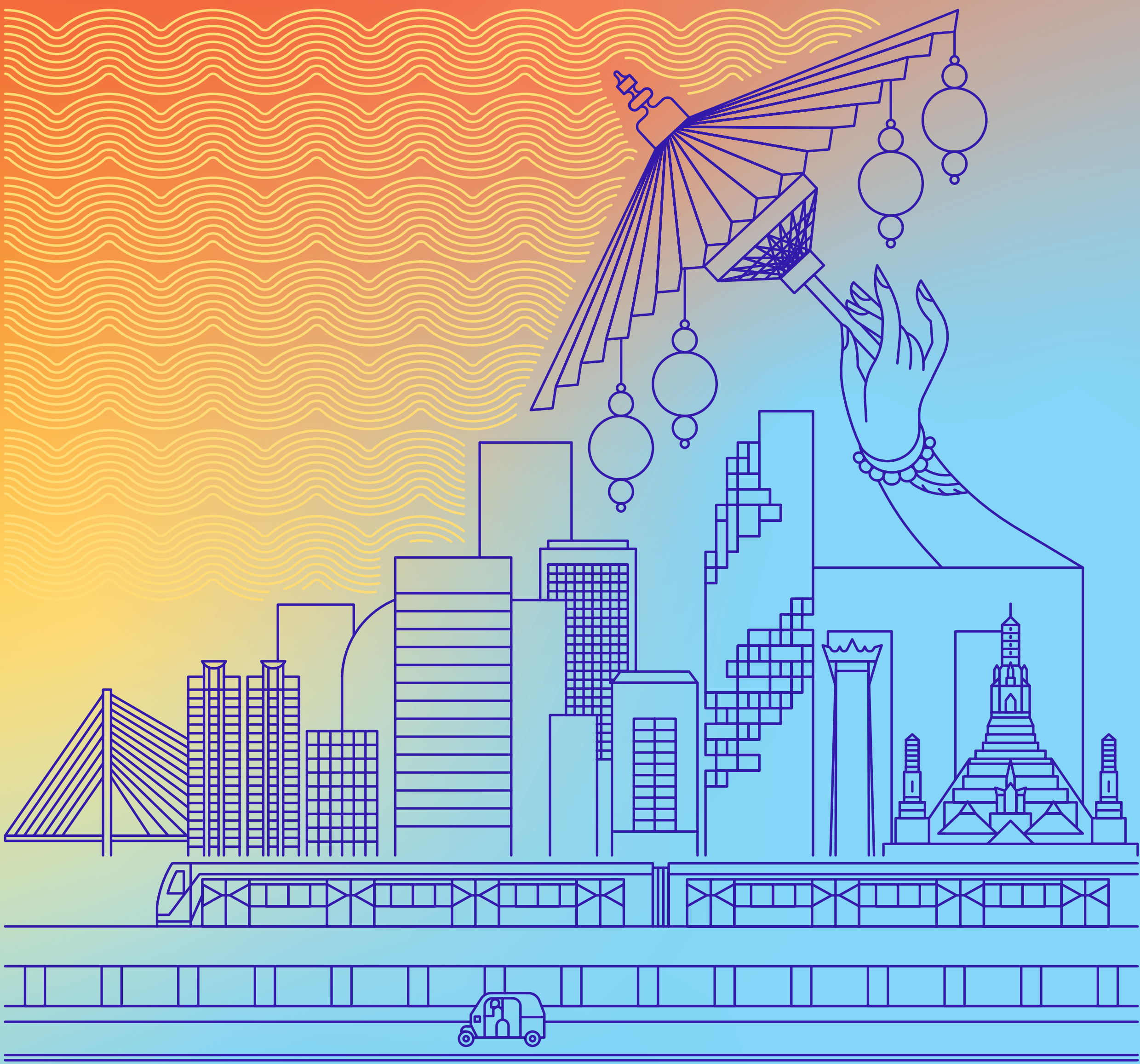
SHAPING A COOLER BANGKOK:

Tackling Urban Heat for a More Livable City



City Resilience Program

GFDRR
Global Facility for Disaster Reduction and Recovery

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FOREWORD

Surging urban temperatures, compounded by climate change, are driving many Asian cities to accelerate adaptation efforts to safeguard lives, livelihoods, and economic growth. Insights from World Bank research on heat adaptation underscore the importance of anchoring strategies with accurate data and strong governance. As Thailand's main economic hub, featuring an expansive geography combined with significant climate vulnerability, Bangkok needs to apply best practices but also pilot innovative approaches.

Our study, developed in close cooperation with the Bangkok Metropolitan Administration (BMA), and supported by the Global Facility for Disaster Reduction and Recovery (GFDRR), highlights the risks of acting inadequately or not at all. This includes public health crises and economic turmoil. But the study also offers pathways forward. Building on the BMA's progress in urban heat management, we combine regional experiences with city-level insights to present recommendations for cooling the urban environment, protecting at-risk communities, and strengthening institutional coordination. We also create actionable, timely, and inclusive solutions for the city's residents. These solutions will require broad, sustained partnerships, and the World Bank is committed to continue working with the BMA on Bangkok's climate resilience journey.

Bjorn Philipp

Practice Manager,
Urban, Resilience and Land,
East Asia and Pacific, World Bank

Extreme heat is no longer a rare disruption but has become an unfortunate daily reality in Bangkok, affecting how we live, work, and coexist. To address this growing threat, the BMA has prioritized the expansion of green spaces, deployed technologies such as district cooling systems, and developed protocols and programs to protect vulnerable communities. But we recognize that more work is required, especially in cross-agency coordination, private sector engagement, and long-term urban planning.

By partnering with the World Bank, the BMA gained deeper insights into Bangkok's unique urban heat profile and identified critical areas where efforts and investments might yield meaningful impact, such as in improving early warning systems and building codes. The targeted, evidence-based solutions derived from our study will inform policies and practices that we hope will help shape Bangkok into a more resilient and livable city for future generations.

Pornphrom Vikitsreth

Chief Sustainability Officer,
Bangkok Metropolitan Administration,
and Advisor to the Governor of Bangkok

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We sincerely appreciate the time, expertise, and insights contributed by all those involved in this effort. Their collaboration has been essential in advancing Bangkok's urban heat management strategies and strengthening resilience for the future.

ACRONYMS

SYMBOL

°C	Celsius

A

AC	Air Conditioning

B

BAU	Business-As-Usual
BMA	Bangkok Metropolitan Administration
BEM	Building Energy Model
BEP	Building Effect Parametrization

C

CBD	Central Business District
CO_2	Carbon Dioxide
CPI	Consumer Price Index
CRP	City Resilience Program

D

DNB	Day/Night Band

E

ENSO	El Nino Southern Oscillation
EPPO	Energy Policy and Planning Office
EWS	Early Warning Systems

G

GDP	Gross Domestic Product
GFDRR	Global Facility for Disaster Reduction and Recovery
GHG	Greenhouse Gas
GPP	Gross Provincial Product

I

ILO	International Labor Organization
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standards Organization

J

JICA	Japan International Cooperation Agency

K

kWh	Kilowatt-Hour

L

LCZ	Local Climate Zone
LSM	Land Surface Model
LST	Local Standard Time

M

MCOT	Mass Communication Organization of Thailand
MEA	Metropolitan Electricity Authority

N

NAP	National Adaptation Plan
NGOs	Non-Governmental Organizations

O

O*NET	Occupational Information Network Database

P

PPP	Public-Private-Partnership

S

SMS	Short Message Service
SSP	Shared Socioeconomic Pathways

T

THB	Thai Baht
TLFS	Thailand Labor Force Survey

U

UHI	Urban Heat Island
UTC	Universal Time Coordinated

V

VIIRS	Visible Infrared Imaging Radiometer Suite
VSL	Value of Statistical Life

W

WBGT	Wet Bulb Globe Temperature
WRF	Weather Research and Forecasting
WUDAPT	World Urban Database and Access Portal Tools

Photo by Waranont (Joe) on Unsplash

CHAPTER

S.

EXECUTIVE SUMMARY

In 2024, global temperatures reached record highs multiple times, highlighting the growing severity of extreme heat and the widespread implications. By 2050, Bangkok, already prone to high temperatures, could see extreme heat risks to health, productivity, economic growth, and infrastructure. The Urban Heat Island (UHI) effect exacerbates these challenges, making some districts, including those with high concentrations of vulnerable populations, significantly hotter than surrounding rural areas.

This report, developed by the Bangkok Metropolitan Administration (BMA), in partnership with the World Bank, examines the growing threat of extreme urban heat in Bangkok, long-term trajectories, and potential impacts. It also quantifies the health, economic, and infrastructure costs associated with rising temperatures and explores targeted interventions and strategic reforms—particularly for the city's most vulnerable communities.

URBAN HEAT IN BANGKOK

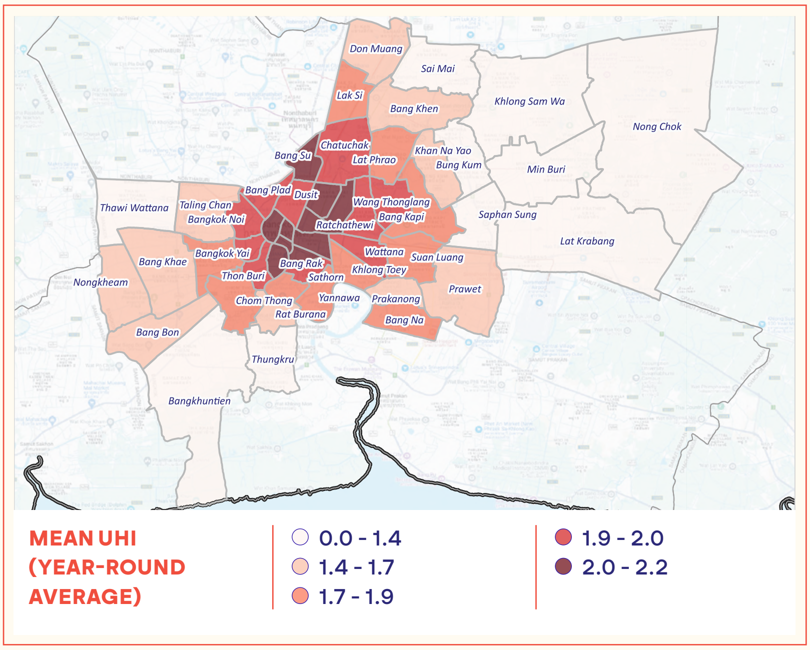
Photo by Waranont (Joe) on Unsplash.

From 1960 to 2000, Bangkok's average annual temperature ranged from 28-30°C. By the end of the century, this figure could rise by 2.5°C under moderate emissions or by 4.5°C under high emissions, leading to longer, more frequent heatwaves and worsening nighttime heat retention that offers less and less respite.

