilation, lacks specific thermal comfort standards, leading to inconsistencies in protecting occupants during extreme heat events. Similarly, Nigeria experiences regional variations without a *harmonized* national standard, complicating efforts to ensure uniform indoor comfort. These findings emphasize the need for establishing climate-responsive and regionally adapted regulatory frameworks to ensure consistent and effective indoor thermal comfort standards across the African continent.

Challenges in addressing thermal comfort

Despite efforts to adopt international standards and develop local regulations, substantial gaps persist in comprehensively addressing indoor thermal comfort across Africa. The scarcity of research and region-specific standards exacerbates these challenges. For instance, South Africa's lack of thermal comfort standards stems from a scarcity of research correlating mean monthly temperatures with comfort levels, emphasizing a deficiency in understanding and addressing the prerequisites of thermal comfort. The landscape of indoor thermal comfort standards across the African continent reflects a varied array of approaches influenced by diverse climatic, socio-economic, and infrastructural considerations. While some countries rely on adherence to internationally recognized standards out of necessity, others have developed context-specific regulations designed to their respective contexts. The geographical expanse and climatic diversity of the continent of climate zones present challenges for regulating indoor thermal comfort. Ranging from the humid tropical rainforest zone to the arid desert zone, variations in temperature, humidity, and precipitation require development of tailored strategies for maintaining comfortable indoor environments (Table 2).

Table 2

Indoor thermal comfort criteria and reported comfort temperatures across various African climate zones

Climate Zone	Description	Temperature range (°C)	Humidity range (%)	Countries	ITC requirements	Reported thermal comfort temperature (°C)
Tropical	High temperatures, heavy rainfall year-round	24°C - 28°C	70% - 90%	Democratic Republic of Congo, Central Africa, Nigeria, Ghana, Cameroon	Cooling systems to maintain comfortable temperatures and humidity levels.	25.5°C to 28.3°C (A. L. S.-N. Ouedraogo et al., 2022a)
Equatorial	High temperatures, significant rainfall, and humidity year-round	25°C - 30°C	75% - 95%	Uganda, Gabon, Kenya, parts of West Africa, Equatorial Guinea	Consistent cooling systems and dehumidifiers to manage high temperatures and humidity.	22°C to 29°C (René Tchinda & Djongyang, 2013)
Semi-arid	Wet and dry seasons, warm to hot temperatures, mix of grasslands and scattered trees	20°C - 35°C	30% - 60%	Burkina Faso, Nigeria, Namibia, Botswana, Mali, Senegal	Cooling during hot periods and heating during cooler times may be required.	25.5°C to 28.3°C (B. I. Ouedraogo et al., 2012)
Desert	Extremely high daytime temperatures, low nighttime temperatures, low humidity, minimal rainfall	30°C - 45°C	10% - 30%	Sahara Desert, North Africa, Egypt, Morocco, Algeria, Libya	Heavy reliance on cooling systems. High potential for passive or hybrid cooling systems. Adequate insulation is important to minimize heat infiltration.	27.4°C and 30.3°C (Bassoud et al., 2021)

Climate Zone	Description	Temperature range (°C)	Humidity range (%)	Countries	ITC requirements	Reported thermal comfort temperature (°C)
Subtropical	Mild, wet winters and warm, dry summers	10°C - 30°C	50% - 70%	Parts of South Africa, Western Cape, Zimbabwe, Swaziland	Both heating and cooling systems may be necessary to adapt to seasonal temperature variations.	23.0°C to 26.0°C (Matandirotya et al., 2021; Naicker et al., 2017)
Mediterranean	Mild, wet winters and hot, dry summers	10°C - 35°C	50% - 70%	Morocco, Tunisia, Egypt, Northern Libya	Cooling ir re-quired, some heating necessary during cooler period of the year.	24.5°C to 27.5°C (Lairgi et al., 2021)
Highland	Cooler con-ditions due to elevation, general-ly cooler temperatures	0°C - 20°C	40% - 80%	Ethiopian highlands, mountain-ous areas in Africa, Kenya, Lesotho	Heating systems are often necessary, especially during colder seasons.	20.0°C to 24.0°C (Ogoli, 2007)

