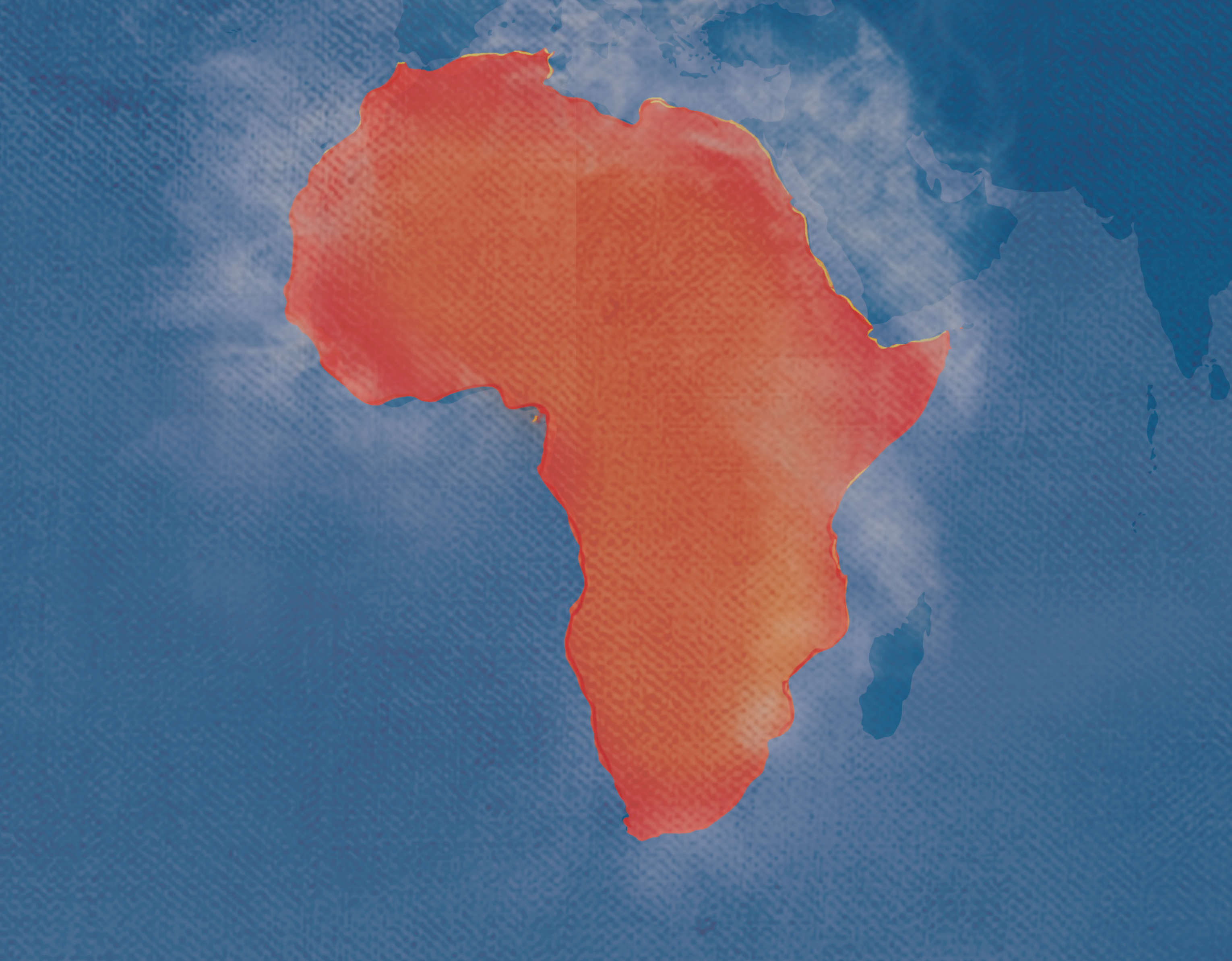
AFRICA: TOO HOT TO COOL?

AGENDA FOR ACTION



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The spotlight

Rising temperatures and growing heat exposures are reshaping public health risks, community vulnerability, and infrastructure risks, while it is also disrupting economies and destabilizing communities. The World Health Organisation has noted in its 2024 report on heat and health, that heat waves account for substantial fatalities and illness worldwide while their frequency, duration, and intensity are climbing sharply.[1] Without robust adaptation and mitigation, large parts of the world will face recurring and unmanageable episodes of life-threatening heat stress in the coming decades.[2]

The rising heat is combined with the danger of wet-bulb temperatures, which combine heat and humidity. Studies show that a 35°C wet-bulb temperature threatens life, even for healthy individuals. Studies indicate that, without significant mitigation, up to 74 per cent of the world's population could be exposed to deadly heat conditions by 2100 eroding and compromising health, crop yields, energy systems, and labour productivity.

The Africa continent mirrors the global crisis

The continent is warming at nearly 1.5 times the global average that will only accelerate. According to the IPCC's Fifth Assessment Report, near-surface temperatures across much of Africa have already risen by at least 0.5°C over the past century, and mean annual warming is likely to exceed 2°C by the end of the century with some regions reaching 3–6°C under high-emission scenarios.[3] Nearly 35 African cities can experience more than 150 days of 40°C plus temperatures annually. This can have disproportionately high impacts on vulnerable groups. Approximately 300 million people in Africa experienced life-threatening heat stress during the last year, representing about 75 per cent of global exposure to this risk.

The factors that are contributing to the vulnerability in Africa include rapid urbanization that is increasing heat exposures for a much larger population; high reliance on outdoor labour, socio economic vulnerability, inadequate healthcare systems, energy poverty, and limited climate research to understand the insidious link to inform policy. Extreme heat threatens livelihoods, food security, labour productivity (projected 5 per cent reduction in West Africa by 2030, equivalent to 9 million jobs), and migration.

There is a variance in the effect and trend of extreme heat across the African sub-regions:

- North Africa experienced the highest temperature anomaly in 2024 at 1.29°C above baseline, closely approaching the 1.5°C global warming threshold. Projections suggest heatwaves could reach nearly 50°C by the end of the century, potentially affecting up to 600 million people, predominantly in urban centers.
- West Africa has seen unprecedented heatwaves, with summer temperatures projected to rise by 3–6°C by 2031–2050. This threatens health, productivity, and education, and could lead to 17–40 million climate-related internal migrants by 2050.
- East Africa faces a marked increase in extreme high-temperature events, with annual mean temperatures projected to rise by 1.5–5.4°C by mid-to-late century.
- South Africa shows clear rises in heatwave frequency, intensity, and duration, with interior regions potentially seeing up to a 6°C increase in maximum temperatures.
- Central Africa has experienced a significant increase in heat stress, with strong heat stress now widespread, and nearly the entire population projected to regularly experience dangerous heat by 2°C of global warming.

This review of available evidence suggest that in 2024, Africa's average temperature anomaly was +0.87 °C above the 1991–2020 baseline. Africa is warming faster than the global average, about +0.3°C per decade vs. the global +0.2°C (1991–2023). North Africa is heating the fastest at +1.29 °C, just 0.21 °C short of 1.5°C. Southern & Central Africa are nearing +1°C warming. East Africa, though relatively cooler, is warming quicker already at +0.66°C above the 1991–2020 baseline.

Urban heat in African cities

The Urban Heat Island (UHI) effect is a critical factor, with urban areas experiencing significantly higher temperatures due to impervious surfaces, dense buildings, and reduced green cover. Wet-bulb temperature is particularly dangerous in humid African cities where the body's natural cooling through sweating is compromised.

The Centre for Science and Environment (CSE) has carried out deeper analysis of selected cities to understand the nature of the risk. CSE has conducted a comparative analysis of Land Surface Temperature (LST) and Land Use Land Cover (LULC) changes in Lagos and Johannesburg over the past decade. The aim is to understand how spatial transformations in urban land cover have influenced the intensity of UHI in these rapidly growing cities.

For this purpose, freely accessible satellite data from the United States Geological Survey (USGS) Earth Explorer platform were used. Specifically, imagery from the Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) was processed to extract information on both LST and LULC. Using spatio-temporal Landsat imageries with their thermal bands and ancillary data, land cover and LST changes were assessed. The assessment included: i) spatial and temporal variations in LST within each city; ii) changes in LULC patterns over the study period; and, iii) the relationship between changes in LST and LULC, highlighting how urban expansion and land transformation contribute to increasing surface heat.

The timing of peak summer heat differs between South Africa and West Africa due to their contrasting locations and climates. In South Africa, which lies in the southern hemisphere, the hottest period occurs during November to March, when solar intensity is strongest and cities such as Johannesburg, Cape Town, and Durban experience their highest temperatures.

In contrast, West Africa experiences intense heat shaped by its tropical climate and seasonal shifts between dry and wet periods. The hottest months generally occur from February to April, during the late dry season just before the rains begin. In this period, temperatures often soar above 35°C, compounded by high humidity in coastal cities such as Lagos, which amplifies heat stress and discomfort.

Accordingly, our analysis focuses on December and January for Johannesburg, which represent the peak summer months in the southern hemisphere. For Lagos, however, due to the limited availability of cloud-free satellite data during its hottest period, we have used December satellite imagery to carry out the assessment.

For Lagos, the analysis was based on satellite scenes acquired on December 18, 2013 and December 19, 2022, while for Johannesburg, the assessment drew upon imagery from January 16, 2014 and December 29, 2021. This has helped to do a comparative evaluation of heat patterns over nearly a decade.

Building on the analysis of land surface temperature and land use changes in Lagos and Johannesburg, we identified areas experiencing consistently high surface heat, commonly referred to as urban heat hotspots.

To further characterise extreme heat exposure in these cities, we applied a standardised definition of heatwaves. While there is no single, continent-wide temperature threshold for severe heat in Africa, as definitions vary by region, climate zone, and national meteorological services. However, scientific and meteorological approaches commonly identify severe heat or heatwave events using absolute temperature thresholds of ≥35°C or when the daily maximum temperature exceeds the 90th or 97th percentile of historical maximum temperatures for two to three consecutive days.

The South African Weather Service defines a heatwave as a period of at least three consecutive days during which the maximum temperature at a specific station or grid point is five degrees or more above the average mean maximum for the hottest month at that location.

Similarly, the Expert Team on Climate Change Detection and Indices (ETCCDI) provides percentile-based definitions such as the 90th or 97th percentile of historical maximum temperatures for two to three consecutive days, widely used in climate research and meteorological monitoring across Africa. Many scientific studies adopt these frameworks, referencing either ETCCDI indices or national thresholds to identify and analyze heatwaves and extreme temperature events.

These criteria form the basis for identifying and analysing heatwave events in Lagos and Johannesburg, allowing for a consistent assessment of extreme heat exposure and urban vulnerability.

Lagos and Johannesburg demonstrate several effects

Lagos, a humid coastal megacity, shows intensified UHI due to rapid urbanization, with built-up areas expanding and green cover declining between 2013-2022, leading to higher and more widespread heat stress. There are proliferating heat hotspots. The 32–34°C zone has spread into new areas like Ifako-Ijaiye and Eti-Osa due to rapid land use change. In 2013, peak heat Ikeja (industrial zone) had hit the peak heat that was 34.43°C. In 2022, Ikeja, Mushin, Surulere had observed peak heat of 33.92°C. There are persistent hot zones such as Ifako-Ijaiye, Ajeromi-Ifelodun, Mushin, Surulere, and Agege, which have remained in the range of 30–34 °C. Built-up areas in Lagos have grown by 70 per cent by 2022, while green cover has shrunk to 13.8 per cent. Heat stress highest in dense built-up zones up to 33.9°C.

Johannesburg has also experienced significant urban expansion and land cover changes, with built-up and barren areas showing substantial temperature increases between 2014-2024, although with some moderation in peak LST compared to Lagos, reflecting geographical and climatic differences. Dense settlements are especially vulnerable due to poor housing materials and lack of cooling options.

Severe heat has been recorded at 35–50°C in built-up zones like Alexandra, Southern Johannesburg, and around Lanseria Airport. In 2024, the extreme heat zones include Lanseria Airport and Stone Ridge Center peaked at a staggering 45–51°C. Lanseria Airport in the northwest and Stone Ridge Center in the eastern region show high peak heat. In 2014, the peak was above 32°C in northern built-up zones. In 2024, it was 51°C near Lanseria & Stone Ridge. The built-up area has increased by 15 per cent in a decade, now covering 55.8 per cent of total area. Sharp rise in LST across all land cover categories, including vegetation and water bodies, but built-up areas saw the steepest jump by +9.7°C.

Increase in night time temperature

Nighttime land surface temperature (LST) has shown a significant upward trend across most regions of Africa in recent decades. A study published in Scientific Reports journal in 2019 found widespread increases in nighttime LST between 2000 and 2014, although some areas in southern, central, and eastern Africa recorded localised decreases. The warming trend is particularly pronounced in rapidly urbanizing areas such as Lagos (Nigeria) and Gaborone (Botswana), where urbanisation has contributed more to nighttime warming than daytime warming due to the urban heat island effect and reduced cooling after sunset.

In East Africa, about 31 per cent of the region experienced significant nighttime LST rise, with trends averaging +0.06 K per year, in many cases outpacing daytime warming. Evidence from North Africa reinforces this pattern, a study published in Remote sensing journal in 2021 reported that Greater Cairo's average nighttime LST increased from 24.94°C in 2000 to 27.22°C in 2019. These changes have made nighttime heatwaves more frequent and intense across African urban clusters, largely driven by rapid urbanization amplifying the urban heat island effect and suppressing natural nighttime cooling.

Growing heat increasing cooling demand and electricity consumption

Heat stress is increasing cooling demand and electricity consumption: Rising temperatures are expected to rapidly increase the demand for cooling appliances like air conditioners and fans, potentially leading to doubling of household electricity demand by 2030.

Global dumping of old and used energy-inefficient air conditioners with ozone-depleting refrigerants further worsening energy impacts. This challenge is exacerbated by the massive dumping of old used, and cheaper air conditioners from the developed countries. These are cheaper upfront but consume significantly more electricity. African countries are beginning to combat this through regulations, import bans and the adoption of Minimum Energy Performance Standards (MEPS). Ghana for example has taken the lead to ban import of old and used air conditioners.

Opportunity in new growth: Despite the challenge, the future growth is an opportunity in Africa. With Africa's building floorspace projected to quadruple by 2070, there's a significant opportunity to embed heat resilience and thermal comfort measures in new construction.

From cooling action plans to heat management action plans: Nearly 40 countries have adopted national cooling action plans or strategies in Africa. These largely align with the objectives of the Montreal Protocol to phase out ozone depleting refrigerants and improve energy efficiency of the appliances and cooling systems. Depending on the scope and design of these plans, some of these have recommended adoption of climate-responsive building architecture, passive cooling designs along with improvement in energy efficiency performance. Several African countries have or are developing building codes, standards and labelling for appliances to improve energy efficiency and are at different level of progress.

However, Sierra Leone is currently the only African country with a dedicated Heat Action Plan. It has adopted an explicit heat action plan this year. While Cooling Action Plans have focussed largely on energy efficiency of cooling technologies and refrigerants, the Heat Action Plans, are a critical way forward to address the broader vulnerability of the communities and build resilience against heat stress. This can enable infrastructure development and material choices to reduce heat load on buildings and cities, urban planning to expand green spaces and water bodies to reduce heat island effects, reduce risks for the poorer people in the dense settlements and in their occupational set-up, adopt early warning system, strong emergency response and disaster management strategies during heat waves, and build responsive healthcare system.