Applying a specialized climate model (i.e., Weather Research and Forecasting—WRF, version 4.2), heat distribution in Bangkok neighborhoods were mapped during the day and night and compared with rural reference points. Results showed heat variation across neighborhoods as well as nighttime temperatures in some dense neighborhoods reaching up to 6°C higher than in outlying green rural areas.

URBAN HEAT ISLAND INTENSITY BY DISTRICT

Part of Bangkok's heat challenge stems from limited vegetation in its urban core. Areas dominated by high-rise structures and paved surfaces, and lacking trees and green spaces, retain more solar energy and experience elevated temperatures well into the evening.



Central districts—such as Pathum Wan, Bang Rak, and Ratchathewi—are typically the hottest. Meanwhile, outlying districts in the north and east, with more open land, experience milder UHI intensities.

This spatial disparity presents crucial insights for designing targeted interventions: the densest, most commercial areas might benefit the most from additional cooling infrastructure such as tree corridors or reflective roofing.

IMPLICATIONS FOR HEALTH, INFRASTRUCTURE, AND THE ECONOMY

Heat can kill in both direct and subtle ways, causing illness and fatalities directly through heat stroke and indirectly by exacerbating cardiovascular or respiratory conditions.

In 2019 alone, urban heat was responsible for an estimated 421 to 1,174 excess deaths across the Bangkok. If average city temperature rises by just 1°C, heat-related deaths could reach up to 2,333 lives lost annually — a mortality figure that is on par with Thailand's national road traffic fatality rate. With a 2°C increase, excess deaths would reach 2,363 to 3,814 lives, highlighting the significant toll and compounding effect that each additional degree in temperature could exact on public health.

Bangkok's elderly (9.3% of the population) and children under 15 (8.2%) are especially vulnerable to heat-related health risks. Low-income communities in poorly ventilated housing with limited access to cooling and green spaces also face higher exposure and fewer means to adapt.

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Hotter days also hinder the economy via their impact on workers' productivity. Each additional 1°C of annual average temperature increase diminishes worker output by about 3.3–3.4 percent, leading to an estimated THB 44.7 billion lost each year—equivalent to around 0.8 percent of Bangkok's GDP in 2019. Outdoor workers in construction, street vending, and motorbike taxis are particularly hard hit, but even those in offices experience drops in concentration and efficiency. Sectors such as trade and services, which make up a large portion of the city's employment, lose the most aggregate output. This loss already exceeds the combined economic damage from other urban issues like traffic congestion and air pollution.

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A 1°C rise in temperature would significantly strain Bangkok's electricity system as demand for air conditioning (AC) increases. This temperature increase alone could drive electricity consumption up by nearly 7 percent, leading to an estimated 35–40 kilowatt-hours (kWh) of additional usage per person per month. For the average Bangkok household, this translates to an extra THB 400–450 in monthly electricity costs—a 29 percent increase. Economically disadvantaged households would bear a disproportionate burden, as a larger share of their income would go toward energy bills. At the city level, a 1°C rise would result in THB 17.31 billion in additional electricity costs annually. Furthermore, this increase in energy consumption would generate approximately 2 million metric tons of carbon dioxide (CO_2) per year, equivalent to 0.7 percent of Thailand's total emissions, exacerbating the very climate challenges driving these changes.

Health	Economic Productivity	Energy Costs and Carbon Emissions
Extreme heat is already deadly in Bangkok. In 2019 alone, urban heat was responsible for an estimated 421 to 1,174 excess deaths across the city. If the average temperature rises by just 1°C, annual heat-related deaths could reach an estimated 2,333 lives lost and THB 52 billion in social costs per year.	Heat reduces productivity and costs Bangkok billions. A 1°C rise in temperature leads to a 3.3–3.4% drop in worker productivity, resulting in annual wage losses of THB 44.7 billion—more than the combined economic losses from traffic congestion and air pollution in Bangkok.	Heat strains household budgets and increases emissions. A 1°C rise leads to THB 17.31 billion in additional electricity costs per year, pushing low-income households to spend nearly 30% more on energy bills. This also adds over 2 million metric tons of CO_2 emissions annually, worsening climate change.

The study also examines additional risks that are more difficult to quantify. For instance, children's academic performance suffers in overheated classrooms. Critical infrastructure like roads and power grids can buckle under sustained heat; such vulnerabilities imply extra repairs and disruptions, compounding the city's economic challenges.

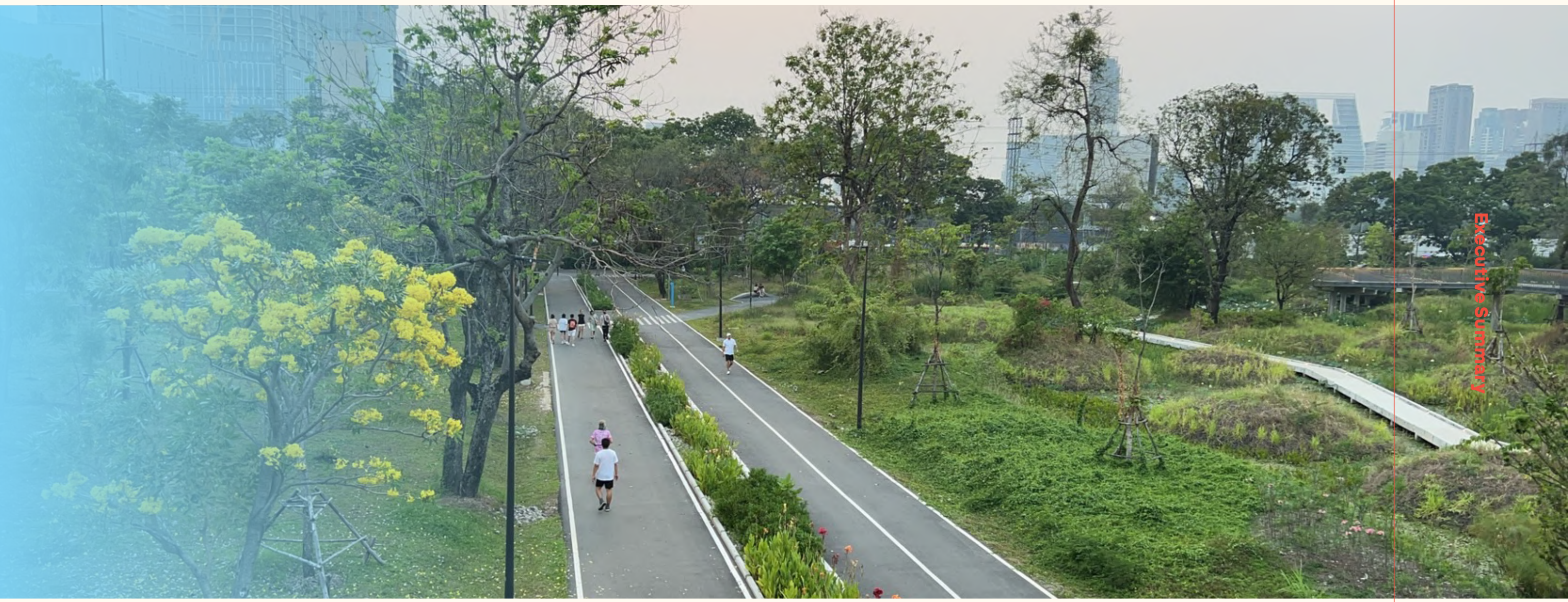
CURRENT MEASURES FOR HEAT RESILIENCE

The Bangkok Metropolitan Administration utilizes a two-part framework: a Year-Round Intervention Framework for ongoing adaptation efforts and a Hot Season Intervention Framework for more targeted measures. In its year-round intervention, the city focuses on expanding green spaces, training healthcare workers, and rolling out high-level initiatives such as 15-minute parks and buildings with partially open facades. Meanwhile, in the hottest months, the BMA sets heat-index thresholds—Monitoring Phase, Warning Phase, Critical Phase, Extreme Critical Phase—each triggering specific actions ranging from public advisories to activating cooling shelters.

Key infrastructure and greening projects showcase the efforts Bangkok has taken to address urban heat. For example, Sabuy Square, Thailand's first solar-powered bus stop, serves as a cool waiting area while promoting energy conservation. Similarly, the city's push to plant one million trees ahead of schedule, combined with the private-led initiatives such as Metro Forest, contributes to a more breathable and shaded environment in select neighborhoods. On the private sector side, large-scale ventures include district cooling systems in One Bangkok and Samyan Smart City.

Metro Forest, an ecological restoration project in eastern Bangkok.

Despite these efforts, the BMA faces challenges in scaling up and enforcing interventions due to overlapping mandates and fragmented decisions involving different departments. These institutional issues hamper BMA's effectiveness at enforcing crucial heat resilience in much-needed heat policies and actions. While the city's newly adopted Heat Action Plan calls for improved inter-departmental coordination, structural changes that are deemed necessary to improve heat policies—such as a dedicated Chief Heat Officer or consolidated funding mechanism—have yet to be realized.



STRATEGIC ACTIONS FOR A HEAT-RESILIENT BANGKOK

Bangkok's rising heat challenges require a coordinated, long-term approach that strengthens governance, prioritizes at-risk communities, and integrates heat resilience into urban planning. While the BMA has made progress in areas such as early-warning systems, tree planting, and cooling initiatives, additional measures are needed to ensure comprehensive and sustainable urban heat management.

This report applies a "People, Places, and Institutions" framework to assess Bangkok's existing efforts and identify opportunities for improvement. "Places" focuses on physical interventions to reduce urban heat island effects. "People" highlights the need for outreach and protective measures for vulnerable populations. "Institutions" addresses governance, regulatory, and funding mechanisms essential for long-term resilience.

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PLACES: ENHANCING THE BUILT ENVIRONMENT TO REDUCE HEAT RISK

Targeting for Heat "Hotspots": Detailed heat mapping and microclimate modeling should be integrated into urban planning to pinpoint areas experiencing the most severe heat impacts. This will enable effective prioritization of resources such as tree planting, reflective surfaces, and shading structures for high-risk neighborhoods, particularly in lower-income, high-density districts.

Green and Blue Infrastructure Expansion: Expanding tree cover, urban wetlands, and rooftop rain gardens can significantly lower ambient temperatures while improving air quality and flood resilience. Strengthening Bangkok's park system, preserving canals, and incentivizing private-sector green spaces will contribute to long-term natural urban cooling.

Integration of Heat Resilience in Planning and Codes: Updating urban planning regulations and building codes to require green roofs, reflective materials, and increased vegetation coverage will systematically embed heat adaptation into future developments. Incentives, such as tax benefits or fast-track permitting, can help accelerate adoption.

PEOPLE: STRENGTHENING COMMUNITY PREPAREDNESS AND PROTECTION

Engagement with At-Risk Communities: Targeted outreach programs should educate and support vulnerable populations, including elderly residents, children, outdoor workers, and low-income communities. A citywide public awareness campaign using billboards, social media, and multilingual materials can improve heat safety knowledge among the broader population.