Challenges related to the current indoor thermal conditions

Ogbonna et. al. (2008) carried a study in Nigeria, where 200 subjects residing in naturally-ventilated buildings provided cross-sectional thermal comfort data for July and August 2006. Indoor climatic data, collected using portable laboratory-grade instruments compliant with ANSI/ASHRAE 55 and ISO 7726 standards, revealed a mean clothing-insulation value of 0.46 clo for the entire sample. The recorded indoor temperature surpassed 26°C 68% of the time, exceeding the overheating criteria stipulated by the standard, while mean relative humidity recorded across sample locations surpassed the 65% threshold recommended by ASHRAE 55, emphasizing the potential challenges in overheating and moisture control (Ogbonna & Harris, 2008). In South Africa, for example, the National Building Regulations encompass various aspects of indoor environmental quality, albeit lacking clear thermal comfort standards. This gap stresses the need for further research and development efforts to bridge the divide between regulatory frameworks and the evolving needs of building occupants (van der Walt et al., 2024). Moreover, the absence of region-specific standards highlights the broader challenge of extrapolating international guidelines to diverse climatic zones and cultural contexts within Africa (Dodoo & Ayarkwa, 2019; Rincón et al., 2019). Rincon et. al. (2019) study focused on assessing thermal neutrality using the ASHRAE 7-point scale pinpointed a temperature of 26.27°C as the threshold, aligning closely with local weather data in sub-Saharan Africa. However, discrepancies were noted between PMV-determined neutrality and direct votes, suggesting limitations in PMV predictions for naturally-ventilated buildings. As such, the study highlighted the importance of night ventilation and solar protections in mitigating indoor overheating, particularly in hot semi-arid climates (Rincón et al., 2019). Ouedraogo et al. (2022) conducted a study in Burkina Faso where a new decision-making tool for the evaluation of the thermal comfort in buildings has been proposed. This tool is based on a comfort index that allows for better and easier design, assessment and improvement of the thermal environment of buildings. This study allowed the characterisation the thermal comfort of the three climatic zones of Burkina Faso namely Bobo-Dioulasso, Dori and Ouagadougou; which evolved between 25.5 and 28.3 °C. It also made it possible to characterize the thermal comfort of experimental pilot buildings representative of the common housing encountered in Burkina Faso. Experimentations have then been carried out on two natural ventilation pilot buildings located in Ouagadougou. The results show that the pilot building, whose walls are made of Earth blocks, achieves 26.4% of thermal comfort while the building made of hollow cement block achieves 25.8% of thermal comfort. (Ouedraogo et al., 2022a). Hema et. al. (2024) carried out a study in Burkina Faso to determine the acceptable temperatures for thermal comfort and analyze the energy consumption related to the use of air conditioning systems to reach such temperatures in a mixed-mode office building. Through a survey and data collection, the study identified neutral air temperature and operative temperature which are between 26.2°C and 26.5°C, and 26.3°C and 26.5°C, respectively. This was confirmed by the activation air conditioning system when the air temperature reaches or exceeds the threshold of thermal neutrality. There was not a significant difference between the neutral temperature of male and female subjects. These findings can serve as a starting point for establishing thermal comfort parameters and design of mixed-mode office buildings in Sudano-Sahelian climates (Hema et al., 2024). This was also comparable to the temperature of the thermal comfort reported in other countries of the region such as 26 °C in Benin (air-conditioned and naturally ventilated office buildings), 27.4-30.3 °C in Ghana (air-conditioned and naturally ventilated office building); 24.9 to 27.7 °C in Nigeria (naturally ventilated residential building), 22 to 30 °C in Cameroon (naturally ventilated residential building. The reviewed academic studies emphasize the need for continued research encompassing longer durations and diverse climatic zones within the African continent. Methodological refinements, such as automating residential typology identification and refining traffic estimation in urban microclimate modeling, would enhance the accuracy and scalability of future studies. Overall, this review contributes to valuable insights into the dynamics of indoor thermal comfort across African countries, laying the groundwork for informed policy interventions and sustainable building practices in the face of climate change.

Indoor overheating has emerged as a significant issue across various climatic regions in Africa, particularly in renovated buildings where absence of standardized approaches to address overheating issues stresses the need for developing unified criteria and adaptable methodologies suited to diverse climatic conditions (Arriazu-Ramos et al., 2023). For instance, Matandirotya et. al. (2021) in their study found that low-cost dwellings in South Africa consistently experienced indoor temperatures above 26°C during the summer (with 53% exceeding this threshold at night), potentially posing health risks, especially for vulnerable groups like young children and the elderly, as stipulated in the WHO recommendations.

Challenges related to the variability of outdoor temperatures

The high indoor temperatures indicate the urgent need for improved thermal insulation and passive design strategies to mitigate the impacts of climate change on indoor thermal environments (Matandirotya et al., 2021). Comparative analyses between different building typologies and passive design strategies across diverse climatic contexts can offer valuable insights into effective mitigation measures, particularly in the context of evolving climate scenarios (X. Chen et al., 2023; Delgado et al., 2022; Hoyt et al., 2013). As such, the historic, contemporary (measured) and future (predictive) climate data were gathered from Meteonorm database for 7 major African cities encompassing various climatic regions of the continent as shown in Fig. 1.

City	Country	Population
Kinshasa	DR Congo	17,032,000
Lagos	Nigeria	15,300,000
Cairo	Egypt	10,100,166
Johannesburg	South Africa	6,065,354
Nairobi	Kenya	5,118,844
Casablanca	Morocco	3,840,396
Ouagadougou	Burkina Faso	3,204,322