There are several policy opportunities to integrate heat management action plan in the countries of Africa. These include the ongoing effort to frame national heat management and cooling action plans; development and implementation of energy efficiency codes and labelling for buildings and appliances, material selection and building design; urban planning guidelines to influence the urban design, material applications in public infrastructure, expansion of greening and water bodies; affordable renewable-powered cooling innovations to improve energy access; integration of heat management in National Adaptation Plans;

scaling nature-based solutions to enhance resilience and restore ecosystem services, and provide co-benefits for health and livelihood security. This can be enabled with appropriate fiscal strategy and regional harmonisation of the action, standards, market based instruments, building codes and resource mobilization.

Leveraging green-blue infrastructure

Though green and blue infrastructure is critical for mitigating urban and regional heat, their cooling capacity is increasingly compromised. Fragmented green spaces and warming waterbodies, worsened by climate change and urbanisation, are driving up surface temperatures, limiting natural cooling.

Global warming is causing African lakes to absorb more solar energy, leading to rising water temperatures, with a particularly strong effect observed in East African rift lakes. Warmer air and increased long-wave radiation from the atmosphere add to this heating, while stratification reduces mixing and traps heat in deeper layers. A study published in Limnology and Oceanography (2009) found that surface water temperatures in Lake Tanganyika have risen by about 1.3°C, while deep waters at 1000 m have warmed by 0.2°C; similarly, Lake Malawi's deep waters have warmed by ~0.7°C over the past six decades.

The effect is further intensified by reduced water volumes, drought, evaporation, water abstraction, land use changes, and altered hydrological cycles, which diminish the heat storage capacity of lakes. For instance, a study in the South African journal of Geomatics in 2019 found that declining depth in Lake Chad accelerated summer warming and altered regional temperature gradients, while the drying of Egypt's Toshka Lakes exposed bare soil and salt crusts that heat more quickly. Rising temperatures also increase evaporation, further reducing water availability and exposing more land to direct solar radiation, compounding surface heating.

Even green areas are recording rises in land surface temperature (LST) due to fragmentation, reduced patch size, irregular shapes, and increased edge density, which weaken their cooling capacity. Rapid urbanization and the encroachment of impervious surfaces around these green spaces further elevate LST. Thus, climate change and overall regional warming can drive up LST in both green and water body areas, sometimes overwhelming their natural cooling benefits.

The way forward

Need comprehensive heat management action plans and implementation strategies: Such plans need to deepen interventions to reduce heat load on buildings and cities through infrastructure development. At the same time it is necessary to retrofit public infrastructure and upgrade dense settlements for thermal comfort; and expand urban green spaces to mitigate urban heat island effects.

At the same time integrate early warning systems, public education, and emergency response. Across all levels, it is necessary to expand heat-health surveillance, improve urban temperature monitoring, and foster cross-sectoral policy coherence for effective adaptation. A coordinated, evidence-based approach that combines technological, institutional, and community-based solutions is necessary to build resilience and protect Africa's most vulnerable populations from the escalating risks of extreme heat.

Need vulnerability assessment: There is a notable lack of vulnerability assessments within demographic groups, particularly for the elderly, children, and residents of dense settlements, who are often the most exposed and least capability to adapt. Empirical data on personal heat exposure is scarce, especially in dense urban environments where indoor and outdoor conditions can differ significantly from those recorded at weather stations. This gap is critical, as studies show that dense dwellings in Southern Africa can experience extreme heat stress for 6–10 hours daily during peak summer, with little agency among vulnerable groups to improve their living conditions.[4] Vulnerable populations, especially those in dense settlements, face high exposure, high sensitivity, and low adaptive capacity, yet their needs are rarely prioritized in policy or infrastructure development.

Strengthen health surveillance and early warning systems: This is critical for timely responses to extreme heat and other climate hazards. City-level heat preparedness remains limited, with most urban adaptation efforts insufficient to build resilience, particularly for poor populations in dense settlements. Urban planning frequently overlooks climate risks, and adaptation responses are fragmented, lacking integration into broader development and national planning processes. Strengthening health systems and implementing early warning networks are critical for building resilience to heatwaves and other climate shocks. Ensure uptake of urban design and housing upgrades that reduce vulnerability to heat stress, lower rates of heat-related illness, and improve community health outcomes. Targeted interventions in vulnerable neighbourhoods can further reduce health disparities exacerbated by extreme heat. Additionally, adaptation finance and technological capacity are insufficient, and institutional barriers further hinder effective implementation.[5]

Ensure access to thermal comfort is affordable in buildings: The ongoing effort to implement energy efficiency measures and codes in buildings and appliances require a more expanded approach to adopt architectural design approaches, low carbon and locally appropriate material choices and insulation, interface with the surrounding open spaces and alignment of building clusters, greening and water bodies, among others, to promote adaptive thermal comfort and reduce cooling demand. Need comprehensive guidelines and mandate on material and design to improve thermal comfort of buildings and to reduce air conditioning hours for energy savings and conservation.

This further requires guidelines for mass housing in terms of fixing orientation, adopting compact urban form with adequate green spaces to improve solar access, ventilation and mutual shading etc. Regulations need to ensure that the buildings continue to remain strong on green performance. Implement decentralised services including water and clean energy access local level waste management and circularity for health and wellbeing. Special attention should be given to vulnerable groups in dense settlements, with targeted programs around thermally comfortable housing with cool roofs, insulation, and passive design. It is also necessary to explore adaptation of traditional material and building techniques in modern buildings to reduce energy and material intensity of structures.

Build energy resilience: Ensuring reliable, sustainable access to electricity is essential for powering life-saving cooling technologies such as fans, refrigeration and air conditioning. Integrating rooftop photovoltaics and energy-efficient building designs can reduce peak energy demand, enhance urban energy resilience, and deliver cooling benefits in regions facing chronic energy poverty and unreliable supply.

Expand green and blue infrastructure: Policy and regulations on green and blue infrastructure is developing in Africa. But the approaches and regulations need to be strengthened at the municipal levels. Empirical studies show that such interventions can decrease surface temperatures by up to 2°C and improve outdoor thermal comfort indices by over 10°C under certain conditions.[6] Beyond cooling, green infrastructure enhances air quality, supports biodiversity, promote mental and physical health, and provide additional co-benefits such as carbon sequestration, storm water management, and social cohesion. Investments in resilient energy and water infrastructure are essential to reduce heat and support cooling needs and safeguard public health as temperatures rise.

Harmonise and tighten regulations and action across Africa region to stop dumping of old and used appliances and air conditioners: Make global regulations stringent to prevent global dumping of old and used energy-inefficient air conditioners with ozone-depleting refrigerants. Several countries have begun to take steps. This needs to accelerate and harmonise. This requires a strategic combination of regulations, import bans, fiscal disincentives, and tightening of Minimum Energy Performance Standards (MEPS).

Develop funding strategies to accelerate resilience and adaptation: Developing robust funding strategies through regional bodies and international financial institutions is necessary. This requires fundamental recentring of heat as a core adaptation priority – the choices made today in research, policy, and planning will determine Africa's capacity to withstand and thrive in the face of rising heat.

Regional bodies like the African Union and African Development Bank need to facilitate heat risk mitigation financing, joint early warning systems, and regional data-sharing platforms, while promoting policy coherence and capacity building across member states. International financial institutions and climate finance mechanism can support the transition. Strengthening of governance, enhancing data and forecasting, cross-sectoral planning and convergence funding along with policy and regulations are needed to reduce both immediate and long-term risks.

Build data and information on the heat risk to inform policy and implementation: It is necessary to address the data and information gaps through improved data collection, targeted vulnerability assessments, and evaluation of adaptation strategies for effective heat risk management and informed policymaking in Africa. This limited research output is attributed to factors such as inadequate funding, restricted data accessibility, limited researcher capacity, and weak international collaboration.

Most African studies rely on remote sensing due to the limited spatial coverage of ground-based weather stations, and there is a lack of high-resolution, city-specific analyses. The intensity and duration of UHI effects, as well as their health and social impacts, are not well quantified, particularly in rapidly urbanizing regions.[7] Furthermore, research on adaptation strategies is limited, with most studies focused toward building materials and passive cooling, with little evaluation of community-level or policy-driven interventions. For example, while cool roof paints can reduce heat stress in dense housing, their effectiveness may decline under future climate scenarios, highlighting the need for integrated, multisectoral approaches.[8] The lack of comprehensive data and targeted research has significant implications for policy and practice. Heat stress is often a silent killer, claiming more lives than many other climate hazards yet receiving far less recognition in public health systems and urban planning.

Section 1: Rising heat – A global challenge

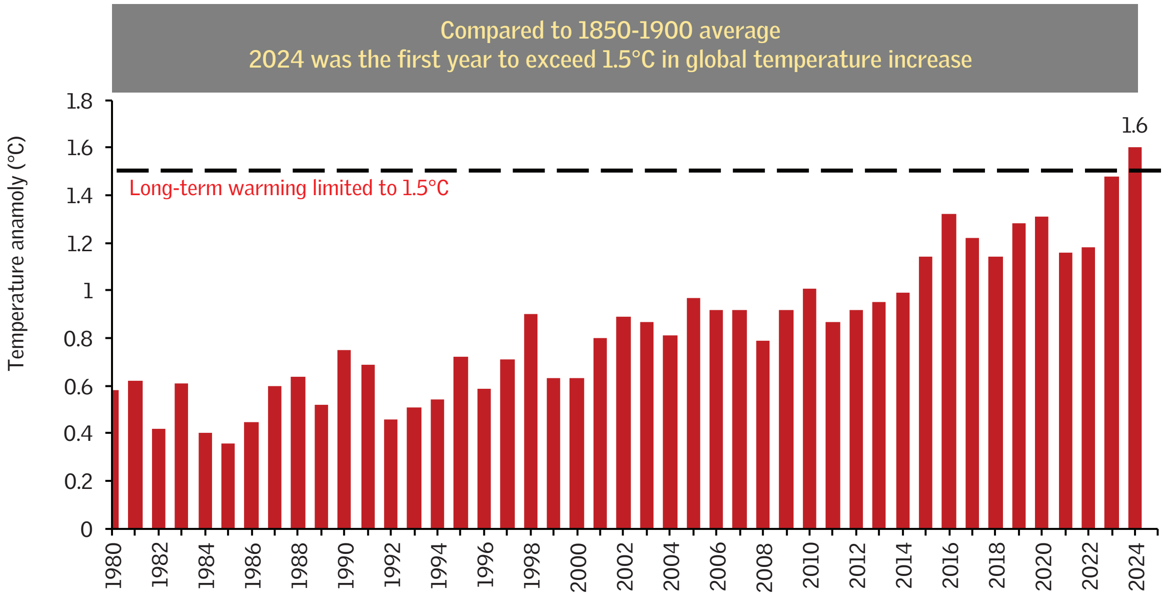
Global temperature records illustrate the scale of the crisis. In 2023, global mean surface temperatures rose by approximately 1.45°C above pre-industrial levels, [9] and 2024 set a new record as the hottest year ever observed, reaching about 1.6°C above pre-industrial baselines.[10] This marks the first time the 1.5°C threshold, identified in the Paris Agreement as a critical guardrail, has been breached. The decade from 2015 to 2024 now stands as the warmest on record, showing that warming is not only continuing but accelerating.[11] Crossing this threshold is not symbolic; it signals profound consequences for human health, livelihoods, and long-term development. The El Niño event of 2023–2024 further amplified these temperatures, pushing many regions into dangerous new territory.[12]

This warming is not uniform. Land areas are heating faster than oceans, and tropical and subtropical regions already the hottest part of the world are projected to experience the greater risks.[13] Local factors such as urbanization and land-use change are amplifying these extremes, turning global warming into intensified local crises. Heat is therefore not just a scientific phenomenon but a lived reality, one that is compounded by human settlement patterns, infrastructure gaps, and socio-economic vulnerabilities.

What makes heat uniquely dangerous is its compound nature. Physiologically, the human body can only withstand a narrow band of thermal conditions, and when high temperatures combine with humidity, the risks escalate sharply. The wet-bulb temperature a metric that combines heat and humidity captures this compound risk. At 35°C wet-bulb, survival becomes impossible even for healthy individuals in shaded, well-ventilated environments.[14] This boundary, once considered hypothetical, is now being approached in parts of the world, underscoring the urgency of preparing for intensifying heat stress.

This ongoing heat accumulation has resulted in a measurable increase in global average temperatures since the mid-20th century, with the rate of heat gain accelerating in recent decades. Observational data and climate models consistently show that this warming is leading to more frequent, intense, and longer-lasting heatwaves across nearly all regions of the world, with the frequency of extreme heat events rising sharply since the 1950s.[15] The combination of continued greenhouse

Graph 1: Global mean surface temperature in 1980–2024



Source: Copernicus Climate Change Service

gas emissions and the Earth's ongoing energy imbalance means that, without significant mitigation efforts, global temperatures and the associated risks of heat exposure will continue to rise throughout the 21st century. Projections indicate that, without significant mitigation, up to 74 per cent of the world's population could be exposed to deadly heat conditions by 2100 under high-emissions scenarios, compared to about 30 per cent today.[16]

The last decade has been the warmest on record, with 2024 registering global temperatures 1.6°C above pre-industrial averages, making it the hottest year ever measured *(see graph 1:Global mean surface temperature in 1980–2024)* Heatwaves that once struck once in a generation are now occurring every few years, often overlapping with humidity and air pollution to create conditions that stretch the limits of human tolerance. Mortality rates often increase sharply during such events, confirming that heat is already a serious public health crisis Across continents, mortality spikes during heat extremes remind us that heat is not a distant climate concern, it is a present and escalating public health emergency.

The danger lies in how the human body reacts. To survive, the body needs to cool itself by sweating and releasing heat. But beyond a certain threshold, especially when humidity is high, this process fails. Long exposure under these conditions can lead to organ failure and death. Older people, children, workers who spend time outdoors, and people without access to cooling are most at risk. But the impacts are not limited to health. Extreme heat lowers crop yields, weakens energy systems when demand rises, reduces labour productivity, and puts stress on water resources.

Despite these wide-ranging impacts, heat is still not treated as a main climate risk in most policies. Global policy frameworks acknowledge heat but rarely treat it as a central priority. The Paris Agreement and the Sendai Framework for Disaster Risk Reduction refer to extreme heat only briefly, framing it within broader climate and disaster risks rather than as a standalone challenge.[17] At the national level, this pattern is echoed: heat is often addressed in a fragmented way through health, agriculture, or energy policies, but rarely through a single, integrated strategy.[18] As a result, responses tend to remain siloed, limiting their effectiveness in tackling the cross-cutting nature of heat risk.

To address heat effectively, it must be recognized as a defining climate risk. This means seeing it not just as an occasional weather event but as a permanent stress that will influence how cities grow, how economies function, and how people live. If left unaddressed, its silent and pervasive reach could make heat the most consequential climate hazard of the 21st century.