Early Warning Coverage and Accessibility: Expanding multi-channel early warning systems—including SMS alerts, public radio, loudspeakers, and community networks—will ensure timely notifications reach all residents, especially those without smartphones or digital access.

Cooling Centers and Hydration Points: Public facilities—such as schools, libraries, community halls, and temples—should be repurposed to include cooling centers, providing accessible, air-conditioned spaces during extreme heat events. Expanding public drinking water stations in transit hubs and public areas will help prevent dehydration.

INSTITUTIONS: STRENGTHENING GOVERNANCE FOR LONG-TERM HEAT RESILIENCE

Coordination Across Departments: Establishing a dedicated interdepartmental heat task force—or appointing a Chief Heat Officer—will improve collaboration among key agencies, including health, environment, urban planning, and public works. A structured approach will ensure coordinated policy implementation and resource allocation.

Regulations and Policies: Strengthening legal protections for outdoor workers and requiring heat mitigation measures in new developments will create a regulatory foundation for urban heat management. Initial voluntary guidelines can transition into enforceable policies to enhance workplace safety and urban design.

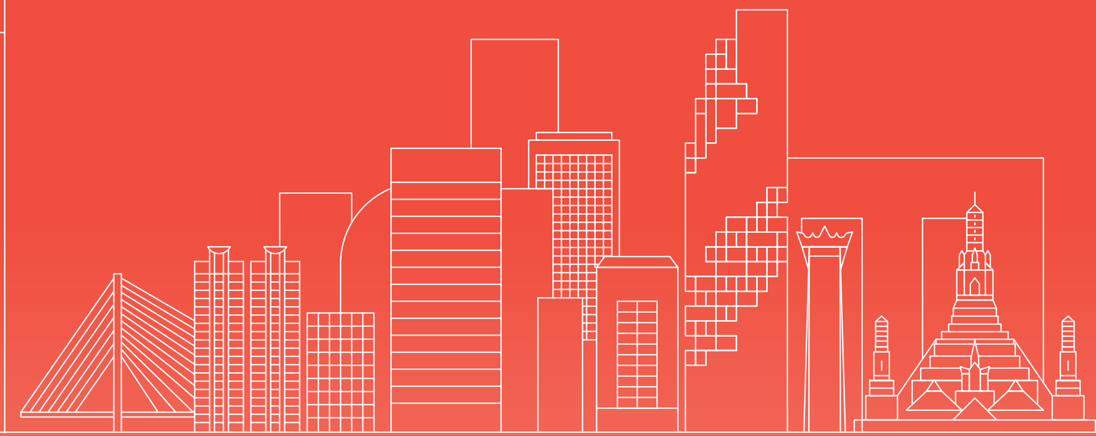
Sustained Governance and Funding Mechanisms: Embedding heat resilience in city budgets and development plans is essential for long-term success. A dedicated urban heat resilience fund, supported by public funding, private-sector contributions, and climate finance, can provide stable resources for ongoing interventions. An annual monitoring and evaluation cycle should track key indicators—such as heat-related mortality, cooling center utilization, and urban greening progress—to refine strategies over time.

Bangkok is at a critical juncture in its response to extreme urban heat. Without decisive action, rising temperatures will further endanger public health, reduce economic productivity, and strain infrastructure, with the greatest impacts on the city's most vulnerable communities. While the Bangkok Metropolitan Administration (BMA) has made notable progress through tree-planting initiatives, early-warning systems, and cooling infrastructure, these efforts must be scaled up and embedded into long-term urban planning to effectively manage escalating heat risks.

This report presents a clear path forward using the People, Places, and Institutions framework. By targeting urban heat hotspots, expanding green and blue infrastructure, and strengthening protections for at-risk communities, Bangkok can mitigate the worst impacts of extreme heat. Equally important, strong interdepartmental coordination, regulatory reforms, and sustained funding mechanisms will ensure that heat resilience becomes a core component of city governance. With bold leadership and strategic investment, Bangkok has the opportunity to become a model for urban heat adaptation, ensuring a livable, competitive, and climate-resilient future.

CHAPTER

1.



WHY EXTREME URBAN HEAT MATTERS

— EXTREME URBAN HEAT: A STRATEGIC CONCERN FOR BANGKOK

The year 2024 was the hottest year for the planet since records began. In July 2024 alone, the world record for earth's hottest day was broken twice in one week.[1] Antonio Guterres, the United Nations Secretary General, warned that the lives and livelihoods of billions of people are at risk due to this "extreme heat epidemic."[2]

Extreme heat matters for the economy: by 2050, approximately 80 million jobs worldwide could become unworkable because of dangerously high temperatures[3]. It also matters for health. Global heat-related mortality among individuals aged 65 and older rose by approximately 85 percent between 2000-2004 and 2018-2022[4]. During a heatwave, those most severely affected include the urban poor, pregnant women and young children, old people, and residents of slum areas and low-quality housing.

1 Copernicus Climate Change Service (2024).
2 United Nations (2024).
3 International Labour Organization (2019).
4 Lancet Countdown (2023).

Bangkok is no exception to these global trends. Bangkok residents are habituated to year-round high temperatures. Given the tropical monsoon climate and location close to the equator, high humidity and intense heat from the sun's rays are a common experience. Heatwaves have become longer, more frequent, and more intense, posing serious risks to health, the economy, and critical infrastructure such as power and transportation networks–many of which were not designed to withstand such high temperatures. Climate change is the main driver of this trend but another key factor exacerbates heat risks: the UHI effect. Built-up areas absorb and retain heat, leaving high-density areas with little green space several degrees hotter than the surrounding countryside. Inadequate housing also makes it difficult to stay cool indoors.

This study examines the rising threat of extreme heat in Bangkok, its long-term outlook, and its impact on infrastructure, health, and economic well-being. It also outlines strategic actions to mitigate these risks, particularly for vulnerable populations.

— FRAMEWORK FOR THIS STUDY

Heat risk can be defined as the combined likelihood and consequences from exposure of people, economies and assets to high temperatures and humidity. These adverse consequences include death, illness, economic loss, and reduced infrastructure functionality. The three key drivers of urban heat as a strategic risk to Bangkok are the increase in frequency and intensity of extremely hot temperatures (or heat hazard); the continued growth in people, economic activities, and infrastructure assets (exposure); and the propensity for heat to cause damage to these (vulnerability) (Figure 1).

FIGURE 1 DRIVERS OF HEAT RISK (PANEL A) AND CONCEPTUAL FRAMEWORK FOR THIS STUDY (PANEL B)

A

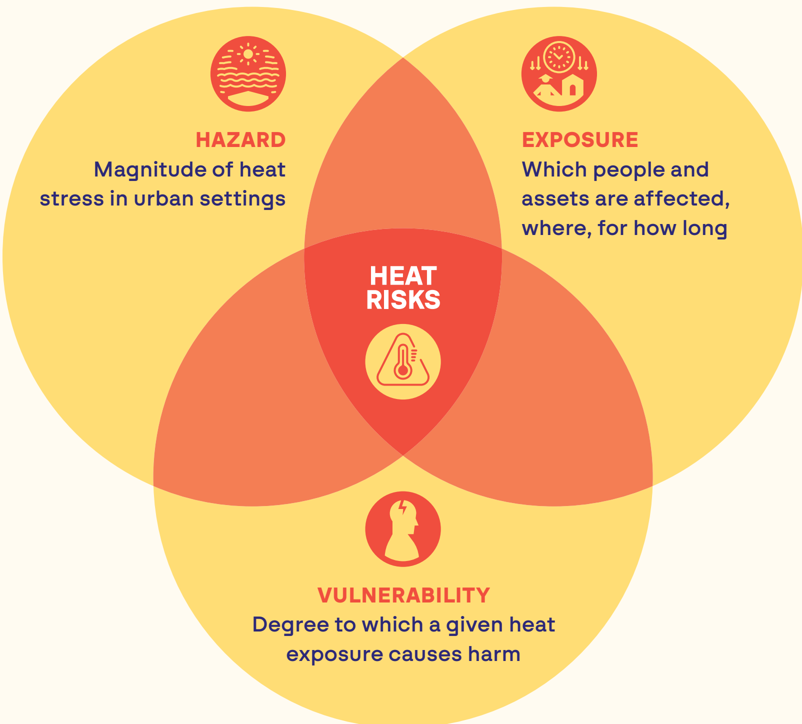


FIGURE 1 DRIVERS OF HEAT RISK (PANEL A) AND CONCEPTUAL FRAMEWORK FOR THIS STUDY (PANEL B)

B

HAZARD

What level of extreme urban heat should the BMA prepare for?

GOAL:
Characterize the physical risks posed by extreme heat today and in future.

METHODS:
(i) Urban-scale climate assessment (WRF-Urban model); (ii) analysis of reanalysis and global climate model data (ERA-5 and CMIP-6).

Health channel

IMPACTS **How will extreme heat affect the population?**

GOAL:
Understand health impacts including risks of heat-related illness and death among affected groups.

METHODS:
Heat-health epidemiology model

Labor productivity and infrastructure channels

IMPACTS **How will extreme heat affect the economy and infrastructure?**

GOAL:
Assess heat-related losses in economic sectors; understand impacts on infrastructure.

METHODS:
Productivity impacts assessment; infrastructure impacts

SOLUTIONS

Identifying strategic options

GOAL:
Identify feasible responses that could avert adverse impacts of extreme heat cost-effectively.

METHODS:
Desk review; international best practices study; stakeholder consultations.

Source: World Bank elaboration based on Field (2012).

The remainder of **Chapter 1** will review, in turn, the three key drivers of heat risk: hazard, exposure and vulnerability”—S” on page 51.

Chapter 2 of the study examines the UHI effect in Bangkok. A comprehensive climate modeling exercise provides detailed insights into how heat varies with time of day and season, across different neighborhoods of the city. This information is combined with data on local neighborhood characteristics – including built form and population characteristics – to inform targeting of interventions.

In Chapter 3, the study examines potential impacts of extreme urban heat in Bangkok through three channels: health, labor productivity, and infrastructure. New estimates of the magnitude of these potential impacts are presented.

Chapter 4 discusses the current measures related to urban heat management and institutional background of the BMA. This chapter also highlights improvement opportunities in BMA’s heat policies.

Finally, Chapter 5 turns to solutions and presents a set of strategic options based on desk review and a consultation workshop with key stakeholders. The chapter presents actions that could be considered by the BMA in partnership with other stakeholders to mitigate the adverse impacts of heat on the population, economy, and infrastructure of Bangkok in a cost-effective way.