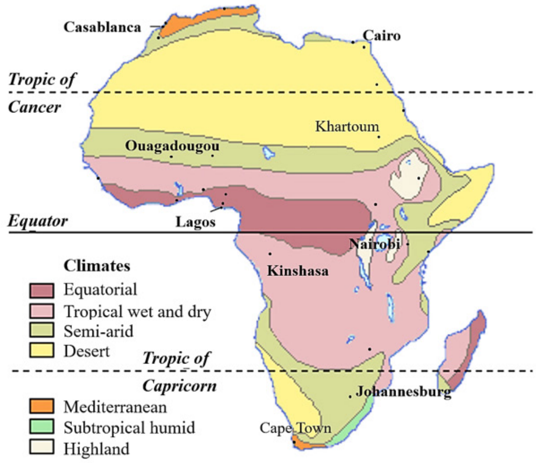

Fig. 1

Selected African cities for climate data analysis

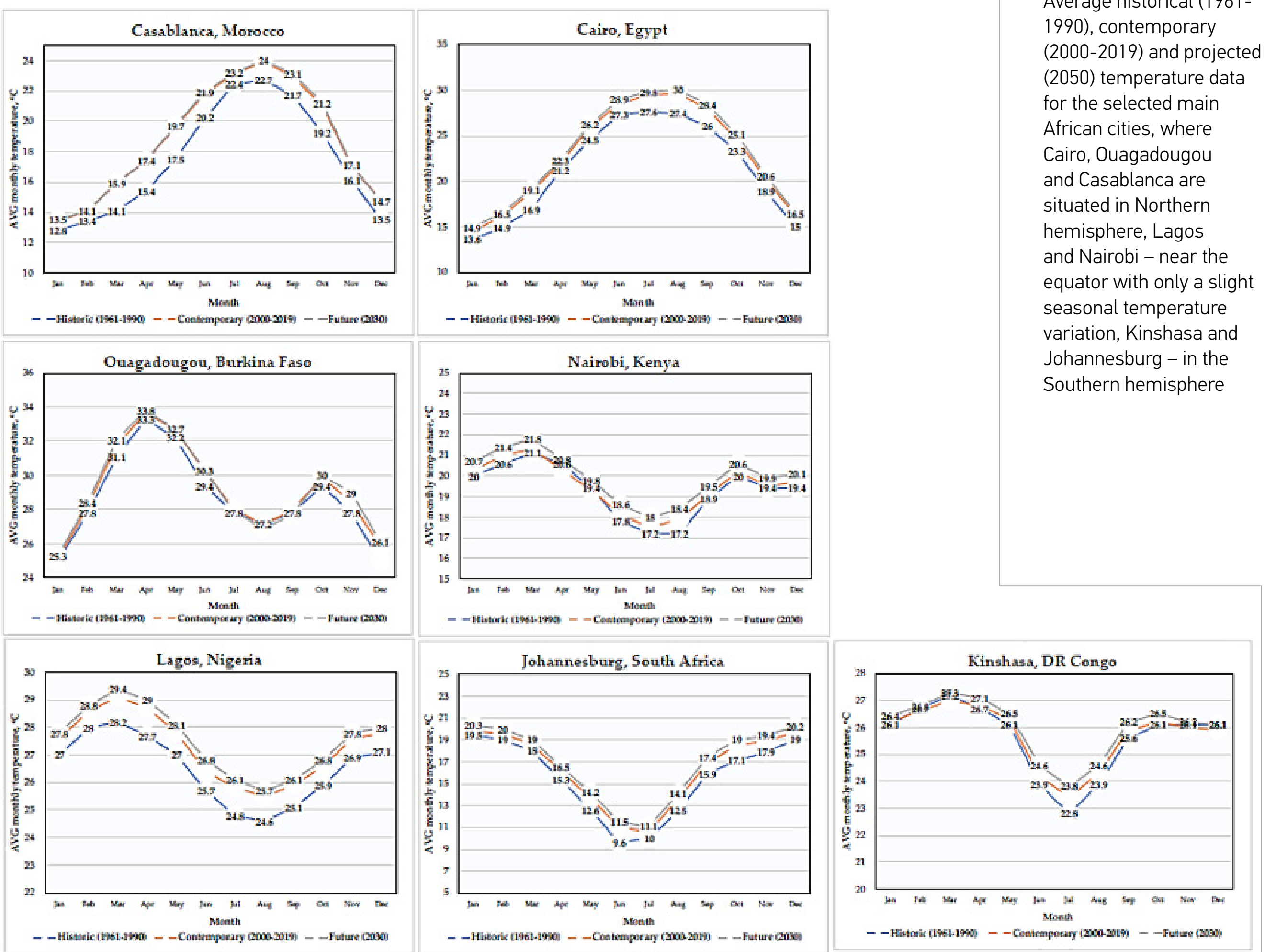

Fig. 2

Average historical (1961-1990), contemporary (2000-2019) and projected (2050) temperature data for the selected main African cities, where Cairo, Ouagadougou and Casablanca are situated in Northern hemisphere, Lagos and Nairobi – near the equator with only a slight seasonal temperature variation, Kinshasa and Johannesburg – in the Southern hemisphere

The figure suggests a gradual and consistent seasonal temperature rise, which implies a steadily increasing risk of overheating in the warm season (late spring through early fall) in the buildings. The data presented in the chart illustrates a pattern of gradual and consistent seasonal temperature increases, particularly pronounced during the warm season spanning from late spring through early fall. This trend carries significant implications for indoor thermal comfort management within buildings across the African continent, where diverse climate zones exist, ranging from humid tropical rainforests to arid deserts, and the seasonal temperature. During the warm season, which aligns with the dry season in many regions, temperatures often soar to extreme levels, especially in desert and savannah areas. This intensification of heat poses substantial challenges for maintaining comfortable indoor environments, particularly in buildings lacking adequate insulation or cooling systems. The prolonged duration of elevated temperatures during the warm season, as predicted by Meteonorm model carries an ever-increasing risk of indoor overheating, leading to discomfort and potential health hazards for occupants.

As such, buildings without effective thermal management strategies will experience increased energy consumption as occupants resort to artificial cooling methods to mitigate the discomfort. The predicted trend of gradual temperature rise stresses the importance of undertaking measures to address indoor thermal comfort in buildings, such as improved insulation, passive cooling techniques, and efficient ventilation systems to mitigate the climate impact.

Occupant behaviors, including common practices such as window-opening habits, clothing traditions adapted to local climates, preferred activity patterns, and culturally specific cooling or heating customs, play a critical role in perceived thermal comfort levels across different regions. For instance, study by Tchinda and Djongyang (2013) on naturally ventilated classrooms in Cameroon demonstrated that local clothing choices and ventilation practices significantly altered thermal acceptability thresholds compared to international standards. These socio-cultural factors often mediate the effectiveness of building designs and environmental control strategies. Therefore, future thermal comfort guidelines and regulatory frameworks must explicitly incorporate cultural dimensions to enhance their contextual relevance, acceptance, and long-term applicability across different climatic, economic, and social settings in Africa.