Section 2: Rising heat in African continent

Africa stands in a uniquely precarious position, with its vulnerability shaped by both climatic and socio-economic factors particularly heat stress and extra cooling demand.[19] The continent is warming at nearly 1.5 times the global average and projections suggest this trend will accelerate. According to the IPCC's Fifth Assessment Report, near-surface temperatures across much of Africa have already risen by at least 0.5°C over the past century, and mean annual warming is likely to exceed 2°C by the end of the century with some regions reaching 3–6°C under high-emission scenarios. [20]

IPCC predicts that nearly 35 African cities can experience more than 150 days of 40°C-plus temperatures annually in case of a 2°C global warming scenario. food and nutritional security will have wider negative implications for equitable economic growth.[21] From 1968–2020, only 58 scientific publications on heat stress and human health originated from Africa, compared to 463 globally.[22]

This matter has drawn considerable policy attention recently. This was put on the table for discussion in the 20th Ordinary Session of the African Ministerial Conference on the Environment (AMCEN-20). It has reported that the last decade was the warmest in Africa. The UNEP and the Global Alliance for Buildings and Construction has stated in this context that the region is projected to experience some of the highest increases in heat exposure globally. About 300 million people in Africa experienced life-threatening heat stress in the last one year; about 75 per cent of all people exposed to this risk globally.[23]

By 2050, nearly 60 per cent of Africa's population is expected to live in urban areas,[24] many in dense settlements with poor-quality housing, limited access to cooling, and little green space, factors that amplify heat exposure and health risks. Climate models project that, by mid-century, the frequency and intensity of heat extremes will increase across Africa, with West, East, and Central Africa facing the largest expansions in dangerous heat stress days.[25] Without urgent adaptation, millions more Africans, especially the poorest and most marginalized will be exposed to life-threatening heat.

Africa is already experiencing longer, hotter, and more frequent extreme heat events, made far more likely by climate change. In December 2024, for example, a heatwave stretching from Senegal to South Sudan was at least 15 times more likely because of global warming.[26]

Extreme heat undermines livelihoods, food security, and social stability. It reduces labor productivity, damages crops, and increases water and energy demand, exacerbating poverty and food insecurity. Heat stress can force migration from uninhabitable areas and has been linked to increased conflict over scarce resources. These cascading impacts make heat not only a health threat but also a hidden driver of broader development challenges.

This is especially concerning given Africa's high exposure and limited resilience: rapid urbanization, reliance on outdoor labour, widespread poverty, fragile healthcare systems, and inadequate access to reliable electricity all compound the risks of heat stress and soaring cooling demand. Unlike high-income countries, that can rely on widespread cooling, insulation, and resilient infrastructure, millions of Africans face direct exposure to heat with little to no protection.

These risks are compounded by stark inequities in data and research capacity. Between 1990 and 2019, Africa received only 3.8 per cent of global climate research funding, of which 78 per cent went to institutions in Europe and North America, and just 14.5 per cent reached African institutions. This imbalance limits Africa's ability to generate locally relevant knowledge and design context-specific solutions, weakening its adaptive capacity.[27]

Climate projections are sobering. While Africa has not yet consistently crossed the wet-bulb survivability threshold, West Africa is projected to be among the hardest hit, with exposure to heat stress rising up to 5.5-fold under high-emission scenarios. Central and East Africa are also expected to experience steep increases, and the Sahel could approach dangerous thresholds by the mid to late century.[28] Overall, exposure to heat stress across Africa could rise by 50–100 per cent under moderate scenarios and by more than 200 per cent under high-emission pathways (SSP5-8.5). Even Southern Africa, though comparatively less exposed, is likely to experience notable expansion in heat stress conditions.[29]

Further, demographic change intensifies this challenge. Africa's population is expected to reach 2.53 billion by 2050 and could account for 40 per cent of the global total by 2100.[30] Rapidly expanding urban areas often poorly planned and lacking green spaces are becoming hotspots of the urban heat island effect, where concrete and asphalt trap and re-radiate heat, driving local temperatures several degrees higher. In megacities such as Lagos and Cairo, these effect combines with global warming to create unprecedented risks for millions of people.[31] By 2030, heat stress in West Africa alone is projected to reduce working hours by nearly 5 per cent, equivalent to the loss of around 9 million full-time jobs, with agriculture and labor most severely affected.[32] In these contexts, heat is not merely a meteorological condition but a structural challenge to urban governance, public health, and economic stability.

Yet despite its scale, heat remains under-prioritized in Africa's climate adaptation agenda. Policy responses have historically focused on more visible hazards such as droughts, floods, and food insecurity while heat has been treated as secondary. But evidence now shows that extreme heat is a silent disruptor, undermining productivity, threatening food systems, straining water and energy supplies, and driving mortality. Addressing heat should not be optional but it is essential for safeguarding Africa's development and resilience.

This report seeks to reframe heat as a priority for Africa's climate agenda. It explores the drivers of intensifying heat, current patterns of exposure, and regional trends, while paying close attention to urban environments where the risks are most acute. Through case-based insights and an exploration of land surface dynamics, it underscores how heat is being amplified in Africa's cities. Finally, it sets out adaptation pathways, emphasizing urban planning, green infrastructure, health systems, and regional cooperation as critical levers of resilience.

By situating Africa's heat crisis at the intersection of planetary warming and local vulnerabilities, this report calls for a fundamental re-centering of heat as a core adaptation priority. The choices made today in research, policy, and planning will determine whether African societies can withstand, adapt to, and ultimately thrive in the face of rising heat.

Africa is experiencing accelerated warming, with temperatures rising faster than the global average. According to the Intergovernmental Panel on Climate Change (IPCC), warming across the continent has been evident since the early 20th century, with mean annual temperatures increasing rapidly from the mid-20th century onward reaching 0.2°C to 0.5°C per decade in regions such as North, North-East, West, and South-West Africa.[33] Projections show that this trend will continue, with temperatures in Africa expected to rise more quickly than the global average, especially in arid and semi-arid zones.[34, 35]

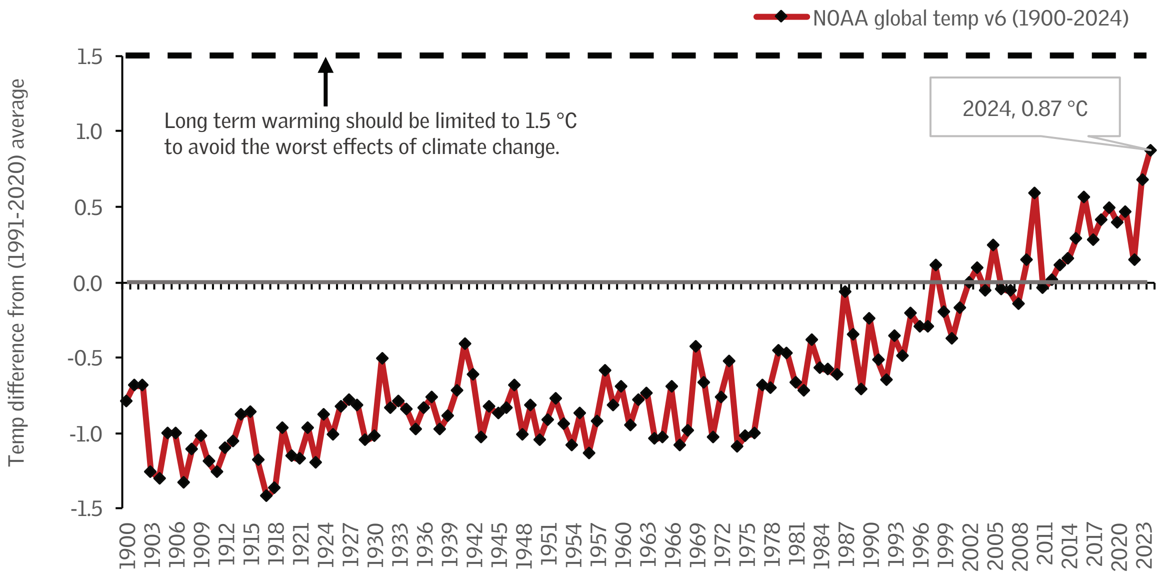
In 2024, near-surface air temperatures across Africa were among the highest ever recorded since 1900, averaging about 0.86°C above the 1991–2020 baseline.[36] The greatest increases in heat stress are projected in equatorial regions, where extreme heat is compounded by high humidity, as well as in North Africa, the Sahel, and Southern Africa, which are already facing some of the sharpest rises in extreme heat.[37] Africa's risk is further amplified by its relatively low year-to-year temperature variability, particularly in the tropics, so even modest rises stand out more clearly and translate into severe impacts.[38] This combination of rapid warming and low variability leaves the continent acutely sensitive and highly vulnerable to climate change.

Although Africa contributes less than 10 percent of global greenhouse gas emissions, the continent bears a disproportionate burden of climate change impacts.[39] Average warming across Africa is advancing at roughly 0.3°C per decade, higher than the global mean of 0.2°C per decade. The acceleration is especially evident in North Africa, where rates reached +0.4°C per decade between 1991 and 2023, compared with +0.2°C per decade during 1961–1990. In 2023, the most severe temperature anomalies were observed in northwestern Africa, notably in Morocco, coastal Mauritania, and parts of Algeria.[40] The consequences of this warming are already evident: in 2022, more than 110 million people across Africa were directly affected by climate and weather-related hazards, leading to economic losses estimated at US $8.5 billion.[41]

In 2024, Africa recorded an average surface temperature anomaly of 0.87°C above the 1991–2020 baseline, with North Africa experiencing the sharpest rise at 1.28°C (see *Graph 2: Annual regional mean surface temperature in 1900–2024 in Africa)*. These anomalies were amplified by global climate drivers such as the 2023 El Niño and the positive Indian Ocean Dipole, both of which extended into early 2024 and intensified extreme heat episodes. Across the continent, these conditions disrupted agricultural cycles, lowered labor productivity, and forced temporary school closures.[42] The physiological toll on humans has been equally severe: exposure to extreme heat elevates core body temperature and heart rate, increasing risks of heat stress, heatstroke, and mortality. Urban areas are particularly vulnerable, with high population density, limited vegetation, and widespread artificial surfaces driving urban heat island effects.

Temperatures in tropical Africa already approach the upper limits of human tolerance, with extreme records of 47.6°C in Faya-Largeau (Chad Republic) and 48.2°C in Bilma (Niger) in 2010. More recently, temperatures exceeding 50°C were reported in northeastern Nigeria.[43]

Graph 2: Annual regional mean surface temperature in 1900–2024 in Africa



Note: Temperature difference calculated fom 1991 – 2020 average.

Source: NOAA Global Surface Temperature Dataset (NOAAGlobalTemp), Version 6.0

The health implications of these extremes extend beyond immediate illness. Research has linked sustained high temperatures with adverse pregnancy outcomes, including preterm births, low birthweight, and stillbirths. Evidence from sub-Saharan Africa suggests that even modest increases in average temperature are associated with a 34 per cent rise in perinatal mortality risk.[44] Heat stress during pregnancy disrupts fetal development and increases complications during delivery, highlighting a significant but often overlooked public health challenge.

Agriculture, the foundation of most African economies and the livelihood source for more than half the population, remains acutely sensitive to heat stress. Since 1961, climate change has reduced agricultural productivity growth in Africa by 34 per cent, the sharpest decline globally. Rising temperatures accelerate evapotranspiration, damage crops physiology, and shorten growing seasons. Food security risks are compounded by rising dependence on import, with African food imports projected to nearly triple, from US $35 billion in recent years to US$ 110 billion by 2025.[45] The negative impact of rising temperatures is expected to cause significant productivity declines, with Western Africa among the hardest hit by agricultural heat stress. By 2030, projected productivity losses in the region could reach 4.8 per cent, equivalent to around nine million full-time jobs.[46]

Economic damages from climate change are projected to escalate dramatically. Loss and damage costs could reach between US $290 billion and US $440 billion depending on future warming scenarios. Crop yields of key staples are projected to fall by 10–20 per cent by 2050, with reductions reaching up to 25 percent in drought-prone regions by 2080. Ethiopia has already experienced climate-driven yield losses, translating into a 5–10 per cent decline in agricultural GDP.[47] Such trends underscore the profound implications of heat for national economies and livelihoods.

The energy sector is under mounting pressure from rising temperatures. Higher heat drives demand for cooling in homes, schools, hospitals, and workplaces, yet energy systems across Africa remain fragile and underdeveloped. In Southern Africa, the combination of higher temperatures and reduced rainfall threatens hydropower generation, which is central to regional electricity supply. The Zambezi Basin, for instance, has already experienced diminished inflows during prolonged hot and dry periods, resulting in recurrent power shortages at peak demand. Hydropower output from key facilities such as the Kariba Dam could decline by an estimated 12 per cent by 2050–2070 under projected drying trends, forcing a shift toward fossil fuel dependence and raising costs for households and industries.[48]

Taken together, these trends underscore the multi-sectoral nature of Africa's heat challenge, linking human health, food security, economic stability, and energy resilience in ways that are already reshaping regional climate vulnerabilities.

Section 3: Varying regional trends in Africa

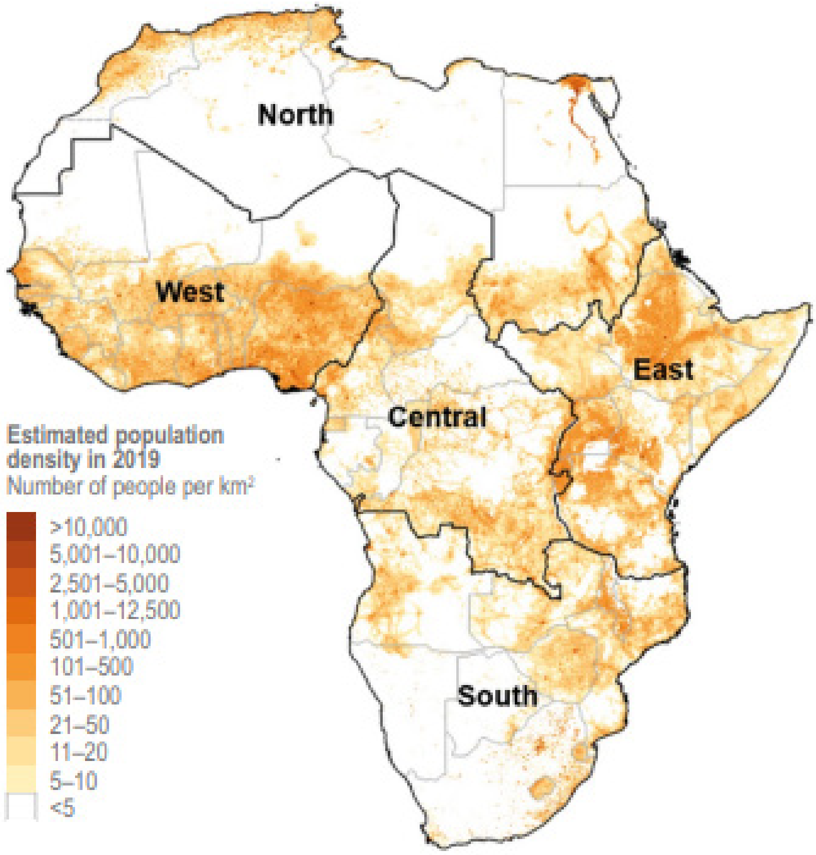
Extreme heat does not affect Africa uniformly. Its intensity and consequences vary widely across the continent's sub-regions, depending on geography, local ecosystems, urbanization patterns, and socioeconomic conditions (see *Figure 1: African subregions)*. As the planet hurtles toward the +2°C threshold of global warming, the African continent is warming at an even faster pace. Despite their limited historical contributions of greenhouse gas (GHG) emissions leading to global warming and climate change, African countries face cascading ecological, economic, and social impacts of climate change. Climate change is impacting the African continent in multitudinous, varying ways. Some regions have been experiencing severe, long-term drought, crop failures, and others, intense rains, sea-level rise, and both coastal and riparian flooding.[49] Extreme, protracted heat spells across the continent have exacerbated such conditions and led to heat-related health impacts. Understanding these regional differences is essential for designing targeted policies and adaptation strategies.

In 2024, Africa recorded an average temperature anomaly of 0.87°C above the 1991–2020 baseline. Among the sub-regions, North Africa experienced the highest anomaly at 1.29°C, while East Africa recorded the lowest at 0.66°C (see *Graph 3: Near-surface air temperature anomalies in °C for 2024 relative to the 1991–2020 reference period)*.