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Why extreme urban heat matters
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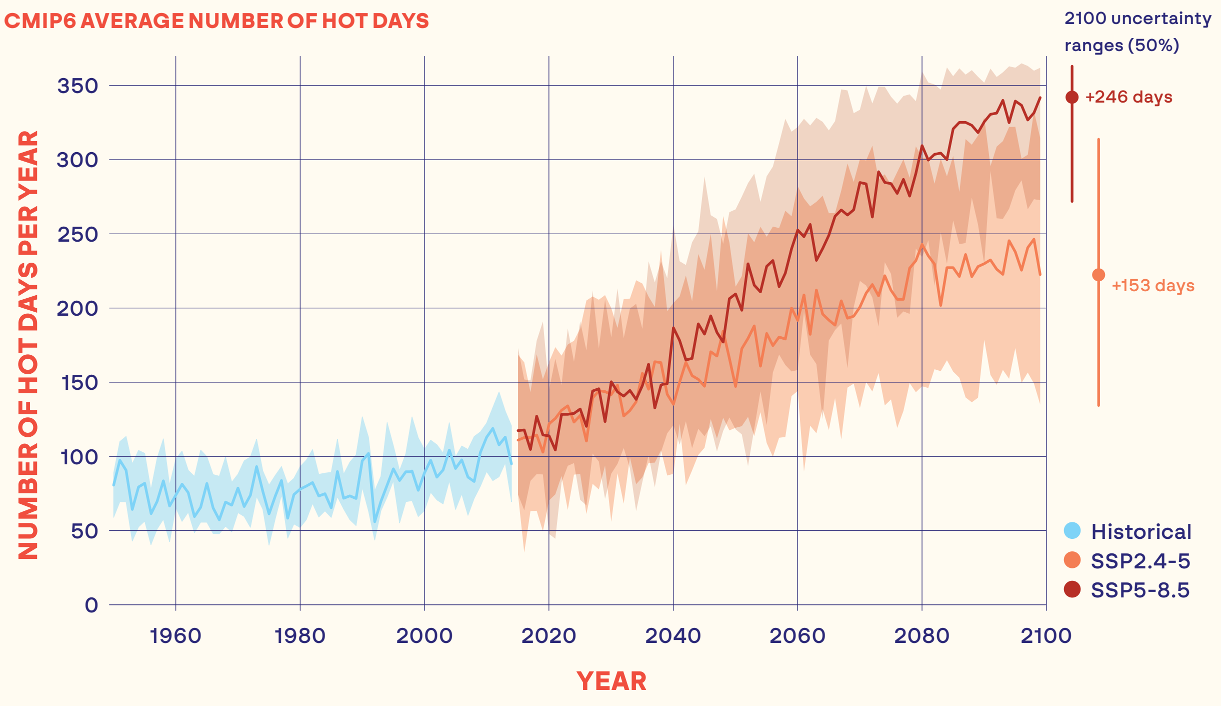
HAZARD: INCREASINGLY FREQUENT AND INTENSE HEATWAVES

Thailand has experienced record-breaking extreme heat in recent years, with cities facing even greater warming due to the UHI effect. Unlike rural areas, urban environments retain and amplify heat because natural landscapes are replaced with heat-absorbing materials like asphalt and steel. The lack of vegetation limits cooling from evapotranspiration, while Bangkok's dense high-rises trap the anthropogenic heat emitted by vehicles and A/C units. This heat accumulates in the urban fabric, further increasing temperatures, especially at night.

Climate change is set to make this problem worse. From 1960 to 2000, Bangkok's average annual temperature ranged between 28°C and 30°C. Global climate models project an increase of approximately 2.5°C by the end of the century under a moderate emissions scenario, or up to 4.5°C under a high emissions scenario. The higher average temperatures mean that residents will experience a larger number of dangerously hot days each year (Figure 2).

FIGURE 2 | PROJECTED NUMBER OF HOT DAYS IN BANGKOK, DIFFERENT CLIMATE SCENARIOS



Source: Team analysis based on NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6, Trasher et al., 2022).

Notes: A hot day is defined as a day with the daily maximum temperature greater than 35°C. The lines present the median of 22 NEX-GDDP-CMIP6 models, whilst the shaded bands depict 50 percent of the projected uncertainty (specifically the 25th to 75th percentiles). SSP2-4.5 and SSP5-8.5 are the Shared Socioeconomic Pathways (SSPs) used by the Intergovernmental Panel on Climate Change (IPCC) to explore how different socioeconomic trends might influence greenhouse gas emissions and climate impacts in the future. The SSP2-4.5 scenario represents a trajectory aligned with current global policy trends and moderate climate change mitigation efforts. Under this scenario, global mean temperatures are projected to rise by approximately 3°C above pre-industrial levels by 2100, assuming neither a significant acceleration of mitigation efforts, nor complete failure of such efforts. SSP5-8.5 is a worst-case scenario that represents high levels of warming.

Photo by Road Trip with Raj on Unsplash

Epidemiology studies have modeled the relationship between temperatures in Bangkok and the city's gross mortality rate – i.e. the number of deaths from all causes on any given day. At 35°C, the number of heat-related daily deaths is estimated to be 28% higher than at 28°C. Between 1960 to 2000, Bangkok experienced around 60 to 100 days per year on which temperatures exceeded 35°C. By the end of the century, there could be an additional 153 such days per year, even under a moderate global emissions scenario, rising to an additional 246 days under a high emissions scenario.

In future decades, the projected rise in the frequency and intensity of hot days will present serious consequences for health, the economy, and infrastructure systems. Bangkok has long experienced a hot climate compared with other cities in the Asia Pacific region. To measure heat stress in a comprehensive manner, researchers use Wet Bulb Globe Temperature (WBGT): a metric that combines the air temperature, humidity, and radiation from the sun or nearby surfaces. When heat stress that exceeds 30.5°C on the WBGT scale, the International Standards Organization (ISO) considers that even light manual occupations – such as cooking or cleaning – can be dangerous to health unless regular breaks are taken. Based on this threshold, Bangkok experiences more days of potentially dangerous heat stress per year than most other large cities in the Asia-Pacific region, except Singapore and Kuala Lumpur (Figure 3). The number of such days is expected to increase further by 2050.

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FIGURE 3 CURRENT AND PROJECTED NUMBER OF DAYS WITH EXTREME HEAT IN THE SUN

Source: World Bank staff analysis using WBGT data from CarbonPlan (Chegwidden and Freeman, 2023) and city data from the Urban Centre Database (Florczyk et al., 2019).

Notes: This figure shows the expected number of days per year when temperatures exceed an extreme heat threshold for outdoor workers in direct sunlight. Extreme heat is defined as a WBGT exceeding 30.5°C. According to international occupational health standards, heat stress above this level poses a health risk to workers, even in light manual occupations, unless regular breaks are taken.

EXPOSURE: THAILAND'S POPULATION CENTER, ENGINE OF ECONOMIC GROWTH, AND GREATEST CONCENTRATION OF ASSETS

Bangkok is Thailand's demographic and economic hub, attracting millions of people each year in search of better opportunities. With a metropolitan population exceeding 10 million residents[5], the city dwarfs other urban centers in both size and density, granting it significant sway over national policies, infrastructure investments, and even cultural trends. As a result, local developments in Bangkok often echo well beyond the capital, shaping the course of Thailand's broader social and economic fabric.[6]

As Thailand's largest population center, Bangkok drives economic growth, generating over a third of national output and contributing more than half of GDP from retail and 63% from tourism and related industries.[7] The importance of safeguarding the city's resilience was underscored by the 2011 Thailand floods, which caused THB 1.43 trillion (USD 46.5 billion) in total damage and losses. The manufacturing sector in and around Bangkok, which is critical for exports, accounted for 70 percent of the total damages and losses.[8] This incident serves as a striking reminder that climate events in the capital can reverberate throughout Thailand's economy.

Bangkok likewise functions as the nation's epicenter of assets and infrastructure. Government agencies and corporate headquarters cluster in the city's high-density commercial cores, creating an unmatched concentration of talent, resources, and networks. Moreover, Bangkok hosts Thailand's principal gateways to the world: major airports, seaports, and distribution centers that power both domestic commerce and international trade. This special status transforms the city into a vital link between the country's internal progress and the global economy.

More than just an urban center, Bangkok is a strategic force driving Thailand's prosperity. Yet as temperatures rise and the urban heat island effect intensifies, the city faces growing threats to public health, infrastructure reliability, and economic stability. Ensuring Bangkok's resilience against urban heat is, by extension, vital to safeguarding Thailand's long-term vitality and preserving the capital's position as the heart of the nation's development.

5 UN World Urbanization Prospects (2018). This number is higher than the official population figure as WUP defines urban population based on actual residency, instead of registry-based headcount to account for the fact that sizable population live and work in Bangkok but remain registered in their home provinces.
6 World Bank (2024).
7 World Bank staff calculation based on CEIC data (2023).
8 World Bank (2012).

VULNERABILITY: AGING POPULATIONS, OUTDOOR WORKERS, AND LACK OF EFFICIENT COOLING SYSTEMS

Heat kills—sometimes suddenly, through heat stroke or heat-related injuries, but more often subtly, by straining the heart, lungs, kidneys and other organs, hastening death among those already vulnerable. The elderly and individuals with underlying health problems are at greatest risk. Heat-exposure among pregnant mothers adds to risks of adverse pregnancy outcomes such as preterm birth, low birth weight, stillbirth, and gestational complications like preeclampsia and dehydration. High temperatures also elevate the incidence of vector-borne diseases like malaria and dengue and exacerbate chronic respiratory conditions such as asthma.

Vulnerable populations are groups that face a greater risk of harm from extreme heat due to their state of health, their working or living conditions, or limited access to resources. They include the elderly, children, individuals with preexisting health conditions, workers in heat-exposed occupations, and people of low socio-economic status. These populations may live in environments that expose them to greater health risks and lack the means to protect themselves adequately.