Strategies towards improving indoor thermal comfort

The integration of climate-responsive design principles tailored to specific regional climates can enhance the resilience of buildings against heat stress, prompting occupants' well-being and productivity. Policymakers and urban planners must prioritize the integration of passive design principles and sustainable building materials, readily accessible at relatively low energy demand and emissions, to enhance indoor thermal comfort while minimizing energy consumption (Hema et. al. (2021); Nshimiyimana et al. (2020); Moussa et. al. (2019). Furthermore, incentives for green building certification and adoption of building codes tailored to regional climatic conditions can incentivize the construction of energy-efficient and thermally comfortable buildings (Harkouss et al., 2018; Tian et al., 2018). To sum it up, achieving improved indoor thermal comfort, especially in the African context, would require using one or more of the following concepts.

Passive design strategies include designing buildings to promote natural ventilation through windows, vents, and open layouts. The orientation of the building and shading should minimize solar heat gain, especially in hotter regions. It is essential to incorporate overhangs, verandas, shutters, and vegetation to block direct sunlight. High ceilings promote better airflow and efficient heat dissipation. When considering thermal mass and insulation strategies, materials such as adobe or stabilized earth blocks may be effective in climates characterized by significant daily temperature variations, where stored heat can be gradually released during cooler night periods. In contrast, in persistently hot climates (as commonly found across large parts of the African continent), lightweight, low-thermal-capacity materials are typically more appropriate, as they reduce heat storage and facilitate faster night-time cooling. Conventional cementitious concrete, due to its high thermal conductivity and low insulation value, tends to increase indoor overheating unless supplemented with additional passive cooling measures or advanced insulation (Hema et. al. 2020; Moussa et al., 2019)

Passive cooling techniques involve using green roofs and walls to create a micro-climate around the building, which helps reduce heat absorption and enhances cooling. Incorporating green courtyards can facilitate natural cooling by providing shaded, ventilated central areas, along with utilizing reflective materials or paints to decrease the temperatures of building surfaces.

Utilizing local and sustainable materials in construction is a well-regarded strategy for enhancing indoor environments. Materials that are traditionally used and sourced locally, such as earth bricks and bio-based options like thatch, bamboo, and wood, offer better thermal performance and indoor conditions than conventional cement-based materials like concrete. Particularly, bio-based materials enable cost-effective, renewable, and recyclable insulation solutions.

In many situations, particularly in hot or hot and dry climates like those in North and West Africa, achieving thermal comfort often requires mechanized solutions rather than relying solely on natural methods. Thus, utilizing renewable and low-energy cooling options such as solar-powered fans or air conditioning, alongside optimized design and smart material selection, can effectively harness the plentiful solar energy available on the continent. These could also be done by evaporative cooling using water to cool air naturally, especially effective in dry climates.

None of the solutions mentioned above can be effective without acceptance and appropriateness from the users. Clear policies should be established to reinforce the standards and building codes. These policies ought to promote climate-responsive design and energy efficiency. Educating local practitioners- architects and builders- about thermal comfort strategies, alongside engaging homeowners in designing solutions, would be significantly more relevant for the acceptance and success of these strategies.

Conclusions

The assessment of indoor thermal comfort criteria across Africa highlights significant challenges driven by diverse climatic conditions, infrastructural disparities, and the absence of unified standards. The analysis demonstrates that Africa's broad geographical range requires the development of regional-specific standards to ensure acceptable indoor environmental conditions. One of the key findings is the inconsistency in thermal comfort regulations across African countries. While some countries incorporate internationally recognized standards such as ASHRAE and ISO, others rely on fragmented local building codes that often fail to address the specific climatic challenges of their regions. The lack of harmonized guidelines limits the ability to implement effective, large-scale improvements in thermal comfort. Another critical factor influencing indoor thermal comfort is the growing impact of climate change, which is leading to increased temperatures and prolonged heatwaves across the continent. The study confirms that rising urbanization and inadequate building designs exacerbate overheating risks, particularly in regions with limited access to efficient cooling solutions. The review of climate data from major African cities indicates a consistent temperature rise, reinforcing the need for adaptive thermal comfort strategies. To address these challenges, the study highlights the importance of strengthening building codes to incorporate climate-responsive designs that align with local climatic conditions. The development of region-specific thermal comfort guidelines is crucial to ensure that regulatory frameworks reflect the realities of both urban and rural environments. Furthermore, increasing professional expertise in thermal comfort assessment and climate-responsive architecture will be instrumental in bridging existing knowledge gaps. This can be reinforced by research and academic institutions in Africa by conducting studies and research related to indoor thermal comfort and environmental conditions. This research can contribute to the development of local guidelines and recommendations.

As such, improving indoor thermal comfort across Africa requires a multi-layered approach that integrates rigorous policy development, stronger enforcement of building standards, and continued research into region-specific comfort thresholds. A coordinated effort among policymakers, researchers, and industry stakeholders is essential to establish long-term solutions that enhance indoor environmental quality, reduce health risks, and improve overall well-being across the continent.

While this review was designed as a secondary study based on literature and climate data analysis, it did not involve primary data collection through occupant surveys, stakeholder interviews, or direct experimental evaluations of ventilation effectiveness and window configurations. Recognizing the significance of these factors in defining indoor thermal comfort, future research should integrate empirical investigations, including occupant-centered studies and building component assessments, to develop a more robust and contextually grounded understanding of thermal comfort dynamics and to enhance the formulation of climate-responsive regulatory frameworks across the African continent.