This highlights the uneven distribution of warming across the continent, with North Africa already much closer to the 1.5°C global warming threshold, just 0.21°C away. In contrast, East Africa remains further below the limit but still shows a clear warming trend (*see Graph 4: Annual region-wise mean surface temperature during 1900–2024)*.

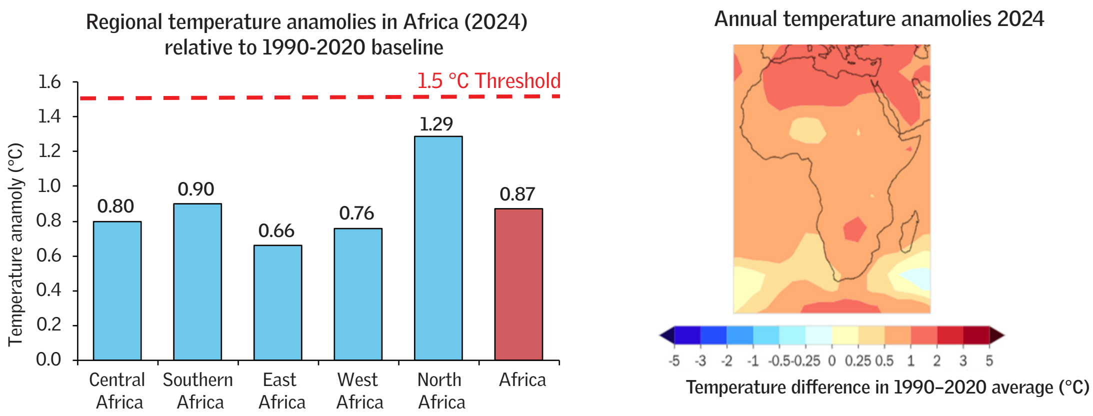
The continental average of 0.87°C indicates that Africa is already over halfway toward the 1.5°C threshold, underscoring the urgency for climate action. Regions with higher anomalies, particularly North Africa, are at greater risk of extreme heat, desertification, and water scarcity, while other regions may experience shifts in rainfall and agricultural productivity.

Figure 1: African subregions



Note: Five regions of Africa showing estimated population density in 2019.
Source: IPCC. 2021. AR6. WGII.

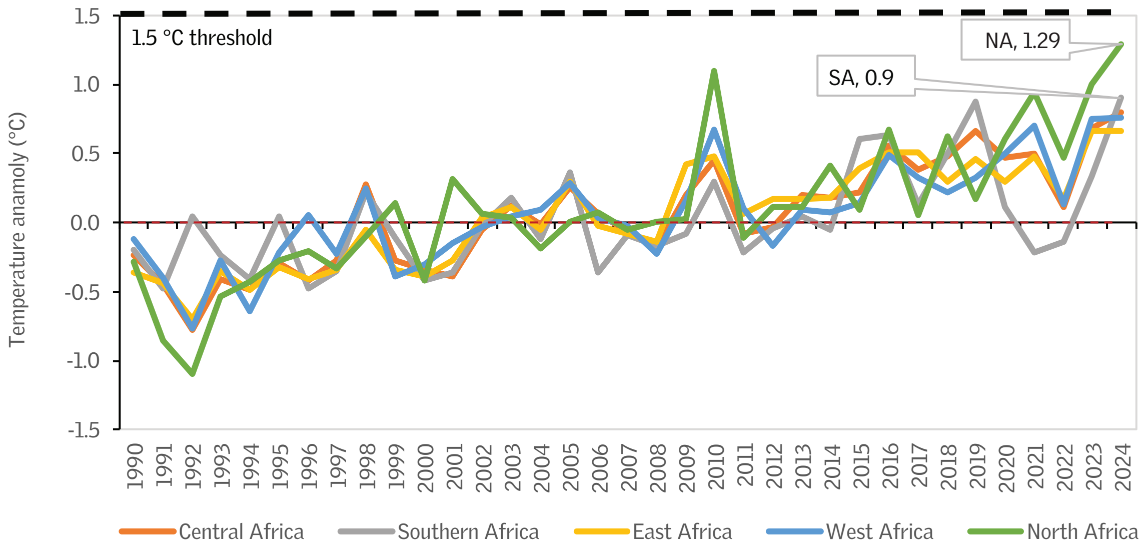
Graph 3: Near-surface air temperature anomalies in °C for 2024 relative to the 1991–2020 reference period



Note: Anomalies for the whole African continent and for each of the African subregions have been calculated using NOAAGlobalTemp v6.

Source: WMO

Graph 4: Annual region-wise mean surface temperature during 1900–2024



Note: Temperature difference calculated from 1991 to 2020 average.

Source: NOAA Global Surface Temperature Dataset (OAAGlobalTemp), Version 6.0; WMO

West Africa

During March–April 2024, an unprecedented heatwave swept across the Sahel, pushing temperatures to record highs and underscoring the region's growing vulnerability to rising heat extremes. These events are not isolated; they build on a long-term trend of increasing warm days and nights that has been documented across West Africa, particularly in the Sahel, between 1961 and 2000.[50] Climate projections reinforce this trajectory: under the A1B emission scenario, summer temperatures in West Africa are expected to rise by 3–6°C between the baseline period of 1981–2000 and 2031–2050. Such projections signal that extreme heat will become both more frequent and more severe in the coming decades.[51]

The human costs of this trend are already visible. Extreme heat directly threatens health and productivity, with agricultural and outdoor workers especially exposed. Heat stress reduces labor capacity, aggravates heat-related illnesses, and even impacts livestock health, undermining livelihoods that depend on pastoralism and farming. Unprecedented levels of heat discomfort are projected for West Africa at 2°C of global warming compared to 1.5°C, highlighting the steep rise in risks with each fraction of additional warming. This heightened sensitivity is partly due to the relatively small year-to-year temperature variability in the tropics, meaning that climate change signals emerge earlier and more strongly here than in other African regions.[52]

The impacts extend beyond health and labor. Children are particularly vulnerable, as extreme heat and related weather disruptions can cause widespread educational setbacks. In 2024, UNICEF reported that at least 242 million children worldwide missed school due to climate-related disruptions, with a significant share in sub-Saharan Africa.[53] Nigeria illustrates the scale of the challenge: its large population and tropical geography expose millions to intense heat stress,[54] compounding risks for health, education, and urban infrastructure.

Over the longer term, heat stress is likely to reshape population dynamics. With global warming of 1.7°C by 2050, internal climate-related migration in sub-Saharan Africa could reach 17–40 million people. At 2.5°C of warming, this number could rise to 56–86 million, with more than 60 per cent of migrants originating from West Africa.[55] Such projections underline how escalating temperatures will not only threaten lives and livelihoods but also drive large-scale social and demographic shifts across the region.

East Africa

Recent decades have seen a marked increase in both the frequency and intensity of extreme high temperature events in East Africa. Hot days and nights have become more common, with the frequency of hot nights rising significantly across the region since 2000.[56,57] Projections using advanced climate models (CMIP5/CMIP6) indicate that by mid- to late-century, annual mean temperatures in East Africa are likely to rise by 1.5–5.4°C, depending on emission scenarios, with the most severe increases expected under high-emission pathway (RCP8.5).[58] By 2071–2095, the intensity of hot days and nights is projected to increase by 1.5–4°C under high-emission scenarios (SSP5-8.5), with the frequency of hot nights increasing to 23–30 per cent. During the recent period (2001–2010) hot days (10–15 per cent) and nights (12–20 per cent) became more frequent across much of East Africa, with a significant positive trend in hot nights.[59]

Extreme heat is projected to exacerbate heat stress, particularly in low-lying regions and urban areas, where urban heat island effects can add 1–4°C to local temperatures and in some cases up to 8°C, amplifying the intensity of heatwaves.[60] For example, Port Sudan, Atbara, Khartoum, Kassala, Gedaref, El Obeid, Nyala and Gode are identified as especially at risk, with Port Sudan being the most vulnerable.[61] The frequency of dangerous heat events those exceeding thresholds for human health and livestock is projected to rise, with some cities likely to experience recurrent extremes every few years.[62] These trends pose serious risks to agriculture, water resources, public health, and food security, especially for populations dependent on rain-fed farming and pastoral systems.

South Africa

South Africa is experiencing a clear rise in extreme heat, with notable increases in the frequency, intensity, and duration of heatwaves. Analyses of meteorological data from 1960 to 2016 show that maximum temperatures have risen at a rate of about 0.02°C per year, with warm days and nights becoming more frequent across most of the South Africa. The strongest increases in warm days have been recorded in the western, northeastern, and eastern regions, while nationwide the frequency of heatwave events has grown at a rate of 0.03 events per year. These trends are particularly pronounced during autumn and summer, and are most evident in low-altitude and coastal regions.[63,64] Long-term data confirm that warm extremes have increased and cold extremes have decreased between 1962 and 2009, with the western half and northeastern regions showing the sharpest trends.[65,66]

Regional climate model projections indicate that by the end of the 21st century, average maximum temperatures in South Africa's interior could increase by up to 6°C under high-emission scenarios, accompanied by more frequent and prolonged heatwaves.[67]

The implications of these changes are significant. Rising heat stress is already contributing to more cases of heat-related illnesses, particularly in densely populated and low-altitude areas. Agriculture faces mounting risks, as higher temperatures reduce crop yields, stress livestock, and strain water resources, especially in arid and semi-arid zones.[68] Ecosystems and tourism are also under pressure; for instance, reserves such as Phinda Private Game Reserve have reported adverse impacts on wildlife, tourism operations, and conservation outcomes linked to extreme heat.[69,70] Urban areas experience amplified impacts through the urban heat island effect, which intensifies risks for public health, infrastructure, and economic productivity.

Several cities and towns stand out as being particularly impacted by extreme heat. Patensie (Eastern Cape), Pietermaritzburg and Pongola (KwaZulu-Natal), Knysna (Western Cape), Hoedspruit (Limpopo), Skukuza and Komatidraai (Mpumalanga) have recorded median apparent temperatures in the danger category, in the range of 39–45°C.[71] The northwest and Northern Cape provinces are projected to experience the steepest increases in heatwave frequency and duration, making them particularly exposed to the escalating risks of extreme heat.[72]

North Africa

In recent decades, North Africa has seen a marked increase in both the frequency and intensity of extreme heat events. Observational data and reanalysis show that the number and severity of heatwaves have risen significantly since the late 20th century, with the period from 2006 to 2015 experiencing a dramatic increase in both the spatial coverage and intensity of extreme heatwaves compared to previous decades.[73] The maximum temperatures during the hottest days in the region have already reached about 43°C, and climate models project that, under high-emission scenarios, these could climb to nearly 50°C by the end of the century.[74] By 2040, heatwaves that are currently considered rare are projected to occur regularly across much of North Africa.[75]

Projections using advanced regional and global climate models indicate that, by the end of the 21st century, around 80 per cent of the most populated cities in the Middle East and North Africa (MENA) region will experience heatwave conditions for at least half of the warm season, with both the mean and maximum intensity of heatwaves increasing substantially.[76] Some scenarios suggest that "super- and ultra-extreme" heatwaves, with temperatures potentially reaching 56°C and persisting for several weeks, could affect up to 600 million people, over 90 per cent of whom will be living in urban centres.[77] The annual mean Universal Thermal Climate Index (UTCI), which measures human thermal stress, is rising by 0.1–0.7°C per decade, with the highest increases in northern and northeastern Africa.[78]

The impacts of these trends are profound. Extreme heat threatens public health, increasing the risk of heat-related illnesses and mortality, particularly among vulnerable populations in cities. The agricultural sector, which is predominantly rain-fed, faces declining productivity and greater risk of crop failure, exacerbating food insecurity and driving rural-to-urban migration. Water resources are under severe pressure, with annual water discharge projected to drop by 15–45 per cent under a 2°C warming scenario, and up to 75 per cent under 4°C, further straining already scarce supplies.[79] These compounding pressures are likely to increase social vulnerability and could contribute to instability in an already politically sensitive region.

Major North African cities such as Cairo, Algiers, Tripoli, and Tunis are among those most affected by extreme heat, with projections indicating that these urban centers will face increasingly frequent and severe heatwaves, putting millions at risk. Even a modest increase of 0.5°C in global mean temperature could add 20 days of moderate thermal stress per year in Egypt and Sudan, along with a significant rise in days of strong thermal stress across the Arabian Peninsula.[80]

Central Africa

Over the past four decades, Central Africa has experienced a significant increase in heat stress and the frequency of hot days. Observational analyses using the Universal Thermal Climate Index (UTCI) show that from 1982 to 2022, heat stress has intensified across most of the region, with peaks typically occurring in January and October. While moderate heat stress is widespread, strong heat stress is now observed in several central, eastern, and western areas, with very few locations have been spared from this trend. Coastal and southern regions have seen slightly less increase, but the overall vulnerability of Central Africa to global warming is clear.[81]

Climate model projections indicate that as global temperatures rise by 1.5°C, 2°C, and 3°C, the spatial extent and frequency of dangerous heat and discomfort conditions will expand dramatically, nearly tripling from the lowest to the highest warming scenario. By the time global warming reaches 2°C, almost the entire population of Central Africa will regularly experience days with potentially dangerous heat-related risks, particularly from March to August.[82] These conditions are expected to reduce worker productivity, increase the need for cooling, and heighten vulnerability to heat-related illnesses, especially in countries along the Atlantic coast and in the northern and central subregions.[83]

The socio-economic impacts of these changes are projected to be severe. Increased heat and recurrent dry spells threaten food security, increase the risk of heat and humidity-related illnesses, and may drive poverty, market inflation, and social instability. Urban areas are especially at risk due to rapid population growth and the urban heat island effect, which amplifies heat exposure. Projections suggest that cities such as Kinshasa (Democratic Republic of Congo), Douala and Yaoundé (Cameroon), and Brazzaville (Republic of Congo) will experience some of the sharpest increases in dangerous heat exposure on the continent by the end of the century, driven by both climate change and rapid urbanization.[84]

Wide temperature variation across Africa's geography: The 2024 monthly land surface temperature (LST) maps clearly show Africa's strong seasonal contrasts, driven by its vast geography and differing summer – winter cycles across hemispheres. The northern belt, dominated by the Sahara and Sahel, consistently records the highest surface temperatures, particularly from May to September, when much of North Africa experiences extreme heat. In contrast, Southern Africa registers its warmest conditions between December and February, coinciding with its summer season. Equatorial and central regions, due to their tropical setting, display less seasonal fluctuation but maintain persistently high temperatures year-round.