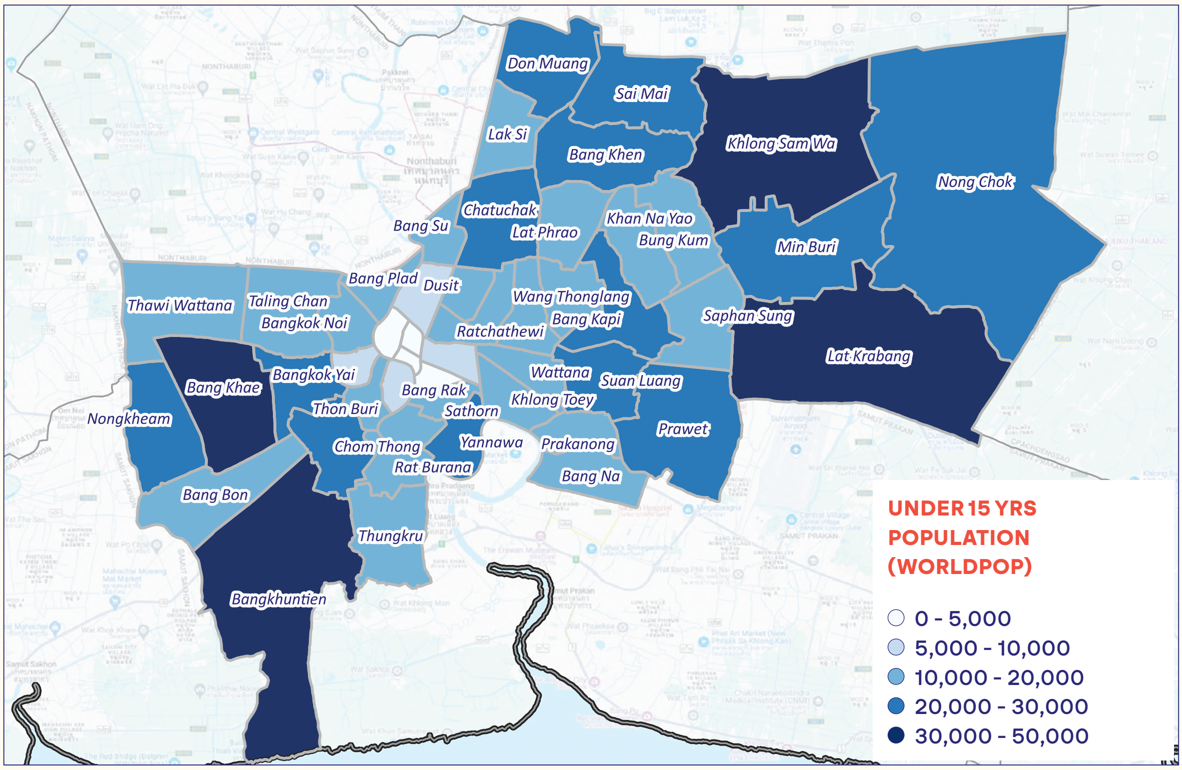
With approximately 880,000 children under 15 (8.2 percent of the population) and one million elderly individuals over 65 (9.3 percent of the population), the city is home to significant numbers of two of the most heat-vulnerable demographic groups. The aging trend is set to continue, with projections indicating that by 2050 around 30 percent of the population will be elderly[9].

Children have immature thermoregulatory systems, making it harder for their bodies to cool down,[10] while the elderly often face diminished physiological resilience, pre-existing health conditions, and reduced social networks, which can hinder timely access to cooling resources. While the proportions of youth and the elderly are lower than national averages, the magnitude of Bangkok's population results in a higher number of these vulnerable groups compared to other regions in Thailand. These vulnerable groups of populations are dispersed differently across Bangkok's districts (Figure 4).

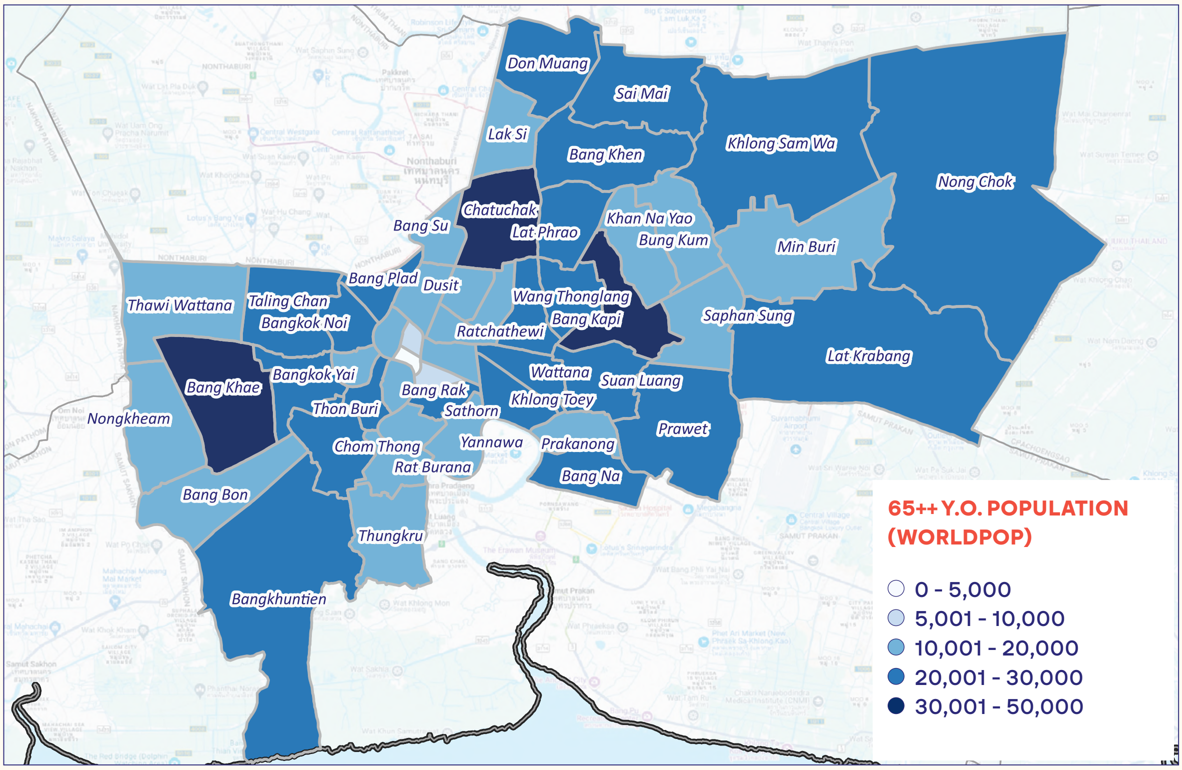
9 Srichuae, Nitivattananon, and Perera (2016).
10 Gomes et al (2013).

FIGURE 4 | CHILD AND ELDERLY POPULATION BY DISTRICTS, BANGKOK

CHILDREN (UNDER 15 YEARS OLD)



ELDERLY (MORE THAN 65 YEARS OLD)



Source: WB staff calculation based on WorldPop (2024).

Bangkok's workforce faces considerable exposure to the risks associated with urban heat, despite the city's economic structure being mostly non-agricultural. In 2019, approximately 1.3 million workers, or about 24.5 percent of the total workforce, work outdoors for at least one day per week.[11] This significant segment of the labor force includes street vendors, motorcycle taxi drivers, construction workers, delivery personnel, and some public service employees, who are directly exposed to high temperatures and heatwaves without adequate protection. Furthermore, many workers in Bangkok operate indoors in environments with minimal climate control, such as in factories, warehouses, and repair shops. These settings, often lacking proper ventilation or cooling systems, can become extremely hot, creating hazardous working conditions.

Urban heat creates a drag on productivity. Urban workers, particularly those in outdoor occupations like construction, maintenance, and delivery services, are facing heightened heat exposure. A study by the International Labor Organization (ILO) estimates that productivity losses from heat stress cost Southeast Asian countries about 3.1 percent of working hours in 2015, equivalent to 6.9 million full-time jobs, primarily in agriculture and construction. This loss is projected to rise to 3.7 percent of working hours, or 13 million full-time jobs, by 2030.[12]

There are many ways to stay cool in the city, but they are not equally accessible to all residents. AC remains out of reach for many residents due to its cost. Outdoor workers—notably those in informal sectors like street vendors and motorcycle taxi drivers —are unable to take a break from the heat without sacrificing significant income. Even when the sun is out, prolonged exposure to high nighttime temperatures without cooling still can lead to sleep deprivation and cardiovascular stress, further amplifying health risks.

Bangkok faces growing risks from extreme heat on three fronts: increasing vulnerability as the population ages, rising exposure as the city's population expands, and intensifying heat hazards due to more frequent and severe heat events. With Bangkok's population expected to reach nearly 13 million by 2035—adding around 1.5 million people in the next decade—more and more residents across all groups will be exposed to more intense and frequent extreme heat. This rapid growth, combined with climate change and an aging population, is expected to lead to a significant increase in heat-related deaths. If extreme urban heat is not addressed promptly, the environmental and socioeconomic impacts could worsen, potentially undermining the benefits of urbanization that have supported Bangkok's development.

11 Figures derived from Thailand Labor Force Survey (2019) data and O*NET database (2024).
12 International Labour Organization (2019).

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Why extreme urban heat matters
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CHAPTER

2.

URBAN HEAT IN BANGKOK

Every day, Bangkok residents feel the effects of the weather—temperature, precipitation, and wind—shaped by both global climate trends and local urban conditions. While global warming is making cities hotter worldwide, Bangkok's climate is also influenced by factors at a much smaller scale. Urban areas absorb and retain heat more than rural surroundings, cooling more slowly at night. The materials used in buildings, street layouts, and density vary across the city, creating distinct temperature differences between neighborhoods. Just as Bangkok's districts differ in appearance, they also vary in how they absorb and radiate heat in their interaction with the background climate, leading to sharp local variations in temperature.

— BANGKOK EXPERIENCES A STRONG URBAN HEAT ISLAND EFFECT

This section presents the results of a detailed climate modeling exercise that simulates the impact of Bangkok's urban fabric on temperatures at different times of the day and year. The modeling was conducted in partnership with climate experts from Singapore using the Weather Research and Forecasting (WRF, version 4.2) model, a widely used software system among meteorologists and climate researchers. To accurately capture heat flux exchanges between the atmosphere and the urban surface, the study incorporated detailed land use and land cover data for the BMA jurisdiction and its surroundings. Additionally, background regional weather conditions were factored in to estimate localized climate outcomes at the neighborhood scale.

To assess the contribution of urban heat, this study compares urban areas within Bangkok to reference locations in rural areas beyond the city's borders. The difference between these areas provides an estimate of UHI Intensity, as shown in Table 1. As in other cities, air temperatures in Bangkok vary significantly across districts and throughout the day and year.

Dense urban areas are significantly hotter than surrounding rural areas, particularly during periods when the UHI effect is most intense. Like many global cities, Bangkok experiences substantially higher nighttime temperatures than its rural surroundings, with some urban developments averaging 6°C warmer at night during the cool and dry season. The UHI effect also varies by season. It is less intense in March, during the hot and dry season, due to drier rural conditions that limit nighttime cooling, but it becomes more pronounced in other seasons when rural areas retain higher soil moisture. As a result, the highest impact of urban heat does not occur during the hottest air temperatures in Bangkok's hot and dry season.