Acknowledgment

This work was supported by NATO Science for Peace and Security Programme under grant number G6245.

References

Adunola, A. O. (2014). Evaluation of urban residential thermal comfort in relation to indoor and outdoor air temperatures in Ibadan, Nigeria. Building and Environment, 75, 190-205. https://doi.org/10.1016/j.buildenv.2014.02.007

Akinsola, F. A., Ologundudu, M. M., Akinsola, M. O., & Odhiambo, N. M. (2022). Industrial development, urbanization and pollution nexus in Africa. Heliyon, 8(11), e11299. https://doi.org/10.1016/j.heliyon.2022.e11299

Arriazu-Ramos, A., Ruiz, G. R., Izquierdo, J. J. P., Gutiérrez, A. S.-O., & Monge-Barrio, A. (2023). From urban microclimate to indoor overheating: Analysis of residential typologies during typical climate series and extreme warm summer. Energy and Buildings, 299, 113620. https://doi.org/10.1016/j.enbuild.2023.113620

Bassoud, A., Khelafi, H., Mokhtari, A. M., & Bada, A. (2021). Evaluation of summer thermal comfort in arid desert areas. Case study: Old adobe building in Adrar (South of Algeria). Building and Environment, 205, 108140. https://doi.org/10.1016/j.buildenv.2021.108140

Chen, S., Wang, X., Lun, I., Chen, Y., Wu, J., & Ge, J. (2020). Effect of inhabitant behavioral responses on adaptive thermal comfort under hot summer and cold winter climate in China. Building and Environment, 168, 106492. https://doi.org/10.1016/j.buildenv.2019.106492

Chen, X., Zou, Z., Hao, F., Wang, Y., Mei, C., Zhou, Y., Wang, D., & Yang, X. (2023). Remote sensing of indoor thermal environment from outside the building through window opening gap by using infrared camera. Energy and Buildings, 286, 112975. https://doi.org/10.1016/j.enbuild.2023.112975

Delgado, J., Matos, A. M., & Guimarães, A. S. (2022). Linking Indoor Thermal Comfort with Climate, Energy, Housing, and Living Conditions: Portuguese Case in European Context. Energies, 15(16), 6028. https://doi.org/10.3390/en15166028

Dodoo, & Ayarkwa. (2019). Effects of Climate Change for Thermal Comfort and Energy Performance of Residential Buildings in a Sub-Saharan African Climate. Buildings, 9(10), 215. https://doi.org/10.3390/buildings9100215

Dunne, R., Morris, T., & Harper, S. (2022). A Survey of Ambient Intelligence. ACM Computing Surveys, 54(4), 1-27. https://doi.org/10.1145/3447242

Emodi, N. V., Haruna, E. U., Abdu, N., Aldana Morataya, S. D., Dioha, M. O., & Abraham-Dukuma, M. C. (2022). Urban and rural household energy transition in Sub-Saharan Africa: Does spatial heterogeneity reveal the direction of the transition? Energy Policy, 168, 113118. https://doi.org/10.1016/j.enpol.2022.113118

Ethiopian Standards Agency. (2003). Ethiopian Standard ES-EBCS 11: Code of Practice for Mechanical Ventilation and Air-Conditioning in Buildings.

Fang, Y., Lim, Y., Ooi, S. E., Zhou, C., & Tan, Y. (2020). Study of Human Thermal Comfort for Cyber-Physical Human Centric System in Smart Homes. Sensors, 20(2), 372. https://doi.org/10.3390/s20020372

Farhan, K. Z., Johari, M. A. M., & Demirboğa, R. (2020). Assessment of important parameters involved in the synthesis of geopolymer composites: A review. Construction and Building Materials, 264, 120276. https://doi.org/10.1016/j.conbuildmat.2020.120276

Földváry Ličina, V., Cheung, T., Zhang, H., de Dear, R., Parkinson, T., Arens, E., Chun, C., Schiavon, S., Luo, M., Brager, G., Li, P., Kaam, S., Adebamowo, M. A., Andamon, M. M., Babich, F., Bouden, C., Bukovianska, H., Candido, C., Cao, B., … Zhou, X. (2018). Development of the ASHRAE Global Thermal Comfort Database II. Building and Environment, 142, 502-512. https://doi.org/10.1016/j.buildenv.2018.06.022

Güneralp, B., Zhou, Y., Ürge-Vorsatz, D., Gupta, M., Yu, S., Patel, P. L., Fragkias, M., Li, X., & Seto, K. C. (2017). Global scenarios of urban density and its impacts on building energy use through 2050. Proceedings of the National Academy of Sciences of the United States of America. https://doi.org/10.1073/pnas.1606035114

Gutu Sakketa, T. (2023). Urbanisation and rural development in sub-Saharan Africa: A review of pathways and impacts. Research in Globalization, 6, 100133. https://doi.org/10.1016/j.resglo.2023.100133

Harkouss, F., Fardoun, F., & Biwole, P. H. (2018). Passive design optimization of low energy buildings in different climates. Energy, 165, 591-613. https://doi.org/10.1016/j.energy.2018.09.019

Hema, C., Messan, A., Lawane, A., Soro, D., Nshimiyimana, P., & van Moeseke, G. (2021). Improving the thermal comfort in hot region through the design of walls made of compressed earth blocks: An experimental investigation. Journal of Building Engineering, 38, 102148. https://doi.org/10.1016/j.jobe.2021.102148