Table 1: Heat stress trends, and impacts by African region

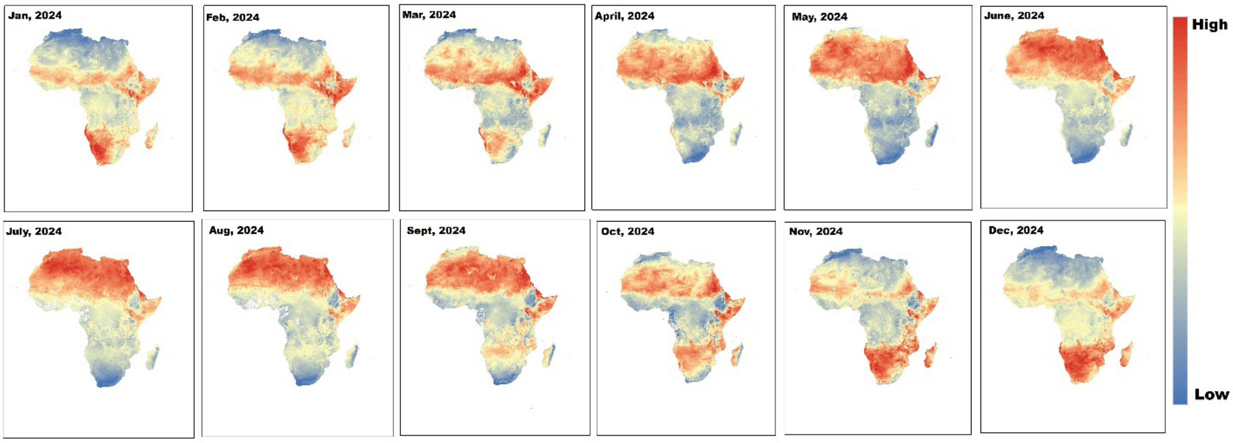
Region	Recent trends /observed/projected heat stress	Key cities/areas	Key impacts
North Africa	Significant increase in frequency, intensity, and duration of heatwaves; projected further rise in dangerous heat stress days, especially under high emissions scenarios	Cairo, Algiers, Tunis, Casablanca	Health risks (heatstroke, mortality), productivity loss, increased cooling demand, infrastructure stress
West Africa	Rapid expansion of "Extreme Caution" and "Danger" heat stress categories; by late 21st century, 50–100% of population at risk during peak months; heatwaves becoming more frequent and severe	Lagos, Accra, Dakar, Niamey, Ouagadougou	Health (heat exhaustion, stroke), reduced labor productivity, food security threats, urban vulnerability
Central Africa	Projected threefold increase in spatial extent of heat/ discomfort; strong heat stress in urban and northern/central areas; moderate to strong heat stress now widespread	Kinshasa, Douala, Yaoundé, Brazzaville	Health impacts, reduced worker productivity, increased cooling needs, urban heat island effects
East Africa	Increasing frequency and duration of dangerous heat events, especially for livestock; projected rise in strong heat stress days and consecutive events	Nairobi, Addis Ababa, Dar es Salaam, Kampala	Livestock and crop losses, food insecurity, health risks, urban vulnerability
Southern Africa	Statistically significant increases in heat stress, especially in spring/summer; coastal and low-altitude towns most affected; more frequent and intense heatwaves	Johannesburg, Cape Town, Durban, Maputo, Harare	Health (heatstroke, sleep disruption), productivity loss, energy demand, drought risk

Source: Compiled by CSE

The cooler phases are observed in Southern Africa during June–August, where winter conditions reduce land surface temperatures, particularly over South Africa, Lesotho, and Namibia. Similarly, parts of East Africa, influenced by elevation in the Ethiopian Highlands and the Great Rift Valley, remain relatively cooler compared to lowland regions. Coastal zones, especially along West Africa and Eastern Madagascar, exhibit moderated temperatures due to oceanic influence.

This spatial and seasonal interplay underlines how Africa's geography drives divergent thermal realities from scorching Saharan summers to milder southern winters, amplifying the continent's vulnerability to heat extremes (see *Map 1: Seasonal variation in land surface temperature*).

Map 1: Seasonal variation in land surface temperature



Source: CSE analysis of MODIS data

Section 4: Urban heat, and wet-bulb temperature: Case studies of Lagos and Johannesburg

The Urban Heat Island (UHI) effect describes the phenomenon where urban areas experience significantly higher temperatures than their rural surroundings, primarily due to the replacement of natural vegetation with impervious surfaces (concrete, asphalt), dense building materials, and reduced green cover. This effect is intensified by rapid urban expansion, loss of vegetation, and the proliferation of dense settlements, which trap heat and reduce nighttime cooling, increasing health risks and energy demand. UHI is typically measured using land surface temperature (LST) data from remote sensing or air temperature differences between urban and rural sites.

Wet bulb temperature, which combines heat and humidity, is a critical metric for assessing human heat stress. In humid African cities, high wet bulb temperatures can be especially dangerous, as the body's ability to cool itself through sweating is compromised. Recent research shows that in wet climates, urban areas can have higher wet bulb temperatures than rural areas, leading to more frequent and severe dangerous heat-stress days for urban residents.[85] This is particularly concerning in African cities with high humidity and dense housing, where ventilation is poor and cooling options are limited.

Evidence from African cities demonstrates strong UHI effects. For example, studies in Lagos (Nigeria), Nairobi (Kenya), Addis Ababa (Ethiopia) and Lusaka (Zambia) show that urban zones near city centres are 3–4°C warmer than peri-urban areas, with the intensity of UHI closely linked to the density of impervious surfaces and the loss of green spaces.[86] Nighttime UHI is often more pronounced in areas with dense settlements, as these areas retain heat absorbed during the day and have limited vegetation to facilitate cooling.[87] Rapid urban expansion and unplanned development further exacerbate these effects, increasing exposure to heat stress, especially for vulnerable populations (*see Table 2: Key urban heat* *drivers and city-specific evidence from African UHI studies).*

Table 2: Key urban heat drivers and city-specific evidence from African UHI studies

Urban heat driver	Mechanism/impact	African city evidence
Loss of green cover	Reduces cooling, increases LST	Lagos, Nairobi, Addis Ababa 88
Dense settlements	Trap heat, poor ventilation, high night-time temperature	Johannesburg, Lagos 89
Rapid urban expansion	Increases impervious surfaces, amplifies UHI	Lagos, Kampala 90, 91
High humidity (wet-bulb temperature)	Increases heat stress, limits sweat-based cooling	Coastal West African cities 92

To better illustrate the urban heat island (UHI) phenomenon and its connection with land use dynamics, the Centre for Science and Environment (CSE) conducted a comparative analysis of Land Surface Temperature (LST) and Land Use Land Cover (LULC) changes in Lagos and Johannesburg over the past decade. The study aimed to understand how spatial transformations in urban land cover have influenced the intensity of UHI in these rapidly growing cities.

For this purpose, freely accessible satellite data from the United States Geological Survey (USGS) Earth Explorer platform were used. Specifically, imagery from the Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) was processed to extract information on both LST and LULC. Using spatio-temporal Landsat imageries with their thermal bands and ancillary data, land cover and LST changes were assessed

The assessment focused on three aspects: (i) spatial and temporal variations in LST within each city; (ii) changes in LULC patterns over the study period; and (iii) the relationship between changes in LST and LULC, highlighting how urban expansion and land transformation contribute to increasing surface heat.

The timing of peak summer heat differs between South Africa and West Africa due to their contrasting locations and climates. In South Africa, which lies in the Southern Hemisphere, the hottest period occurs during November to March, when solar intensity is strongest and cities such as Johannesburg, Cape Town, and Durban experience their highest temperatures.

In contrast, West Africa experiences intense heat shaped by its tropical climate and seasonal shifts between dry and wet periods. The hottest months generally occur from February to April, during the late dry season just before the rains begin. In this period, temperatures often soar above 35°C, compounded by high humidity in coastal cities such as Lagos, which amplifies heat stress and discomfort. Accordingly, our analysis focuses on December and January for Johannesburg, which represent the peak summer months in the Southern Hemisphere. For Lagos, however, due to the limited availability of cloud-free satellite data during its hottest period, we have used December satellite imagery to carry out the assessment.

For Lagos, the analysis was based on satellite scenes acquired on 18 December 2013 and 19 December 2022, while for Johannesburg, the assessment drew upon imagery from 16 January 2014 and 29 December 2021. This has helped to do a comparative evaluation of heat patterns over nearly a decade.

Building on the analysis of land surface temperature and land use changes in Lagos and Johannesburg, we identified areas experiencing consistently high surface heat, commonly referred to as urban heat hotspots.

To further characterize extreme heat exposure in these cities, we apply a standardized definition of heatwaves. While there is no single, continent-wide temperature threshold for severe heat in Africa, as definitions vary by region, climate zone, and national meteorological services. However, scientific and meteorological approaches commonly identify severe heat or heatwave events using absolute temperature thresholds of ≥35°C or when the daily maximum temperature exceeds the 90th or 97th percentile of historical maximum temperatures for 2–3 consecutive days.

The South African Weather Service defines a heatwave as a period of at least three consecutive days during which the maximum temperature at a specific station or grid point is five degrees or more above the average mean maximum for the hottest month at that location.

Similarly, the Expert Team on Climate Change Detection and Indices (ETCCDI) provides percentile-based definitions such as the 90th or 97th percentile of historical maximum temperatures for 2–3 consecutive days, widely used in climate research and meteorological monitoring across Africa. Many scientific studies adopt these frameworks, referencing either ETCCDI indices or national thresholds to identify and analyze heatwaves and extreme temperature events.

These criteria form the basis for identifying and analyzing heatwave events in Lagos and Johannesburg, allowing for a consistent assessment of extreme heat exposure and urban vulnerability.

4.1. Lagos

Lagos is a coastal megacity characterized by high humidity and extensive dense housing. Lagos State has been experiencing an increase in surface temperature due to growing areas of impervious surfaces caused by anthropogenic urban sprawl.[93] The city's rapid urbanization has led to significant conversion of green areas to built-up surfaces, intensifying the UHI effect and increasing both daytime and nighttime heat exposure.

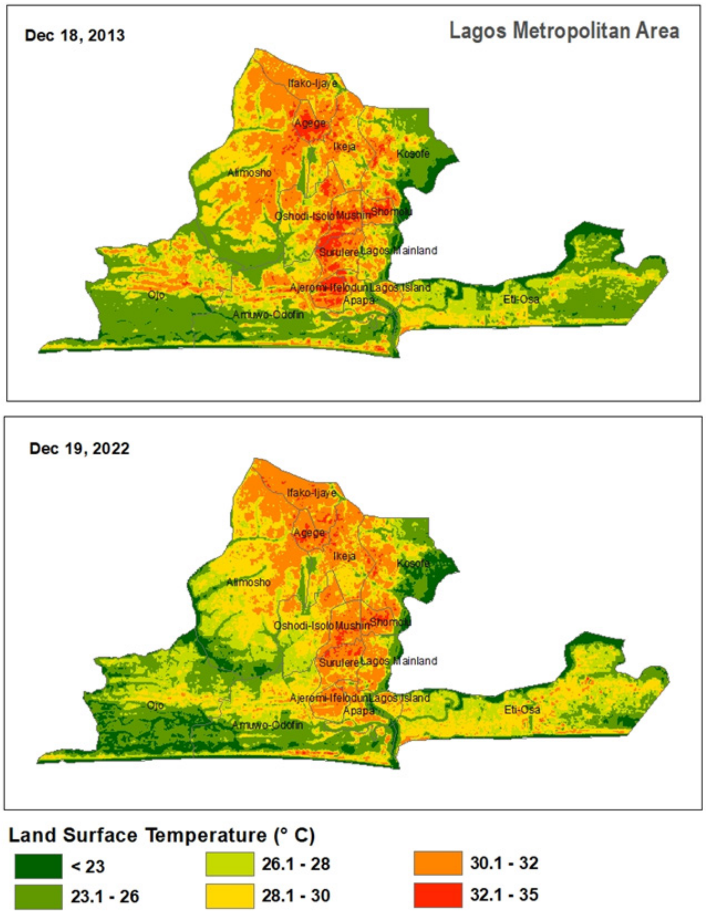
Land surface temperature variations: Analysis of satellite data reveals that the highest land surface temperatures were consistently recorded in densely populated urban areas. Both in 2013 and 2022 in Lagos, the highest LST of 34.4°C and 33.9°C were recorded in the industrial area of Ikeja.

On December 19, 2022, hotspots were observed in Ifako-Ijaiye, Ikeja, Agege, Ajeromi-Ifelodun, Surulere, Shomolu, and Mushin. Fragmented patches exceeding 32°C were also detected in Amuwo-Odofin, Eti-Osa, Lagos Mainland, Oshodi-Isolo, and Kosofe. By comparison, on December 18, 2013, surface temperatures above 32°C were largely concentrated in Agege, Ikeja, Surulere, Shomolu, Mushin, Oshodi-Isolo, and Kosofe.

The temperature band of 32–34°C expanded in 2022 to include previously rural LGAs like Ifako-Ijaiye and Eti-Osa, reflecting ongoing urban development. Areas with consistently high temperatures (30–34 °C) were mainly already urbanized LGAs including Ikeja, Ifako-Ijaiye, Ajeromi-Ifelodun, Mushin, Surulere, and Agege, while other LGAs averaged between 25–30°C. The highest LST in 2013 was 34.43°C in the industrial belt of Ikeja, whereas in 2022, the peak reached 33.92°C in Ikeja, Mushin, and Surulere. In both years, the lowest LST of 21.5°C was observed near the Lagos Lagoon in Eti-Osa *(see Map 2: Variation in land surface temperature over Lagos Greater Area for 2013 and 2022)*

Land use land cover change: Land cover transformations have significantly influenced the spatial distribution of temperature across Lagos. Built-up areas, bare lands, and soils registered the highest surface temperatures, while water bodies and vegetation showed relatively cooler surfaces. Between 2013 and 2022, built-up areas expanded from 645.41 sq. km to 701.75 sq. km, while green cover declined from 23.08 sq. km to 13.84 sq. km *(see Graph 5: Change in the LULC area of Lagos Greater Area in 2013 and 2022)*

Map 2: Variation in land surface temperature over Lagos Greater Area for 2013 and 2022



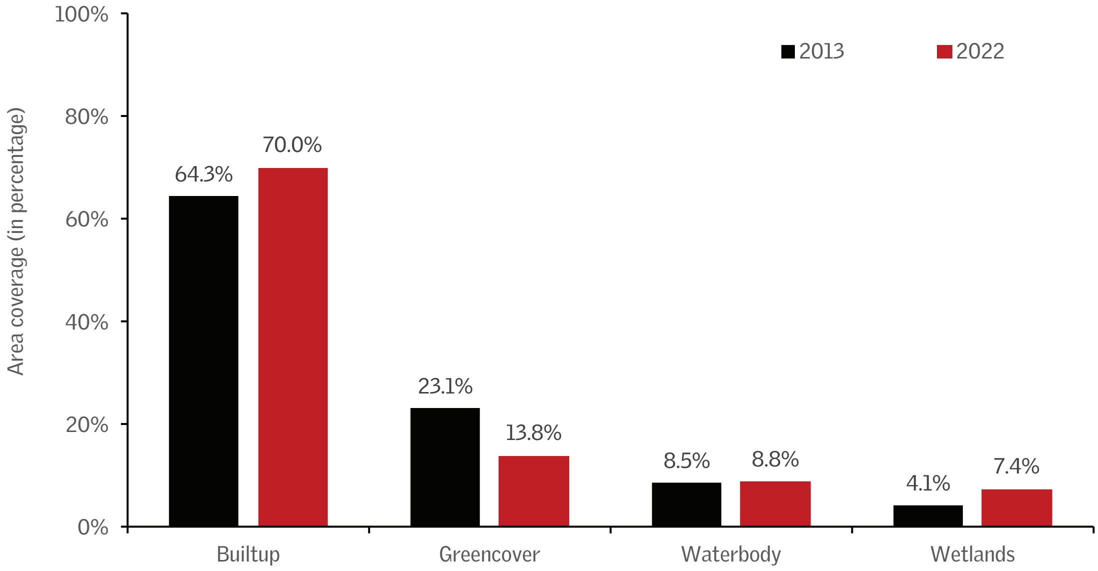
Note: Heatwave months (Dec-Jan) are chosen to analyze the Land Surface Temperature (LST). The respective date of acquisition of the images are Dec 18, 2013, and Dec 19, 2022.

Source: CSE analysis of Landsat 8 satellite images from United States Geological Survey (USGS) Earth Explorer.