TABLE 1 DAILY MAXIMUM, MINIMUM, AND MEAN TEMPERATURES IN THREE SEASONS IN BANGKOK

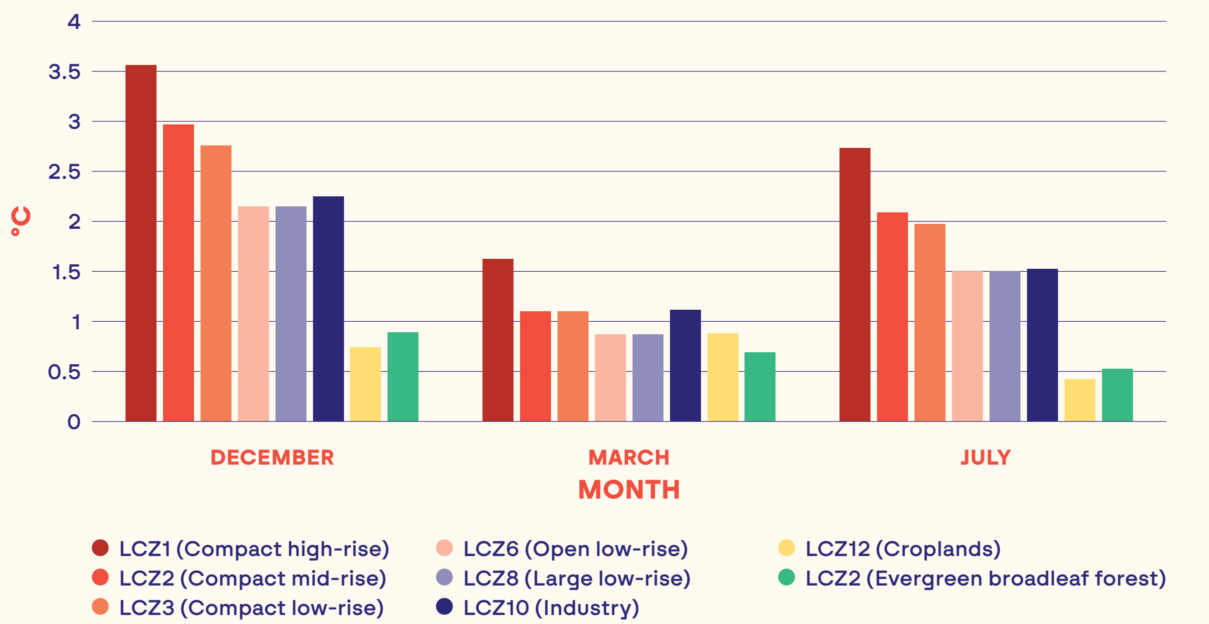
	Cold & dry season (December 2019)			Hot & dry season (March 2020)			Wet monsoon season (July 2020)		
	Daily max (°C)	Daily min (°C)	Daily mean (°C)	Daily max (°C)	Daily min (°C)	Daily mean (°C)	Daily max (°C)	Daily min (°C)	Daily mean (°C)
Rural location	31.0	18.8	25.0	34.4	24.8	28.6	32.6	22.3	28.2
Dense urban location	31.5	23.9	27.8	34.0	27.1	29.7	33.2	28.3	30.4
Difference	0.5	5.1	2.8	-0.4	2.4	1.1	0.6	0.6	2.0

Source: World Bank / National University of Singapore.

HIGH DENSITY AND LOW VEGETATION INTENSIFY HEAT RISKS

Bangkok's urban form plays a crucial role in heat accumulation. Two key factors that influence how much heat a neighborhood retains are building density and vegetation cover. The impact of urban heat is most pronounced in compact high-rise developments, where daily mean temperatures can be 1.5 to 3.5°C higher than in rural areas, depending on the season (Figure 5). These densely built environments, with limited greenery, absorb heat throughout the day and trap it within the urban canopy, keeping temperatures elevated well into the night. In contrast, areas with greater vegetation, such as urban parks, tend to experience lower UHI intensities, as plants help dissipate heat more efficiently.

FIGURE 5 MEAN URBAN HEAT ISLAND INTENSITY FOR SELECTED LAND USE TYPES DURING THREE SEASONS

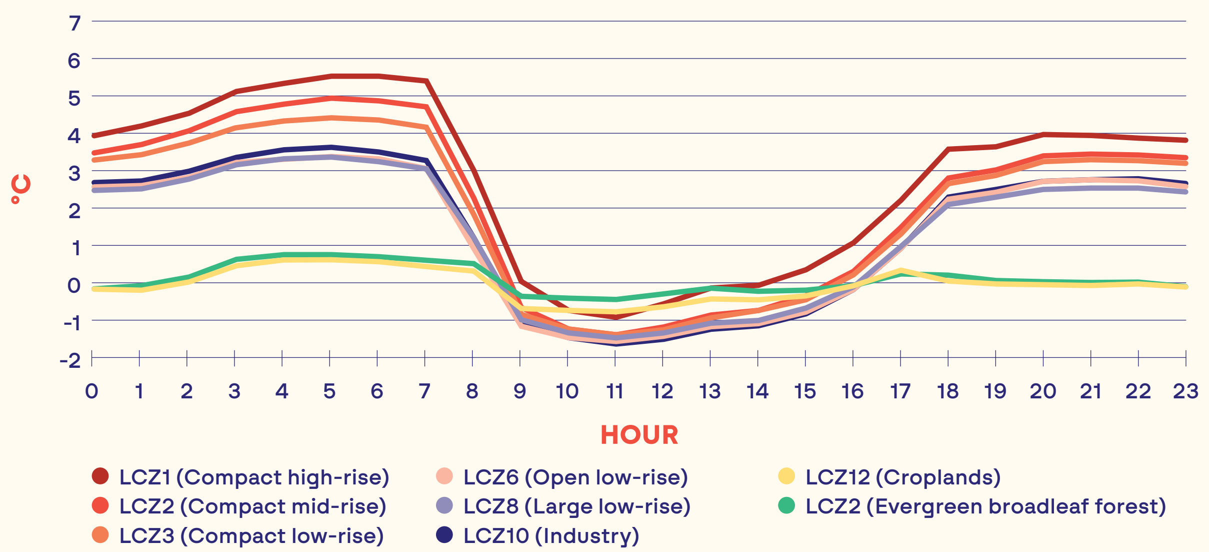


Source: World Bank / National University of Singapore.

Note: Heat island intensity is modeled for selected land use and land cover categories in the Bangkok Metropolitan Area using the Local Climate Zone (LCZ) scheme. Each LCZ represents a distinct category of land cover based on building height, spacing, and surrounding surface cover.

UHI intensity follows a distinct daily cycle, as shown in Figure 6. In December, compact high-rise areas experienced peak UHI intensity levels of up to 6.3°C just before sunrise. As the day progresses, temperature differences between urban and rural areas decrease significantly, with heat dispersing more evenly across the city.

FIGURE 6 MEAN URBAN HEAT ISLAND INTENSITY BY TIME OF DAY DURING DECEMBER 2019 FOR DIFFERENT LAND USE TYPES IN BANGKOK



Source: World Bank / National University of Singapore.

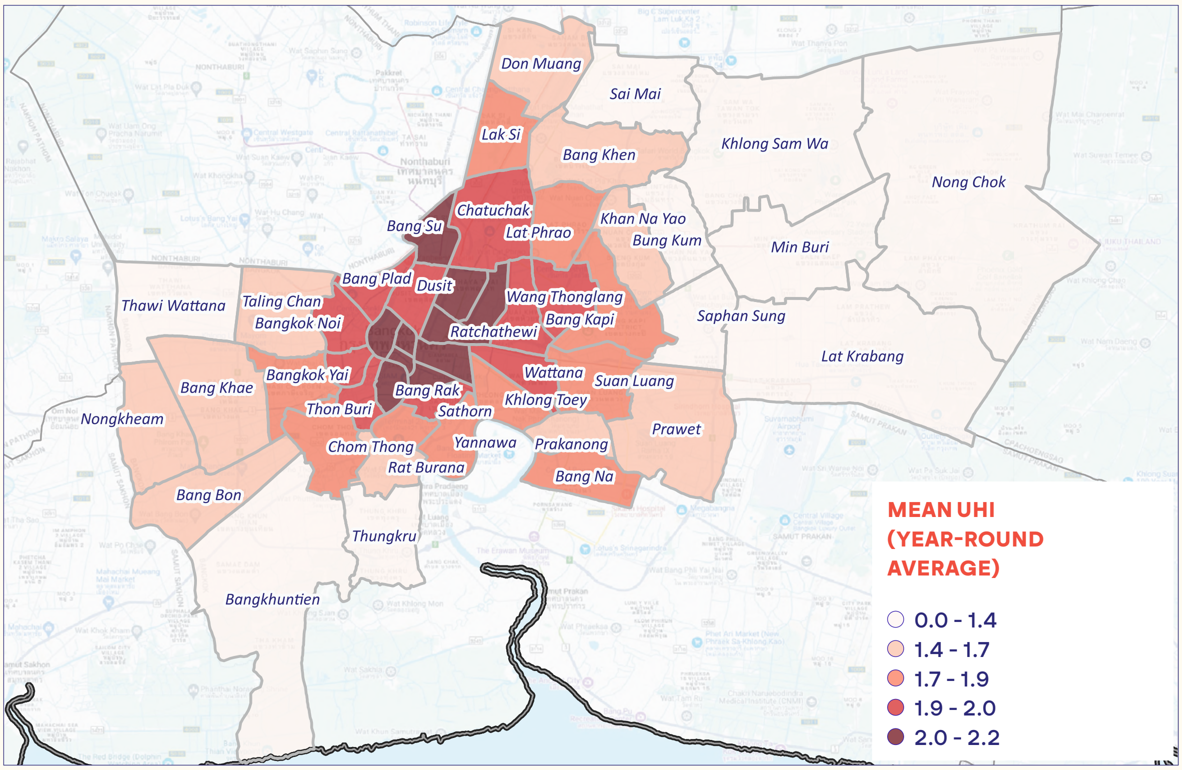
Note: Heat island intensity is modeled for selected land use and land cover categories in the Bangkok Metropolitan Area using the LCZ scheme. Each LCZ represents a distinct category of land cover based on building height, spacing, and surrounding surface cover.

Interestingly, dense urban areas can be slightly cooler than rural areas during the morning and midday hours. While sun-exposed rural landscapes heat up quickly in the morning, tall buildings in densely built areas block incoming solar energy, delaying the warming process. However, once urban areas absorb heat, they retain it well into the night. The significantly higher nighttime temperatures caused by Bangkok's UHI effect pose a serious concern. Extensive public health research has shown that elevated nocturnal temperatures disrupt sleep and hinder the body's ability to rest and recover, increasing the risk of illness and mortality[13].

— URBAN HEAT OVERLAPS WITH VULNERABLE POPULATIONS AND ECONOMIC ACTIVITY

Heat island intensity varies significantly across Bangkok's districts, a difference that becomes apparent when walking through the city center at midday. Neighborhoods such as Pathum Wan, Bang Rak, Ratchathewi, and Phaya Thai experience some of the highest temperatures, averaging up to 2.8°C warmer than the surrounding countryside. The reason is clear: dense clusters of high-rises and vast concrete surfaces absorb and retain heat, particularly in areas with limited tree cover. In contrast, districts in the northern and eastern parts of Bangkok—such as Don Muang, Sai Mai, Nong Chok, and Bang Khen—tend to feel noticeably cooler. These peripheral areas benefit from more open spaces and greenery, which help dissipate heat more effectively throughout the year (Figure 7).

FIGURE 7 URBAN HEAT ISLAND INTENSITY BY DISTRICT



Source: World Bank / National University of Singapore.