Hema, C., Messan, A., Lawane, A., & Van Moeseke, G. (2020). Impact of the Design of Walls Made of Compressed Earth Blocks on the Thermal Comfort of Housing in Hot Climate. Buildings, 10(9), 157. https://doi.org/10.3390/buildings10090157

Hema, C., Ouédraogo, A. L. S.-N., Bationo, G. B., Kabore, M., Nshimiyimana, P., & Messan, A. (2024). A field study on thermal acceptability and energy consumption of mixed-mode offices building located in the hot-dry climate of Burkina Faso. Science and Technology for the Built Environment, 30(2), 184-193. https://doi.org/10.1080/23744731.2023.2291007

Hoyt, T., Schiavon, S., Piccioli, A., Moon, D., & Steinfeld, K. (2013). CBE Thermal Comfort Tool. Center for the Built Environment, University of California Berkeley 2013. http://cbe.berkeley.edu/comforttool

Hugo, J., du Plessis, C., & Masenge, A. (2021). Retrofitting Southern African cities: A call for appropriate rooftop greenhouse designs as climate adaptation strategy. Journal of Cleaner Production, 312, 127663. https://doi.org/10.1016/j.jclepro.2021.127663

IEPF. (2010). Efficacité énergétique de la climatisation en région tropicale. 1. Conception des nouveaux bâtiments.

Iyakaremye, V., Zeng, G., Yang, X., Zhang, G., Ullah, I., Gahigi, A., Vuguziga, F., Asfaw, T. G., & Ayugi, B. (2021). Increased high-temperature extremes and associated population exposure in Africa by the mid-21st century. Science of The Total Environment, 790, 148162. https://doi.org/10.1016/j.scitotenv.2021.148162

Kelly, A. M., & Ngo Nguéda Radler, R. D. (2024). Does energy consumption matter for climate change in Africa? New insights from panel data analysis. Innovation and Green Development, 3(3), 100132. https://doi.org/10.1016/j.igd.2024.100132

Kenya Bureau of Standards (KEBS). (2009). KS Code: Building Code of the Republic of Kenya .

Khourchid, A. M., Ajjur, S. B., & Al-Ghamdi, S. G. (2022). Building Cooling Requirements under Climate Change Scenarios: Impact, Mitigation Strategies, and Future Directions. Buildings, 12(10), 1519. https://doi.org/10.3390/buildings12101519

Lagat, D., Kivaa, T., Njuguna, M., Nyakondo, S., Maklago, E., Onkangi, R., Kamulla, C., & Kimathi, B. (2024). Factors Affecting the Physical and Functional Performance of Buildings in Kenya. Journal of the Kenya National Commission for UNESCO. https://doi.org/10.62049/jkncu.v4i1.72

Lairgi, L., Lagtayi, R., Daya, A., Elotmani, R., & Touzani, M. (2021). The Impact of Arid Climate on the Indoor Thermal Comfort in the South-East of Morocco. International Journal of Photoenergy, 2021, 1-15. https://doi.org/10.1155/2021/5554629

Lamrani Alaoui, A., Amrani, A.-I., Mousavi Ajarostaghi, S. S., Saffari Pour, M., Salhi, J.-E., Daoudia, A., & Halimi, M. (2023). An Investigation towards Optimizing the Construction Materials and Configurations of Buildings for Improving Energy Efficiency and Consumption in Morocco. Buildings, 13(7), 1705. https://doi.org/10.3390/buildings13071705

Laouadi, A., Bartko, M., & Lacasse, M. A. (2020). A new methodology of evaluation of overheating in buildings. Energy and Buildings, 226, 110360. https://doi.org/10.1016/j.enbuild.2020.110360

Leonidis, Korozi, Kouroumalis, Poutouris, Stefanidi, Arampatzis, Sykianaki, Anyfantis, Kalligiannakis, Nicodemou, Stefanidi, Adamakis, Stivaktakis, Evdaimon, & Antona. (2019). Ambient Intelligence in the Living Room. Sensors, 19(22), 5011. https://doi.org/10.3390/s19225011

Lindsey, R., & Dahlman, L. (2024). Climate Change: Global Temperature. NOAA Climate. https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

Marcotullio, P. J., Keßler, C., & Fekete, B. M. (2021). The future urban heat-wave challenge in Africa: Exploratory analysis. Global Environmental Change, 66, 102190. https://doi.org/10.1016/j.gloenvcha.2020.102190

Matandirotya, N. R., Cilliers, D. P., Burger, R. P., Pauw, C., & Piketh, S. J. (2021). Risks of Indoor Overheating in Low-Cost Dwellings on the South African Lowveld. In African Handbook of Climate Change Adaptation (pp. 1583-1600). Springer International Publishing. https://doi.org/10.1007/978-3-030-45106-6_123

Matthews, T. K. R., Wilby, R. L., & Murphy, C. (2017). Communicating the deadly consequences of global warming for human heat stress. Proceedings of the National Academy of Sciences, 114(15), 3861-3866. https://doi.org/10.1073/pnas.1617526114

Mora, C., Dousset, B., Caldwell, I. R., Powell, F. E., Geronimo, R. C., Bielecki, C. R., Counsell, C. W. W., Dietrich, B. S., Johnston, E. T., Louis, L. V., Lucas, M. P., McKenzie, M. M., Shea, A. G., Tseng, H., Giambelluca, T. W., Leon, L. R., Hawkins, E., & Trauernicht, C. (2017). Global risk of deadly heat. Nature Climate Change, 7(7), 501-506. https://doi.org/10.1038/nclimate3322