Surface temperature by land cover: This expansion of impervious surfaces is strongly correlated with rising LST across all land cover categories. Although built-up areas grew from 64 per cent in 2019 to nearly 70 per cent in 2022, LST in these zones increased only slightly by about 0.5°C.

This stability is likely because much of the growth occurred within already urbanized cores with high baseline heat, while surface heterogeneity such as open spaces, scattered vegetation, roads, and proximity to coastal areas helped moderate temperatures. As a result, LST in built-up and coastal

Graph 5: Change in the LULC area of Lagos Greater area in 2013 and 2022



Source: CSE analysis of Landsat 8 satellite images from United States Geological Survey (USGS) Earth Explorer.

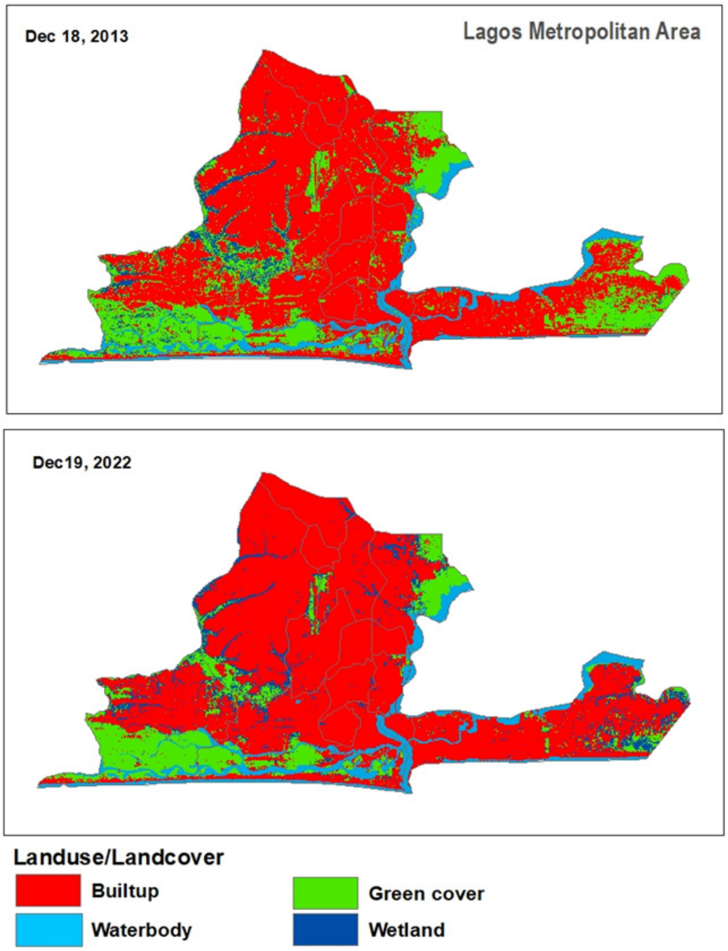
urban areas remains relatively consistent, masking smaller-scale thermal variations. *(see Map 3: Land use land cover of Lagos Greater Area in 2013 and 2022* and *Table 3: Descriptive statistics of mean LST by land cover class, 2013 and 2022).*

Table 3: Difference in surface temperature of land cover features in 2013–2022

Land cover	Land surface temperature (°C)		Change (°C)
	2013	2022	
Built-up	34.4	33.9	-0.5
Green cover	32.0	32.7	0.8
Wetland	30.9	31.5	0.6
Waterbody	27.4	27.4	0.0

Heat hotspots: Dense built-up areas in central Lagos continue to act as constant heat hotspots. On December 18, 2013, hotspots peaked at 34.4°C, while on December 19, 2022, the peak was slightly lower at 33.9 °C. In both years, central LGAs such as Agege, Ikeja, Kosofe, Mushin, Shomolu, Surulere, and parts of Ajeromi-Ifelodun registered the highest heat intensities, strongly linked with high population densities.

Map 3: Land use land cover of Lagos Greater Area in 2013 and 2022



Note: Heatwave months (Dec-Jan) are chosen to analyze the Landuse Landcover (LULC) for each year –2013 and 2022.

Source: CSE analysis of Landsat 8 satellite images from United States Geological Survey (USGS) Earth Explorer.

In 2022, however, the spatial spread of hotspots showed a slight decrease, with some areas dispersing outwards. Newer hotspots emerged in Ifako-Ijaiye and Eti-Osa, reflecting the urban expansion and conversion of rural land to built-up areas. Industrial zones such as Ajeromi-Ifelodun within the Badagry Division also displayed persistently high temperatures due to industrial activity.

4.2. Johannesburg

Johannesburg, one of the largest cities in Sub-Saharan Africa, has experienced rapid urban expansion, with significant land cover changes influencing the city's heat profile. The shift from green and open spaces to built-up areas has intensified heat stress and modified the spatial distribution of urban hotspots.

Land surface temperature variations: Satellite analysis highlights substantial changes in the distribution of heat across Johannesburg. On December 13, 2024, the highest LST values were concentrated in densely populated built-up areas in the eastern region of Alexandra, southern part of the city and the north-western belt near Lanseria International Airport, with surface temperatures exceeding 35–50°C. By contrast, on January 16, 2014, the city recorded more widespread surface temperatures above 32°C, particularly in the northern suburbs and areas with higher building density *(see Map 4: Variation in land surface temperature over Johannesburg Metropolitan Area for 2014 and 2024)*

Consistently high LST values in the range of 45–51 °C were observed around Lanseria International Airport and the Stone Ridge Center in the eastern region. Cooler temperatures were recorded in areas with water bodies and dense vegetation, underscoring the cooling role of natural land covers.

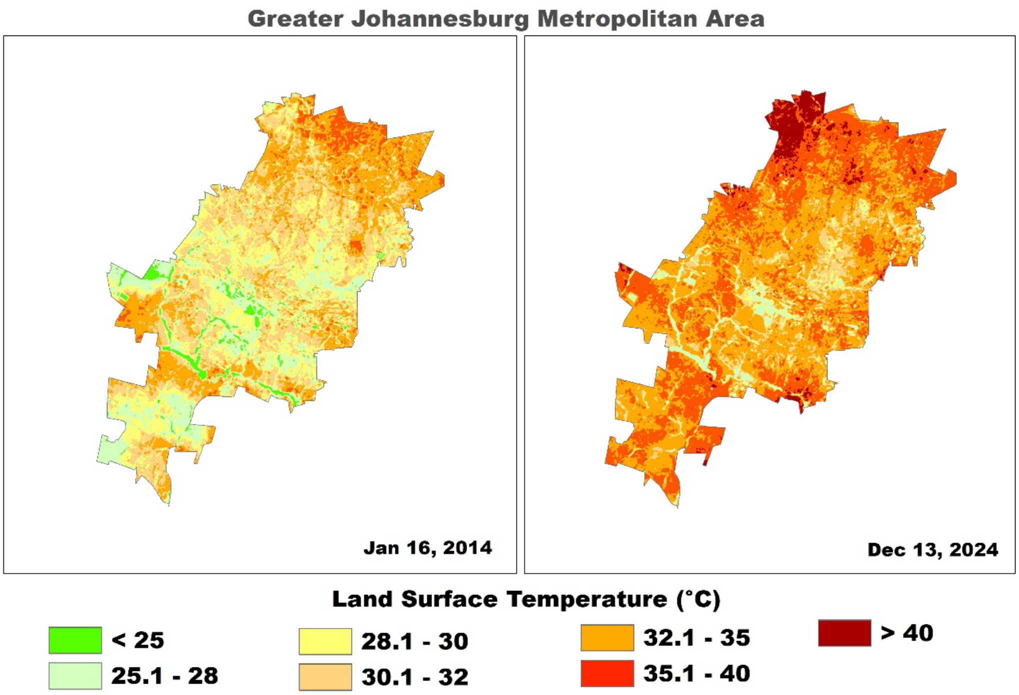
Land use land cover change: Between 2014 and 2021, Johannesburg witnessed a significant increase in built-up areas, expanding from 720.63 sq. km to 917.33 sq. km, while green cover declined from 510.68 sq. km to 423.72 sq. km. Waterbodies, however, remained constant *(see Graph 6: Change in the LULC area of Johannesburg Metropolitan Area in 2014 and 2021)*

The expansion of built-up land was accompanied by rising heat stress, though temperature variations differed across land cover categories. Built-up surfaces displayed the widest LST range, while vegetated areas consistently recorded lower values *(see Map 5: Land use land cover of Johannesburg Metropolitan Area in 2014 and 2021).*

Surface temperature by land cover: A detailed comparison of LST across land cover types reveals an increase in temperature values between 2014 and 2024. Built-up areas recorded a rise from 41.5°C to 51.2°C, while green cover also increased from 38.8°C to 48.7°C. Open and/or barren land also saw a significant increase of 8.7 °C, and other categories increased by 5.7°C. Waterbodies recorded a increase of +6.5°C despite maintaining the same coverage *(see Table 4: Difference in surface temperature of land cover features between 2014 and 2024).*

Overall, impervious and bare surfaces showed a maximum LST range of 39–42°C, while minimum values in vegetated and open areas reached as low as 8–12°C across both years.

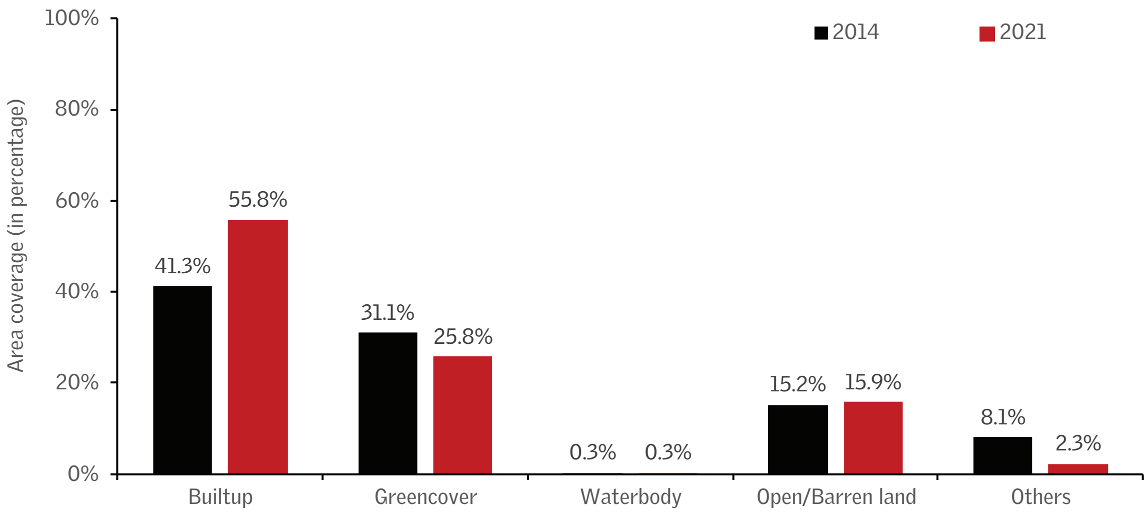
Map 4: Variation in land surface temperature over Johannesburg Metropolitan Area for 2014 & 2024



Note: Heatwave months (Dec–Jan) are chosen to analyze the Land Surface Temperature (LST). The respective date of acquisition of the images are Jan 16, 2014, and Dec 13, 2024.

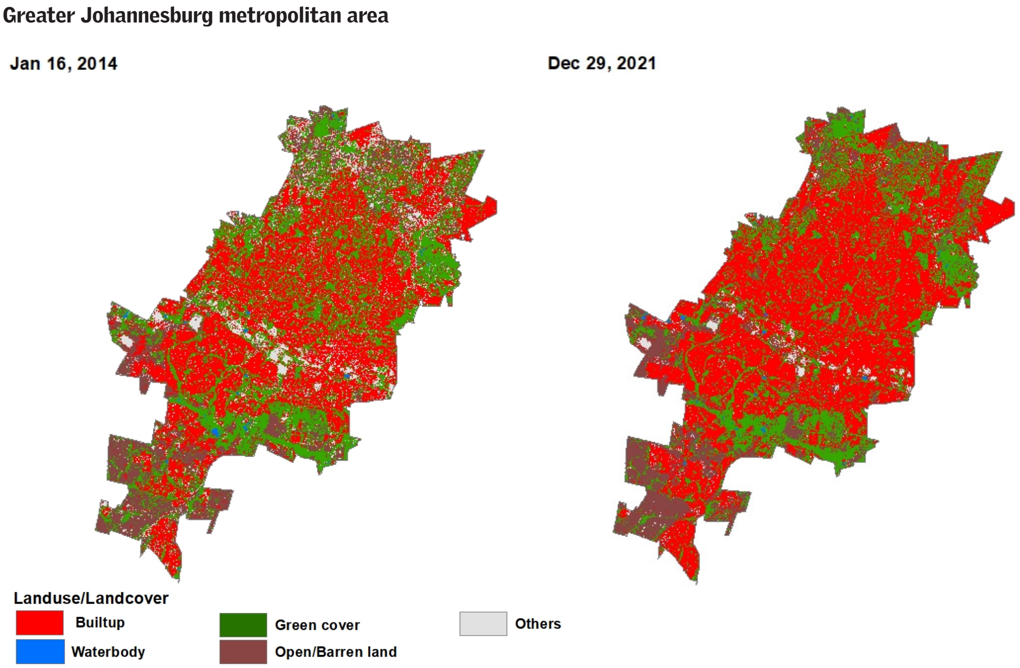
Source: CSE analysis of Landsat 8 satellite images from United States Geological Survey (USGS) Earth Explorer

Graph 6: Change in the LULC area of Johannesburg Metropolitan Area in 2014 and 2021



Source: CSE analysis of Landsat 8 satellite images from United States Geological Survey (USGS) Earth Explorer

Map 5: Land use land cover of Johannesburg Metropolitan Area in 2014 and 2021



Note: Heatwave months (Dec-Jan) are chosen to analyze the Landuse Landcover (LULC) for each year –2014 and 2021.

Source: CSE analysis of Landsat 8 satellite images from United States Geological Survey (USGS) Earth Explorer.

Table 4: Difference in surface temperature of land cover features between 2014 and 2024

Land cover	Land Surface Temperature (°C)		Change (°C)
	2014	2024	
Built-up	41.5	51.2	9.7
Green cover	38.8	48.7	7.8
Waterbody	35.0	41.4	6.5
Open and/or barren land	42.2	50.9	8.7
Others	41.3	47.0	5.7

Heat hotspots: The north-eastern region of Johannesburg, particularly Alexandra, consistently emerged as a major heat hotspot. On January 16, 2014, the city recorded the highest hotspot value of 41.5°C, while on December 13, 2024, the maximum LST increased to 51.2°C. The persistence of high temperatures in densely built-up regions highlights the strong link between urban density, land cover change, and surface heat intensities.

Section 5: Why is Africa more vulnerable?

Africa is challenged by the rapid demographic and socioeconomic changes. Growing urbanisation and population is exposing more people to heat stress and urban heat island effect caused by heat-absorbing surfaces and reduced vegetation that intensifies local temperatures. Projections done by studies show that by the late 21st century, the area and population exposed to high-risk heat stress in Africa could increase 12-fold, with the number of days with dangerous heat conditions rising by 10–30 per cent and their intensity by 6–20 per cent across West, Central, and North-East Africa.[94]

A large share of the workforce is employed in outdoor sectors such as agriculture, construction, and mining, where prolonged exposure to high temperatures reduces productivity and elevates the risk of heat-related illnesses or even mortality. The International Labour Organization estimates that in some regions, heat exposure could lead to a loss of up to 5 percent of total working hours annually by 2030, translating into billions of dollars in lost economic output.