13 Ebi et al (2021).

To assess risk levels, this analysis categorized districts into four groups—low, medium, severe, and very severe—based on their UHI intensity[14]. Table 2 outlines the key characteristics of districts within each category.

Districts with higher UHI intensity tend to have smaller residential populations but higher GDP per capita, likely due to their role as Central Business Districts (CBDs), where commercial spaces dominate and residential areas are limited. While these districts may have fewer vulnerable individuals in absolute numbers, they often have a higher concentration of vulnerable populations relative to their total population. The limited availability of green spaces and parks in these areas further exacerbates heat risks.

On average, districts with severe UHI levels have significantly less park area per capita than those with lower UHI intensities, reducing opportunities for cooling and increasing heat retention. Additionally, these high-UHI districts experience higher annual rainfall levels. The combination of fewer parks, higher humidity, and dense urban structures with limited green space makes these districts particularly vulnerable to extreme heat throughout the year.

TABLE 2 CHARACTERISTICS OF DISTRICTS BY URBAN HEAT ISLAND INTENSITY

	Low	Medium	Severe	Highly Severe
Mean UHI (°C)	1.0	1.6	1.9	2.1
Mean Population	254,541	249,250	232,181	120,513
Mean Under-15 Population	24,060	20,180	17,341	8,666
Under-15 Population Density (persons per sq.km)	436	892	1,220	1,285
Total 65++ Population	20,194	21,549	24,328	14,164
65++ Population Density (persons per sq.km)	383	977	1,763	2,214
GDP per Capita (THB)	33,400	47,039	46,191	85,324
Average number of Parks	203	215	156	144
Park area (sq.m) per Capita	10.9	7.1	5.4	7.7
Annual Rainfall (cm)	167	173	179	188

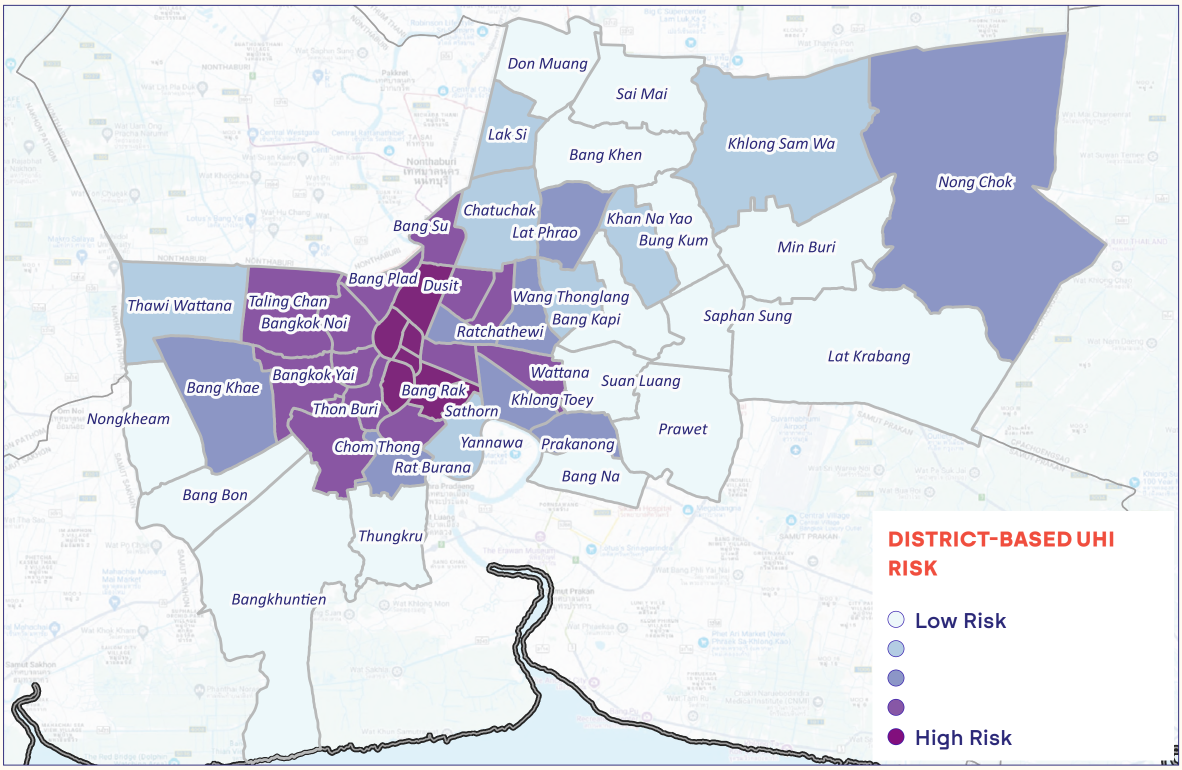
Source: World Bank staff calculations with data from WorldPop (2020), Wang and Sun (2022), Bangkok Metropolitan Administration (2022).

14 For each factor, the districts are divided into 4 categories based on the factor values using Jenks natural breaks classification.

This study also categorizes districts based on the population density of elderly individuals and children[15], helping to identify areas where high UHI intensity overlaps with a high concentration of vulnerable populations. This approach supports targeted policy interventions to mitigate heat-related risks.

As shown in Figure 8, the resulting map highlights the districts most vulnerable to extreme heat, including Khlong San, Sathorn, Din Daeng, Pom Prab Sattru Phai, and Samphantawong—all of which are relatively central. These districts not only experience persistently high UHI intensities throughout the year but also have substantial populations of elderly individuals and children, two groups particularly susceptible to heat-related health risks.

FIGURE 8 HEAT RISK CLASSIFICATION FOR DISTRICTS OF BANGKOK



Source: World Bank staff calculations.

Note: The map presents a heat risk index for districts of Bangkok. The index is calculated as a weighted average of Urban Heat Island intensity together with density of vulnerable population groups (elderly and young children).

15 This is done by calculating categorizing districts based on their size of children and elderly population into 4 groups (low, medium, high, very high). Each category is assigned a score from 1 to 4, respectively. Similarly, the low, medium, severe and highly severe category of UHI intensity also receives similar scoring. Ordinal risk measure is based on sum of score from vulnerable population plus score from UHI category, which has range between 2 (low risk) to 8 (high risk).

CHAPTER

3.

IMPLICATIONS FOR HEALTH, INFRASTRUCTURE AND THE ECONOMY

In their daily lives today, Bangkok residents already experience adverse impacts from extreme urban heat. Vulnerable groups, including children, older people, and those living in poverty are disproportionately affected. Moreover, these impacts are all but certain to increase in future decades as warming trends continue unless stronger countermeasures are put in place.

This section examines three key types of impact—on health, on infrastructure, and on the economy—and considers their implications for Bangkok. By quantifying impacts, this chapter seeks to make a business case for interventions and solutions that will be discussed in Chapter 4.

— HIGH TEMPERATURES CAUSE AVOIDABLE DEATHS

Among the many consequences of rising temperatures and heatwaves, the most critical may be their impact on human health. Extreme heat can be deadly—both in obvious ways and through more subtle, harder-to-detect effects[16]. Exposure to high temperatures has been shown to worsen conditions such as cardiovascular disease and diabetes, increase the risk of adverse pregnancy outcomes, and impair both physical and cognitive function. It can also take a toll on mental health.

Unfortunately, heat-related mortality has not been adequately quantified in many parts of the world—including Bangkok—due to measurement difficulties. However, in several regions, researchers have quantified heat-related deaths, often leading governments to take decisive

16 World Health Organization (2024).

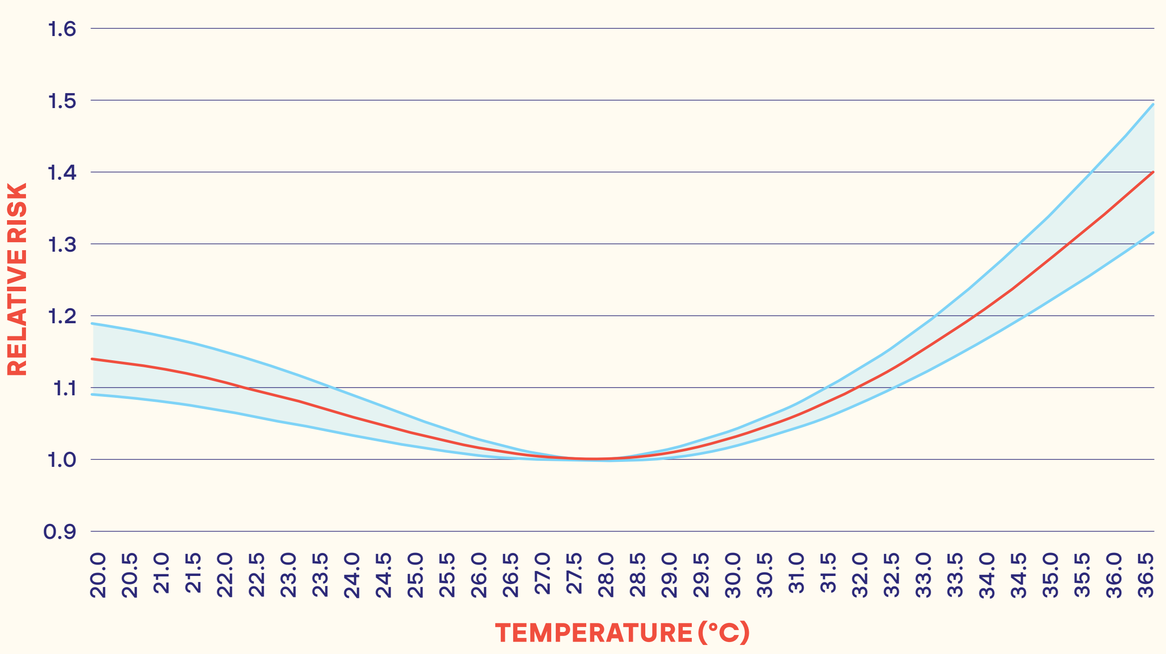
action to avert such a death toll in future. In the United States, Philadelphia's Heat Health Early Warning System was established after a deadly 1993 heatwave. In Europe, after a 2003 heatwave caused 70,000 excess deaths, European countries developed heat action plans and early warning systems. When the Indian city of Ahmedabad experienced a heatwave with peak temperatures of 48°C in 2010, the city-wide daily death rate spiked to three times its usual level, prompting city authorities to develop a Heat Action Plan that the national government is now scaling up as a nation-wide model.

Globally, extreme heat is estimated to cause approximately 500,000 deaths per year – three times the number of fatalities from tropical cyclones. Modeled estimates suggest that the heat-related death rate among people aged 65+ globally could increase nearly three-fold by 2050[17].