Moussa, H. S., Nshimiyimana, P., Hema, C., Zoungrana, O., Messan, A., & Courard, L. (2019). Comparative Study of Thermal Comfort Induced from Masonry Made of Stabilized Compressed Earth Block vs Conventional Cementitious Material. Journal of Minerals and Materials Characterization and Engineering, 07(06), 385-403. https://doi.org/10.4236/jmmce.2019.76026

Murtagh, N., Gatersleben, B., & Fife-Schaw, C. (2019). Occupants' motivation to protect residential building stock from climate-related overheating: A study in southern England. Journal of Cleaner Production, 226, 186-194. https://doi.org/10.1016/j.jclepro.2019.04.080

Naicker, N., Teare, J., Balakrishna, Y., Wright, C., & Mathee, A. (2017). Indoor Temperatures in Low Cost Housing in Johannesburg, South Africa. International Journal of Environmental Research and Public Health, 14(11), 1410. https://doi.org/10.3390/ijerph14111410

Nshimiyimana, P., Hema, C., Zoungrana, O., Messan, A., & Courard, L. (2020). Thermophysical and mechanical properties of compressed earth blocks containing fibres: by-product of okra plant and polymer waste. 149-161. https://doi.org/10.2495/ARC200121

O. Efeoma, M., & Uduku, O. (2014). Assessing thermal comfort and energy efficiency in tropical African offices using the adaptive approach. Structural Survey, 32(5), 396-412. https://doi.org/10.1108/SS-03-2014-0015

Ogbonna, A. C., & Harris, D. J. (2008). Thermal comfort in sub-Saharan Africa: Field study report in Jos-Nigeria. Applied Energy, 85(1), 1-11. https://doi.org/10.1016/j.apenergy.2007.06.005

Ogoli, D. M. (2007). Thermal Comfort in a Naturally-Ventilated Educational Building. Enquiry The ARCC Journal for Architectural Research, 4(2). https://doi.org/10.17831/enq:arcc.v4i2.44

Ouedraogo, A. L. S.-N., Messan, A., Yamegueu, D., & Coulibaly, Y. (2022a). A model for thermal comfort assessment of naturally ventilated housing in the hot and dry tropical climate. International Journal of Building Pathology and Adaptation, 40(2), 183-201. https://doi.org/10.1108/IJBPA-02-2021-0011

Ouedraogo, B. I., Levermore, G. J., & Parkinson, J. B. (2012). Future energy demand for public buildings in the context of climate change for Burkina Faso. Building and Environment, 49, 270-282. https://doi.org/10.1016/j.buildenv.2011.10.003

Ozel, M. (2014). Effect of insulation location on dynamic heat-transfer characteristics of building external walls and optimization of insulation thickness. Energy and Buildings, 72, 288-295. https://doi.org/10.1016/j.enbuild.2013.11.015

Pathan, A., Mavrogianni, A., Summerfield, A., Oreszczyn, T., & Davies, M. (2017). Monitoring summer indoor overheating in the London housing stock. Energy and Buildings, 141, 361-378. https://doi.org/10.1016/j.enbuild.2017.02.049

Ponce, V., & Abdulrazak, B. (2022). Ambient intelligence governance review: from service-oriented to self-service. PeerJ Computer Science, 8, e788. https://doi.org/10.7717/peerj-cs.788

RenéTchinda, & Djongyang, N. (2013). Field Study of Thermal Comfort in Naturally Ventilated Classrooms of Cameroon. Universal Journal of Environmental Research and Technology, 3, 555-570.

Rincón, L., Carrobé, A., Martorell, I., & Medrano, M. (2019). Improving thermal comfort of earthen dwellings in sub-Saharan Africa with passive design. Journal of Building Engineering, 24, 100732. https://doi.org/10.1016/j.jobe.2019.100732

Rwanda Housing Authority. (2012). Rwanda Building Control Regulations (2nd Edition).

Song, Y., Mao, F., & Liu, Q. (2019). Human Comfort in Indoor Environment: A Review on Assessment Criteria, Data Collection and Data Analysis Methods. IEEE Access, 7, 119774-119786. https://doi.org/10.1109/ACCESS.2019.2937320

Su, Y., Zhao, M., Zhang, H., Zhao, P., Wang, H., Huang, Q., & Yang, J. (2024). Numerical study of human thermal comfort in changing environments of high and low temperature. Building and Environment, 252, 111228. https://doi.org/10.1016/j.buildenv.2024.111228

Thakur. (2020). A Review of Assistive Technologies for Activities of Daily Living of Elderly. In Elderly Care: Current Issues and Challenges. Nova Science Publishers. https://doi.org/10.52305/SACY9980

Tian, Z., Zhang, X., Jin, X., Zhou, X., Si, B., & Shi, X. (2018). Towards adoption of building energy simulation and optimization for passive building design: A survey and a review. Energy and Buildings, 158, 1306-1316. https://doi.org/10.1016/j.enbuild.2017.11.022

UN. (2018). World Urbanization Prospects, 2018 Revisions. https://esa.un.org/unpd/wup/:

van der Walt, R. E., Grobbelaar, S. S., & Booysen, M. J. (2024). Dataset of indoor air parameter measurements relating to indoor air quality and thermal comfort in South African primary school classrooms of various building infrastructure types. Data in Brief, 53, 110045. https://doi.org/10.1016/j.dib.2024.110045