Adaptive capacity across the continent remains constrained. Approximately 600 million people, about 43 per cent of Africa's population lack access to electricity, with the majority concentrated in sub-Saharan Africa. [95] In rural areas, reliance on traditional biomass fuels for cooking and limited electrification hinder the uptake of cooling technologies. Currently, around 970 million Africans lack access to clean cooking solutions. While liquefied petroleum gas (LPG) is widely promoted as an urban alternative, recent price spikes have rendered it unaffordable for nearly 30 million people.[96] Cookstoves using solid fuels are also sources of heat exposures.

Urban populations face unique vulnerabilities. Dense settlements, where homes are often built with corrugated metal sheets or concrete blocks, trap heat and create indoor conditions that can exceed outdoor ambient temperatures.[97] These densely populated settlements, which accommodate a large share of Africa's urban poor, rarely benefit from planning measures such as ventilation corridors, reflective surfaces, or green infrastructure that could help mitigate urban heat.

For many households, the cost of cooling appliances such as fans or air conditioners is prohibitive, while access to improved housing remains limited. Public health systems, already under-resourced, are often ill-prepared to manage large-scale heat-related emergencies. Early-warning systems and risk communication channels remain weak or fragmented, leaving populations with little time or information to prepare for dangerous heat events.

Institutional responses to heat stress remain inadequate across the continent. Even though national cooling action plans have begun to take shape, heat risk is largely addressed in fragmented ways through broader disaster management or health strategies.

These combined with limited resources for adaptation, weak infrastructure, and unaffordability are exacerbating the structural vulnerabilities.

As discussed earlier, the city-level assessments of Lagos and Johannesburg demonstrate how land use change and rapid urbanization are reshaping the thermal environment of African megacities, though with different outcomes. In Lagos, the expansion of impervious surfaces and the sharp decline in green cover have amplified the urban heat island (UHI) effect, resulting in higher and more widespread heat stress across the metropolitan area. Johannesburg, which previously showed moderated peak temperatures, now exhibits a substantial increase in land surface temperatures (LST) in 2024, with all land cover categories including vegetation and water bodies recording higher temperatures. This recent spike reflects the growing thermal burden of uncontrolled urban expansion, even in cities with historically cooler climates. The findings emphasize that geographical advantages like elevation and dryness are no longer sufficient buffers against urban heat, especially when natural land covers are increasingly lost.

These patterns highlight that the UHI effect interacts with local geography and climate to shape city-level vulnerabilities. In Lagos, the increasing heat stress is compounding risks for densely populated settlements where adaptive capacity is limited. In Johannesburg, the spike in land surface temperatures across all land cover types reveals a growing and more widespread heat burden. Heat exposure is now intensifying in industrial hubs, inner-city zones, and expanding peri-urban areas, pointing to increasingly uneven and deepening vulnerability within the city.

The contrasting experiences of these two cities also provide lessons for other regions of Africa. Coastal cities such as Abidjan, Accra, or Dar es Salaam share similarities with Lagos, where rapid conversion of green space into built-up land can significantly intensify UHI, particularly under humid tropical conditions. Inland cities at higher elevations, like Addis Ababa or Nairobi, may not always register the same degree of rising land surface temperature as lowland counterparts, but the spread of built-up areas and loss of vegetation can still lead to localized hotspots with strong socioeconomic impacts.

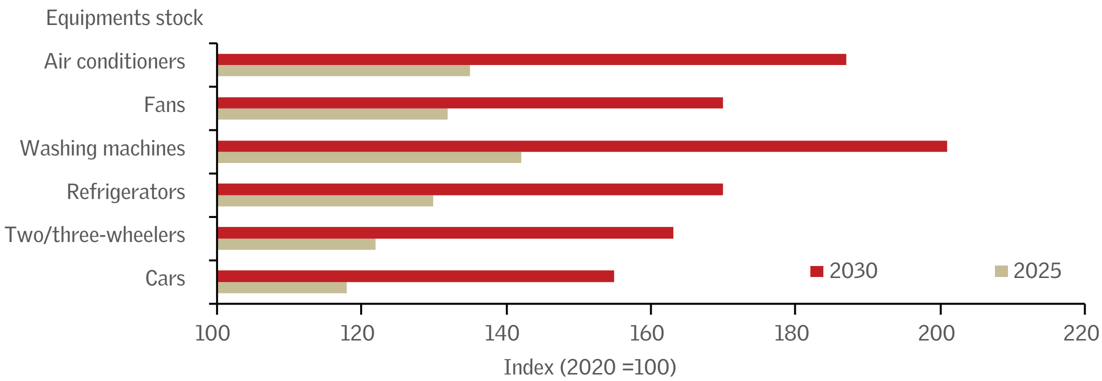
Overall, the evidence underscores that while UHI dynamics manifest differently across African cities, the underlying drivers remain consistent – rapid, unplanned urban growth, loss of natural land cover, and concentration of impervious surfaces. Without deliberate planning for green infrastructure, water-sensitive design, and climate-resilient urban expansion, the risks of heat stress to health, productivity, and urban livability will intensify across the continent.

Section 6: Impact of growing heat on cooling demand and thermal comfort

Even though Africa has the world's lowest levels of per capita use of modern energy, demand for energy services in Africa is expected to grow rapidly due to rising heat and cooling demand.[98] Despite being at the lower end of the global appliance market, the number of air conditioners, fans and refrigerators that is projected to more than double, will make households the largest final energy consumers in Africa in 2030. Heat combined with rising incomes and expanded access to electricity will spur this trend. This is evident from the Africa Energy Outlook report 2022 of International Energy Agency.[99] Many locations across Africa experience 4,000–5,000 cooling degree days annually, an order of magnitude higher than countries in temperate climate such as France (a cooling degree day (CDD) is a measurement designed to quantify the demand for energy needed to cool buildings).[100]

Therefore, demand for energy services will increase rapidly over this decade, with stock of air conditioners and washing machines doubling, estimates IEA (see *Graph 7: Growth in selected energy-related economic activities in Africa in the SAS, 2020-2030*).

Graph 7: Growth in selected energy-related economic activities in Africa in the SAS, 2020–2030



Source: International Energy Agency 2022, Africa Energy Outlook

This shows that the ownership of air conditioners will increase by around 17 million to 40 million and electric fans by 110 million to around 340 million over 2020–30 in the SAS. The refrigerators will increase by over 80 million to nearly 200 million and washing machines by 20 million to around 40 million. This will double the household electricity demand from around 160 TWh to 350 TWh. Growth is fastest in sub-Saharan Africa (excluding South Africa), with electricity use for appliances and other electrical equipment quadrupling by 2030. Over 270 million major appliances, including air conditioners, set to be purchased across Africa in the current decade.[101]

Currently, across Africa, air conditioner ownership averages only 0.08 units per household, while fans are more common, averaging 0.8 units per household. The air conditioner ownership rise rapidly, reaching an average of 0.10 units by 2030 and 0.25 units by 2050 in the SAS. This contrasts with average ownership today of 0.7 units globally and 2.2 units in the United States.[102]

6.1 Global dumping of old and used appliances locking in high electricity demand

What is compounding the problem is the massive dumping of old and second hand air conditioners that are not only more energy inefficient but also use the ozone depleting refrigerants. It is estimated by the Yale Environment that these old air conditioners consume two to three times more electricity than new models. Research by CLASP and the Institute for Governance & Sustainable Development (IGSD) has shown that 35 per cent of new room air conditioners sold in Africa's 10 largest countries in 2018 were low-efficiency units that could not be sold legally in the countries of origin, including the United States, Japan, South Korea and China. A smaller number of units were imported and assembled in Africa, mostly in Nigeria and Egypt.

Due to the challenges of affordability, cheaper units become attractive and becomes a barrier to quicker uptake of action to regulate imports. It is evident from the literature that more efficient appliances cost two to three times as much as used ones, but consume a third as much electricity. But upfront capital cost makes adoption challenging despite the huge savings.

Combating dumping: There is now a concerted effort by the countries to regulate and reduce import of used appliances. Several African countries have joined a United Nations working group to stop this trade. In fact, under both the Basel Convention, an international treaty governing hazardous waste, and the European Union's Waste Shipment Directive, such dumping is often illegal.[103]

In September 2022, the Union of African Associations of Refrigeration and Air Conditioning Stakeholders (U-3ARC) took steps to address environmental dumping. During its general assembly in Casablanca, U-3ARC had issued the Casablanca Declaration to end dumping of obsolete air conditioners in Africa.[104] This was signed by members from across Africa aligned with the objectives of the Kigali Amendment to stop the dumping of used cooling appliances and promote the adoption of low-global warming potential (GWP) refrigerants like R32 and R290 and energy-efficient technologies.[105]

Ghana has demonstrated the leadership in this matter and has banned all used air conditioner and refrigerator imports in 2008. According to the National Cooling Action Plan[106] in Ghana, in October 2008, the Minister of Energy, empowered by the Energy Commission Act 541, promulgated the Energy Efficiency Regulation 2008 (LI 1932) which prohibited importation and sale of used air conditioner, used refrigerator, used freezer and used combination refrigerator/freezer, among other products.[107] The full effect of the LI came into effect on January 1, 2012. According to the Energy Commission's estimates the old units cause about 30 per cent waste in electricity consumption. Moreover, these appliances also operate on CFC gases.

Several African countries are taking steps towards mandatory minimum energy performance standards. These include Benin, Ghana, Nigeria and Senegal and all members of the Economic Community of West African States [ECOWAS], as well as Algeria, Egypt, Kenya, Rwanda, South Africa and Uganda. It is evident that around 40 per cent of African countries have adopted mandatory MEPS for cooling equipment or are planning to do so, and around 20 per cent for refrigeration.

IEA 2022 report has estimated that if appliances with the lowest efficiency rating are banned, it can save over 40 TWh of electricity demand in 2030 in the SAS, equivalent to one-third of total appliance-related demand today.[108] But implementation of mandatory MEPS and MCL across all appliance types in the Continent can reduce electricity consumption by 2030. More stringent policies to improve the energy efficiency of cooling equipment and building envelopes, passive cooling through better design of buildings and use of vegetation, can avoid almost 20 TWh of demand by 2030. This is equivalent to the average generation from around 4,400 MW of gas-fired power plant capacity, the construction of which would cost US $2.7 billion. Refrigerators and air conditioners see the biggest improvements, with the average stock efficiency increasing by around 50 per cent to 2030 for both end-uses.[109]

Section 7: Rapid construction of buildings need heat resilience and thermal comfort measures

According to the United Nations Environment Programme (UNEP), 80 per cent of floor area growth expected by 2030 is expected in low-income countries that lack stringent building codes. Yet the fact is that a large share of the future building stock are yet to be built. This offers an opportunity to set the terms of the new growth and prevent lock in of energy intensity in the built structures.

A study published in the *Journal Science Direct* in 2024, states that the total building floorspace in Africa will increase at a compound annual rate of 3.0 per cent between 2000 and 2070, reaching approximately four times the floorspace in 2020. By 2070, the total building floorspace of Africa will reach 91.9 billion m^2, respectively, with residential buildings comprising and 90.0 per cent.[110]

Africa Construction Market Analysis by Mordor Intelligence[111] shows that by construction type, new buildings command 71.6 per cent of the Africa construction market share in 2024, and renovation is set to expand at a 9.5 per cent CAGR to 2030.

By construction method, conventional on-site techniques retained an 85.7 per cent share in 2024; prefabricated and modular approaches are the fastest growing at a 10.0 per cent CAGR. Egypt has captured 37.8 per cent of the Africa construction market in 2024, and Kenya is the fastest-growing country at a 9.1 per cent CAGR to 2030. Residential sector led with 38.65 per cent revenue share of the Africa construction market size in 2024, while infrastructure is projected to advance at a 9.4 per cent CAGR through 2030.[112]

In Africa, there is substantial deficit in public affordable housing. There is a shortfall of at least 51 million affordable housing units across the continent (CAHF, 2023). Nigeria is deeply affected with a housing deficit of 28 million units, while the Democratic Republic of Congo faces an estimated shortage of 3.9 million, requiring over 260 thousand housing units annually. South Africa faces an affordable housing shortage of approximately 3.7 million units. It is reported in the same study that as per the Statistics South Africa's Household Survey in 2021, 12.1 per cent of the country's 14.75 million households still live in dense settlements. [113] The affordable housing deficit in Kenya is nearly 2 million houses and continues to grow at a rate of about 200,000 units a year.[114] Countries like Kenya, Rwanda and Zimbabwe among other are increasing investments in affordable housing as per the study published in the journal *Science Direct* in 2024.[115]

This builds a strong case for adoption of climate-responsive building architecture, passive architecture, enhancement of indoor thermal comfort and reduction in heat island effect. This can improve thermal comfort and reduce cooling demand and energy intensity of built structures.

7.1. Towards national cooling strategies to tame energy guzzling

The emerging national cooling plans are helping to chart the roadmap on energy efficiency, refrigerants and in some cases the larger approaches to improving thermal comforts in buildings. As noted earlier, around 40 per cent of African countries have adopted plans to implement mandatory minimum environment performance for cooling equipment or are planning to do so, and around 20 per cent for refrigeration. These are part of their cooling action plans. The primary focus of these plans are to provide regulatory framework for adoption of energy efficiency standards and labelling of energy efficient appliances, and reduction in cooling demand. Some countries have also added the dimensions of appropriate passive architecture and material for heat management in buildings. Some of these plans have also provided for green and blue infrastructure. However, the central focus is on addressing the cooling technologies, energy efficiency and refrigerants.

The governments in Africa have also begun to adopt building codes to promote energy efficient buildings and appliances. As per the GlobalABC Regional Roadmap for Buildings and Construction in Africa 2020–2050, Morocco and Tunisia have mandatory building codes in place that cover the entire buildings sector. Ghana and Nigeria have codes that cover part of the sector. Egypt and South Africa have voluntary codes. A number of countries are currently in the process of developing building code standards, including Botswana, Burundi, Cameroon, Cote D'Ivoire, Ghana, the Gambia, Kenya, Senegal, Tanzania and Uganda. The remaining countries are yet to implement building energy codes.

For instance, the national cooling action plan of Kenya seeks updating of the building codes to make nature based and passive cooling a design requisite for new buildings and refurbishment of existing buildings to include passive cooling strategies, such as the cool roof. This will be backed by system design and servicing to maintain energy efficiency.[116] Already, Energy Management Regulations, 2012, requires large consumers of electricity to carry out audits of their consumption and implement viable measures. National Building Regulations 2015 and 2017 requires adoption of passive cooling in building design.

Simultaneously, Kenya is implementing a standards and labelling program and revising efficiency levels for room air conditioners (ACs) and domestic refrigerators in 2019 and 2020, respectively. Kenya is also aiming to develop sustainable end-of-life management of cooling equipment to prevent venting of refrigerants into the atmosphere.

GhanaNational Cooling Plan[117] has outlined the measures for improving efficiency, designing of new buildings with reduced cooling loads with cool roof technology, shading, using low U-value materials and promoting energy efficient cooling technology. As part of the ECOFRIDGE project, which is a U4E partnership initiative of countries, innovative financial mechanisms are being looked at to facilitate the replacement of outdated refrigerators and air conditioners.

Rwanda National Cooling Strategy[118] of the Government of Rwanda is largely focussed on the measures needed to promote energy efficiency regulations, new codes and standards, economic incentives such as subsidies for energy efficient equipment and appliances. It has primarily focused on the energy efficient requirements and standards for air conditioners and their refrigerants, and labelling. It seeks to reduce split incentives for energy-efficient technologies in buildings and promote bulk procurement strategies for lighting.

The strategy highlights that implementation of low energy consumption standards in buildings and services in Rwanda could result in an 80 per cent reduction in energy use.

Similarly, the "Nigeria Cooling Action Plan" (N-CAP)[119] is also a strategy to be in compliance with the targets under the Paris Agreement, the Montreal Protocol and the Kigali Amendment. This focuses on air conditioners, refrigerators and refrigerants. It proposes import ban on used cooling devices, swap out programme for old units, end of life management, Minimum Energy Performance Standards (MEPS) and labelling scheme, funding mechanism, and sectoral integration of these requirements. This is not focussed on overall heat management and reduction in thermal load in buildings and urban spaces.

Most other countries are working through their National Adaptation Plan and Nationally Determined Contribution (NDCs) as well as green building codes and energy efficiently requirements to address the climate extremes. For instance, Ethiopia is developing green building initiatives under Climate-Resilient Green Economy (CRGE) Strategy to promote sustainable construction, reduce environmental impact, and achieve climate resilience. Several countries have focussed on cooling technologies to align with the requirements of the Montreal Protocol and Kigali amendment to reduce the ozone depleting refrigerants. For instance, South Africa is moving towards mitigating this with energy efficiency measures of cooling products to enable refrigerant transition.

It is also evident that floor space certified as green is also increasing throughout the continent, and many African countries are expanding their green building markets.[120] The green-certified buildings have been shown to save billions in energy costs while averting substantial health impacts linked to air pollution and heat stress [121]. This needs to be driven by performance-linked standards to deliver real energy and resource savings on the ground.

As the building construction industry is growing rapidly, the urban and peri-urban areas are undergoing material transition. Application of more concrete, cement, steel, aluminium, glass among others in modern buildings is increasing. If not designed well with passive architectural design for better ventilation and day lighting or without appropriate insulation, these structures can become heat trappers.

These structures are also moving away from the traditional ad locally available material like thatch, mud, wood, bamboo, stone among others that make traditional houses more thermally comfortable and energy efficient. It is therefore, necessary to understand how these traditional techniques and material can also be adapted in modern buildings to reduce energy and material intensity of the structures (see *Box: Material transition in buildings in Africa: Need fusion approach*).

However, a lot more harmonised efforts are needed develop a comprehensive action to reduce cooling demand. This requires regulatory and fiscal drivers as well as alignment of target oriented action for thermal comfort in buildings, energy efficient material and appliances, and green blue and blue infrastructure.

This requires national and sub-national action plans and action on building regulations and capacity building for passive cooling, and, heat resilient city planning to mitigate UHIE. Upgrading housing with cool roofs, insulation, and passive design strategies reduces indoor heat exposure and lowers energy demand for cooling.

MATERIAL TRANSITION IN BUILDINGS IN AFRICA: NEED FUSION APPROACH

Africa is experiencing material transition in buildings. The dominant building materials in modern buildings in Africa include cement concrete, structural steel, etc. This is largely displacing the traditional local material including mud, bricks, timber, bamboo, natural stones, rammed earth, etc. These are still predominant in peri-urban and rural areas and these are cheaper, locally sourced and are environmentally friendly. Precast and prefabricated concrete walls are gaining significant traction in various regions due to their cost-effectiveness, speed of construction, and durability.

It is necessary to ensure that the that the prefabricated materials and applications are co-joined with adaptive passive design principles including ventilation, and shading in modern buildings to enhance energy efficiency and thermal comforts.

Reinvent traditional material and building techniques
Traditionally, mud/earth techniques, woods, stones, grass and straw are widely prevalent in sub-Saharan Africa. These offer an opportunity to adapt them in the modern buildings to improve thermal comfort, local resilience, reduce energy and material intensity of the built structures and keep the structures affordable and sustainable.

Experts and architects have begun to document these traditional material and techniques to understand the sustainability value and its possible integration in modern structures while also retaining them. Their documentation has brought out that many traditional African buildings have energy-saving features like ventilation and shading.[122, 123] For example the 'banco' building technique in Mali is mud and straw-layered adobe homes with complex patterns and designs. These structures are heat resilient and energy-efficient. North African architecture shows intricate ornamentation and skillful tile work. Courtyards and fountains are used in this hot, dry climate. East African architecture display use of thatch and other organic materials with simple and functional layouts with good natural ventilation and light.[124]

The Maasai, for example, are known to construct traditional huts using a frame made of branches and a thatch or grass roof. These are energy-efficient constructed and have high, conical roofs that aid in temperature regulation. The architecture of Central Africa has unique structural patterns using bamboo and timber. For instance, the BaAka people of the Central African Republic make houses with "thatch roofs that reach the ground and a framework made of poles and woven branches".[125] This is resistant to strong winds and heavy rains. In Southern Africa traditional Zulu huts have woven grass or reed walls and thatched roofs and whitewashed walls and thatched roofs with "ornamental gables of Cape Dutch architecture",[126] which indicate Dutch influence. The Nubian vault is an ancient African architectural technique for creating vaulted roofs with mud (adobe) bricks without formwork. It uses local earth for bricks and mud mortar. This is low-cost, and works well in areas that do not have adequate wood and timber. It is said that "bricks are laid at an incline, creating a self-supporting arch that corbels to form the vaulted roof".[127] This is now being promoted by the organizations like the Nubian Vault Association to address housing needs in the Sahel region. An example of Nubian architectural influence is the Great Mosque of Djenné in Mali.

As is now acknowledged and promoted in several parts of the Global South including India, it is possible to enable modern adaptations of these sustainable materials, and local traditional building techniques in thermal insulation, natural ventilation, and integration with the landscape.

There are examples in India where architect community has begun to adapt several of these traditional and local material in modern building. This fusion approach can not only improve thermal comfort but also reduce the material and energy intensity of the modern structures.[128]

Section 8: Need roadmap for heat management plans and action for co-benefits

It is necessary to distinguish between cooling action plans and the heat action plans. In most of the countries in Africa the cooling action plans have been designed to be more in line with the objectives of the Montreal protocol to address the ozone depleting refrigerants and energy efficiency of cooling technologies. Some of the better designed plans have also included measures like passive architecture and have made references to greening and water bodies to manage thermal load.

However, heat management action plans are needed to address not only what the cooling action plans' technocentric focus is expected to deliver but also to have a much wider focus to address vulnerability and resilience against rising heat stress. This is needed not only at the building level but also at the city level. This is yet to progress in the Continent.

The only country that has adopted a heat action plan in Africa so far is Sierra Leone in 2025. Its plan outlines targeted actions, policies and partnerships to enhance heat resilience. These include implementation of cooling corridors and green spaces to reduce heat exposure, infrastructure improvements to adapt urban areas to rising temperatures and protective measures for vulnerable groups, including women, children and the elderly. It also emphasises public awareness campaigns on heat-related risks and solutions.

The heat action plans need to be contextualised in the local climatic conditions, local urban and regional planning and mapping of vulnerability of population to heat stress that is differentiated by income class, occupation, gender, age, nutritional status, access to housing and shelter, community shelters and shades, health care among others.

This needs to integrate both short term and long terms measures. In the short run the regions need to integrate early warning systems, disaster preparedness and emergency response and requisite infrastructure for emergency healthcare. In the medium to long term adequate infrastructure and systems need to be created to reduce structural vulnerability and also build resilience of the systems, infrastructure and people.

This requires regulations, standards and guidelines to upscale affordable sustainable buildings, access to sustainable cooling and thermal comfort for all income classes including dense settlements, greening and water bodies to reduce heat load and heat island effect in cities, while addressing the equity and inclusivity in urban planning. Cities and regions need restoration of urban ecology, and expansion and regeneration of green areas and waterbodies to provide a range of ecosystem services. This requires urban planning guidelines, and codes, and also adequate regulatory and planning safeguards to prevent maladaptation and gentrification of urban spaces that marginalises the urban poor.

Heat action plan is a much bigger opportunity to maximise multiple gains from investments in infrastructure, improvement in housing for thermal comfort, responsive health systems, access to green and blue infrastructure, reliable energy, and access to emergency measures during heatwaves.

There are several policy opportunities in the Africa countries to strengthen Africa's climate adaptation. These include:

- Framing of national heat management and cooling action plans
- Development and implementation of energy efficiency codes and labelling for buildings and appliances, material selection and building design.
- Urban planning guidelines to influence the urban design, material applications in public infrastructure, and expansion of greening and waterbodies.
- Affordable renewable-powered cooling innovations can address rising heat risks and improve energy access.
- Integrating heat into National Adaptation Plans (NAPs) can mainstream adaptation action and ensure coordinated action at national and local levels
- Scaling nature-based solutions including urban forests, wetlands, and agroforestry can enhance resilience, restore ecosystem services, and provide co-benefits for health and livelihoods.
- Enable stronger regional collaboration among African Union, African Development Bank, and United Nations Environment Programme to support regional harmonisation of the action, standards, market based instruments, building codes and also resource mobilization.[129, 130]

8.1. The way forward

Need comprehensive heat management action plans and implementation strategies: Such plans need to deepen interventions to reduce heat load on buildings and cities through infrastructure development. At the same time it is necessary to retrofit public infrastructure and upgrade dense settlements for thermal comfort; and expand urban green spaces to mitigate urban heat island effects.

At the same time integrate early warning systems, public education, and emergency response. Across all levels, it is necessary to expand heat-health surveillance, improve urban temperature monitoring, and foster cross-sectoral policy coherence for effective adaptation. A coordinated, evidence-based approach that combines technological, institutional, and community-based solutions is necessary to build resilience and protect Africa's most vulnerable populations from the escalating risks of extreme heat.

Need vulnerability assessment: There is a notable lack of vulnerability assessments within demographic groups, particularly for the elderly, children, and residents of dense settlements, who are often the most exposed and least capability to adapt. Empirical data on personal heat exposure is scarce, especially in dense urban environments where indoor and outdoor conditions can differ significantly from those recorded at weather stations. This gap is critical, as studies show that dense dwellings in Southern Africa can experience extreme heat stress for 6–10 hours daily during peak summer, with little agency among vulnerable groups to improve their living conditions.[131] Vulnerable populations, especially those in dense settlements, face high exposure, high sensitivity, and low adaptive capacity, yet their needs are rarely prioritized in policy or infrastructure development.

Build data and information on the heat risk to inform policy and implementation: It is necessary to address the data and information gaps through improved data collection, targeted vulnerability assessments, and evaluation of adaptation strategies for effective heat risk management and informed policymaking in Africa. This limited research output is attributed to factors such as inadequate funding, restricted data accessibility, limited researcher capacity, and weak international collaboration.

Most African studies rely on remote sensing due to the limited spatial coverage of ground-based weather stations, and there is a lack of high-resolution, city-specific analyses. The intensity and duration of UHI effects, as well as their health and social impacts, are not well quantified, particularly in rapidly urbanizing regions.[132] Furthermore, research on adaptation strategies is limited, with most studies focused toward building materials and passive cooling, with little evaluation of community-level or policy-driven interventions. For example, while cool roof paints can reduce heat stress in dense housing, their effectiveness may decline under future climate scenarios, highlighting the need for integrated, multisectoral approaches.[133] The lack of comprehensive data and targeted research has significant implications for policy and practice. Heat stress is often a silent killer, claiming more lives than many other climate hazards yet receiving far less recognition in public health systems and urban planning.

Strengthen health surveillance and early warning systems: This is critical for timely responses to extreme heat and other climate hazards. City-level heat preparedness remains limited, with most urban adaptation efforts insufficient to build resilience, particularly for poor populations in dense settlements. Urban planning frequently overlooks climate risks, and adaptation responses are fragmented, lacking integration into broader development and national planning processes. Strengthening health systems and implementing early warning networks are critical for building resilience to heatwaves and other climate shocks. Ensure uptake of urban design and housing upgrades that reduce vulnerability to heat stress, lower rates of heat-related illness, and improve community health outcomes. Targeted interventions in vulnerable neighbourhoods can further reduce health disparities exacerbated by extreme heat. Additionally, adaptation finance and technological capacity are insufficient, and institutional barriers further hinder effective implementation.[134]

Ensure access to thermal comfort in buildings is affordable: The ongoing effort to implement energy efficiency measures and codes in buildings and appliances require a more expanded approach to adopt architectural design approaches, low carbon and locally appropriate material choices and insulation, interface with the surrounding open spaces and alignment of building clusters, greening and water bodies, among others, to promote adaptive thermal comfort and reduce cooling demand. Need comprehensive guidelines and mandate on material and design to improve thermal comfort of buildings and to reduce air conditioning hours for energy savings and conservation.

This further requires guidelines for mass housing in terms of fixing orientation, adopting compact urban form with adequate green spaces to improve solar access, ventilation and mutual shading etc. Regulations need to ensure that the buildings continue to remain strong on green performance. Implement decentralised services including water and clean energy access local level waste management and circularity for health and wellbeing. Special attention should be given to vulnerable groups in dense settlements, with targeted programs around thermally comfortable housing with cool roofs, insulation, and passive design. It is also necessary to explore adaptation of traditional material and building techniques in modern buildings to reduce energy and material intensity of structures.

Build energy resilience: Ensuring reliable, sustainable access to electricity is essential for powering life-saving cooling technologies such as fans, refrigeration and air conditioning. Integrating rooftop photovoltaics and energy-efficient building designs can reduce peak energy demand, enhance urban energy resilience, and deliver cooling benefits in regions facing chronic energy poverty and unreliable supply.

Expand green and blue infrastructure: Policy and regulations on green and blue infrastructure is developing in Africa. But the approaches and regulations need to be strengthened at the municipal levels. Empirical studies show that such interventions can decrease surface temperatures by up to 2°C and improve outdoor thermal comfort indices by over 10°C under certain conditions.[135] Beyond cooling, green infrastructure enhances air quality, supports biodiversity, promote mental and physical health, and provide additional co-benefits such as carbon sequestration, storm water management, and social cohesion. Investments in resilient energy and water infrastructure are essential to reduce heat and support cooling needs and safeguard public health as temperatures rise.

Harmonise and tighten regulations and action across Africa region to stop dumping of old and used appliances and air conditioners: Make global regulations stringent to prevent global dumping of old and used energy-inefficient air conditioners with ozone-depleting refrigerants. Several countries have begun to take steps. This needs to accelerate and harmonise. This requires a strategic combination of regulations, import bans, fiscal disincentives, and tightening of Minimum Energy Performance Standards (MEPS).

Develop funding strategies to accelerate resilience and adaptation: Developing robust funding strategies through regional bodies and international financial institutions is necessary. This requires fundamental re-centring of heat as a core adaptation priority – the choices made today in research, policy, and planning will determine Africa's capacity to withstand and thrive in the face of rising heat.

Regional bodies like the African Union and African Development Bank need to facilitate heat risk mitigation financing, joint early warning systems, and regional data-sharing platforms, while promoting policy coherence and capacity building across member states. International financial institutions and climate finance mechanism can support the transition. Strengthening of governance, enhancing data and forecasting, cross-sectoral planning and convergence funding along with policy and regulations are needed to reduce both immediate and long-term risks.

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This report lays bare Africa's escalating heat crisis. It details how rising temperatures, intensifying urban heat islands, and surging cooling demand are reshaping lives across the continent.

Drawing on ground evidence and satellite analysis, it highlights the stark regional differences and the severe vulnerabilities faced by dense settlements, children, and the elderly. It traces how, from Lagos to Johannesburg, rapid urbanization is fuelling the rise in land surface temperatures and worsening exposure.

This report calls for urgent, integrated action across health, housing, energy, and urban planning to build resilience and protect Africa's most vulnerable from the silent but deadly force of extreme heat.

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