Verma, P. (2020). The effect of presentation, product availability and ease upon transaction reliability for online food delivery aggregator applications-moderated mediated model. Journal of Foodservice Business Research. https://doi.org/10.1080/15378020.2020.1761586

Wang, Z., Zhang, H., He, Y., Luo, M., Li, Z., Hong, T., & Lin, B. (2020). Revisiting individual and group differences in thermal comfort based on ASHRAE database. Energy and Buildings, 219, 110017. https://doi.org/10.1016/j.enbuild.2020.110017

World Bank. (2015). Growing African Cities Face Housing Challenge and Opportunity. https://www.worldbank.org/en/news/press-release/2015/12/01/growing-african-cities-face-housing-challenge-and-opportunity

World Bank. (2018). The number of extremely poor people continues to rise in Sub-Saharan Africa. https://blogs.worldbank.org/opendata/number-extremely-poor-people-continues-rise-sub-saharan-africa

Yadav, N., Rajendra, K., Awasthi, A., Singh, C., & Bhushan, B. (2023). Systematic exploration of heat wave impact on mortality and urban heat island: A review from 2000 to 2022. Urban Climate, 51, 101622. https://doi.org/10.1016/j.uclim.2023.101622

Ye, Y., & Koch, S. F. (2023). Towards accessibility or affordability? Multidimensional energy poverty across the South African urban-rural divide. Energy Research & Social Science, 97, 103002. https://doi.org/10.1016/j.erss.2023.103002

About the authors

ALEKSEJS PROZUMENTS

Postdoctoral researcher

Riga Technical University, Faculty of Civil and Mechanical Engineering, Institute of Sustainable Building Materials and Engineering Systems

Main research area

Building energy, thermal comfort

Address

Kipsalas str. 6A-531 Riga, LV-1048, Latvia
E-Mail: aleksejs.prozuments@rtu.lv

ANATOLIJS BORODINECS

Full professor, Head of the Institute

Riga Technical University, Faculty of Civil and Mechanical Engineering, Institute of Sustainable Building Materials and Engineering Systems

Main research area

Building energy, building physics, thermal comfort

Address

Kipsalas str. 6A-539 Riga, LV-1048, Latvia
E-Mail: anatolijs.borodinecs@rtu.lv

ADAMAH MESSAN

Full professor, Research Director

International Institute for Water and Environmental Engineering (2iE)

Main research area

Eco Materials and Sustainable Habitats

Address

1, Rue de la Science, 01 BP 594 Ouagadougou 01 - Burkina Faso
E-Mail: adamah.messan@2ie-edu.org

KOKOUVI EDEM N'TSOUKPOE

Associate Professor

International Institute for Water and Environmental Engineering (2iE)

Main research area

Sustainable and environmentally friendly materials

Address

1, Rue de la Science, 01 BP 594 Ouagadougou 01 - Burkina Faso
E-Mail: edem.ntsoukpoe@2ie-edu.org

PHILBERT NSHIMIYIMANA

Assistant Professor

International Institute for Water and Environmental Engineering (2iE)

Main research area

Expert in Materials and Sustainable Constructions

Address

1, Rue de la Science, 01 BP 594 Ouagadougou 01 - Burkina Faso
E-Mail: philbert.nshimiyimana@2ie-edu.org

CÉSAIRE HEMA

Lecturer, PhD

International Institute for Water and Environmental Engineering (2iE)

Main research area

Sustainable materials in construction

Address

1, Rue de la Science, 01 BP 594 Ouagadougou 01 - Burkina Faso
E-Mail: cesaire.hema@2ie-edu.org

DANIEL YAMEGUEU NGUEWO

Lecturer, PhD

International Institute for Water and Environmental Engineering (2iE)

Main research area

Sustainable materials in construction

Address

1, Rue de la Science, 01 BP 594 Ouagadougou 01 - Burkina Faso
E-Mail: daniel.yamegueu@2ie-edu.org

MOHAMED TARIQ KAHN

Full professor, Director at Energy Institute

Cape Peninsula University of Technology (CPUT), Faculty of Engineering and the Built Environment, Energy Institute

Main research area

Building energy, infrastructure energy

Address

P.O. Box 1906, Bellville, 7535, Cape Town, South Africa
E-Mail: khant@cput.ac.za

EFE ORUMWENSE

Senior Lecturer

Cape Peninsula University of Technology (CPUT), Faculty of Engineering and the Built Environment, Energy Institute

Main research area

Building energy, infrastructure energy

Address

P.O. Box 1906, Bellville, 7535, Cape Town, South Africa
E-Mail: OrumwenseE@cput.ac.za

CHRISTOPHE MÉNÉZO

Full Professor

Cape University Savoie Mont Blanc, Polytech Annecy-Chambéry, LOCIE Laboratory (UMR CNRS 5271)

Main research area

Solar energy, building energy systems

Address

LOCIE - Polytech Annecy-Chambéry, INES - Institut National de l'Énergie Solaire, Campus Scientifique Savoie Technolac, Avenue du Lac Léman, F-73376 Le Bourget-du-Lac, France
E-Mail: christophe.menezo@univ-smb.fr

ADEY FELEKE DESTA

Associate Professor

Addis Ababa University, College of Natural and Computational Sciences, Department of Microbial, Cellular & Molecular Biology, and Africa Center of Excellence for Water Management

Main research area

Environmental biotechnology, microbial ecology in wastewater treatment, resource recovery, antibiotic resistance, water quality, public health

Address

Addis Ababa University, Institute of Biotechnology, 4 Kilo Campus, P.O. Box 1176, Addis Ababa, Ethiopia
E-Mail: adey.desta@gmail.com