Public health researchers use exposure-response models to assess the impact of heat on mortality.[18] Using records of the daily number of deaths from all causes and daily mean temperature, the models estimate the risk of mortality to be low when temperatures remain within a mild range relative to a region's typical climate. However, as temperatures become very hot or very cold, deaths increase. Models of the temperature-mortality relationship can be used to estimate how deaths vary with temperature today and under future temperature rises.

Applying similar models for Bangkok, researchers have estimated that daily deaths are lowest at around 28°C. The estimated heat-mortality relationship for Bangkok is shown in Figure 9. On a day with a mean temperature of 35°C, the model suggests that heat-related mortality would be nearly 28 percent higher compared to a 28°C day.

FIGURE 9 MODELED RELATIONSHIP BETWEEN DAILY TEMPERATURE AND ALL-CAUSE MORTALITY RISK IN BANGKOK (7-DAY LAG)



Source: World Bank elaboration based on Denpetkul & Phosri (2021).

17 Zhao et al (2021), Lancet Countdown (2023).

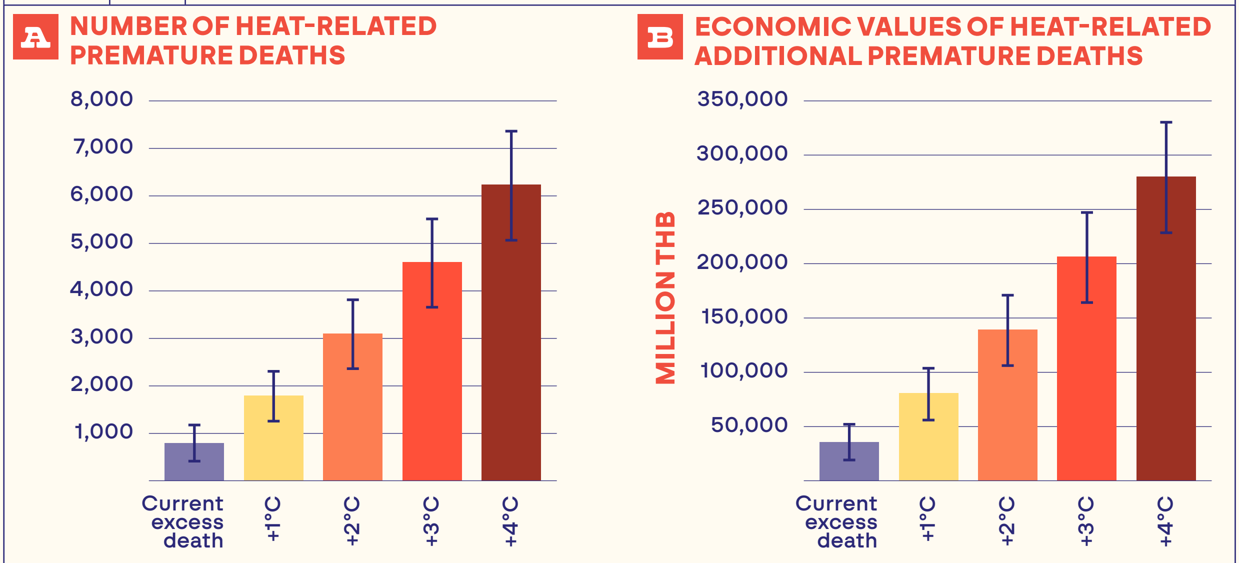
18 Gasparrini and Armstrong (2011).

This study estimates the excess deaths caused by heat in Bangkok by using data from existing research and simulating deaths under current urban heat conditions. It then converts these estimated deaths into monetary values using the Value of Statistical Life (VSL) method. More details on the methodology can be found in Annex 2.

The analysis suggests that Bangkok is already seeing a notable number of excess deaths due to temperatures above the minimum-mortality threshold (Figure 10). In 2019 alone, the city's 50 districts experienced an estimated 421 to 1,174 excess deaths attributable to urban heat. If the average temperature were to rise by 1°C, that figure would climb to between 1,248 and 2,333—a jump of roughly 827 to 1,158 additional lives lost each year. The upper bound of this mortality number are on par with the national road traffic fatality rate (25.4 per 100,000 in 2021[19]). Under a 2°C increase, excess deaths would reach 2,363 to 3,814, highlighting the significant toll that each additional degree in temperature could exact on public health. Rising temperatures have a compounding effect on both the number of excess deaths and their associated social costs. When valued using the VSL method, a 1°C increase from Bangkok's current temperature translates to an additional social cost of THB 35 billion to THB 52 billion per year, roughly 0.7 to 1 percent of the city's 2019 GDP[20]. At a 2°C rise, the annual social cost can reach between THB 80.5 billion and THB 104 billion, amounting to about 1.6 to 1.9 percent of Bangkok's 2019 GDP. These figures highlight how each incremental temperature increase can drive up the financial burden linked to heat-related mortality.

However, it is important to note that these estimates rely on broad assumptions regarding the economic value of a life, which may differ across socioeconomic settings. The numbers also exclude certain indirect costs, such as those tied to chronic illness or reduced quality of life stemming from heat exposure. Consequently, a modest temperature reduction could have meaningful public health benefits by averting heat-related deaths, underscoring the value of proactive strategies to mitigate urban heat.

FIGURE 10 EXCESS DEATHS AND ECONOMIC ESTIMATE OF DEATH-RELATED LOSS



Source: WB staff calculation based on Witvorapong & Komonpaisarn (2020).

Notes: None = No mitigation action. Each bar shows the range of economic values associated with each scenario. Percentage values are based on the median of each range.

19 World Health Organization (n.d.).

20 This study relies on official provincial-level GDP data published by the National Economic and Social Development Council (NESDC). The year 2019 is used as the reference year, as it is the most recent dataset unaffected by the economic disruptions caused by COVID-19.

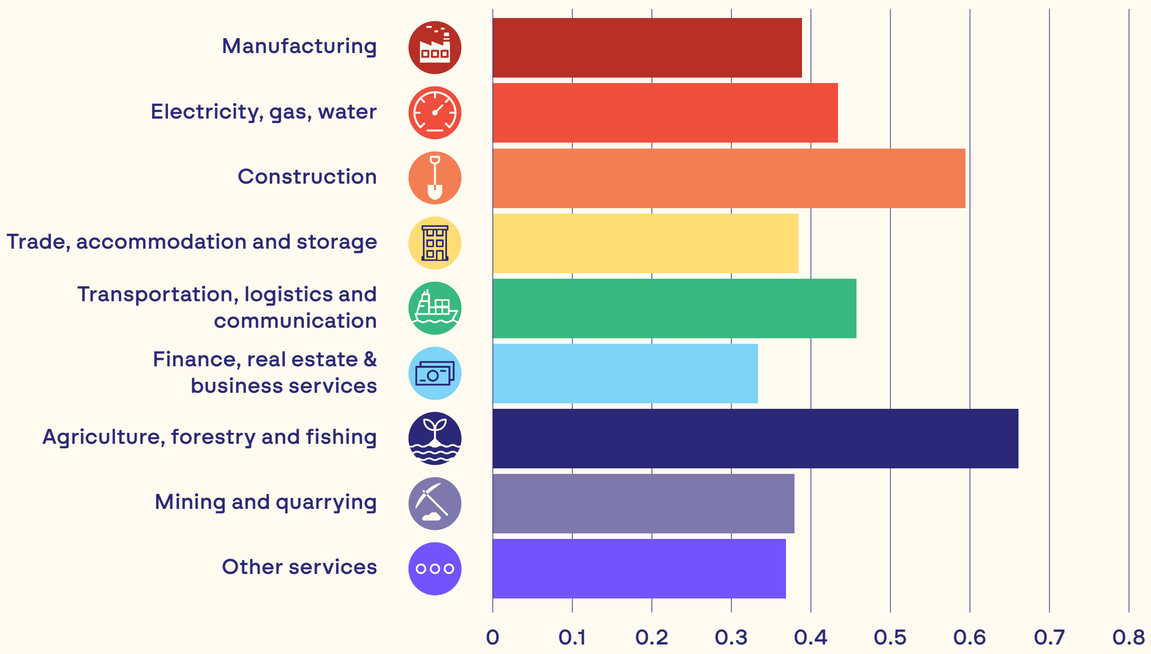
— HEAT-EXPOSED SECTORS FACE PRODUCTIVITY LOSS

Heat stress presents significant economic and labor productivity challenges, leading to reduced efficiency, increased absenteeism, higher injury rates, and lower overall output. Workers in outdoor roles, like construction and street vending, face higher hazards because of prolonged sun exposure. However, even indoor workers experience disruptions in focus and energy, highlighting the broad impact of rising temperatures.

To measure the effect of heat on productivity in Bangkok, this report recognizes that workers' environments differ. Some laborers sweat through daily tasks on roads and construction sites, while others manage offices or assembly lines under hot conditions. Our analysis merges two data sources: the Thailand Labor Force Survey (TLFS) and the Occupational Network database (O*NET). The TLFS provides essential data on workers' demographics, employment status, and sector of employment, while the O*NET database provides estimates of varying environmental heat exposure by labor category. A detailed note on the methodology of measuring productivity loss is available in Annex 3.

Figure 11 illustrates the variation in heat exposure by sector and occupation. The agriculture sector, despite only comprising 0.3 percent of Bangkok workers, has the highest heat score. Construction ranks second, accounting for 5.6 percent of workers in 2019, followed by transportation and logistics (10.9 percent). The trade, accommodation, and storage sector, which employs the largest share of workers (34.0 percent), has a relatively lower heat score.

FIGURE 11 WORKER HEAT SCORE INDEX, BY SECTOR



Source: World Bank Staff Calculation based on O*NET Database (2021).

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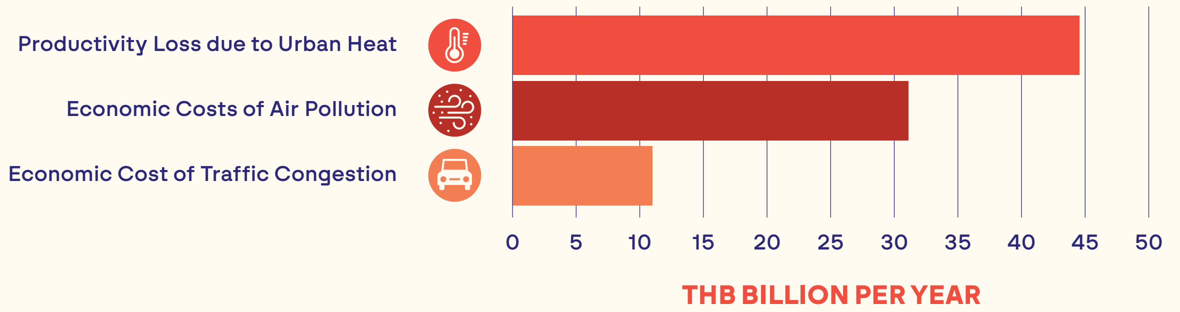
This analysis draws on a statistical approach that compares wages under normal temperatures to those earned in hotter conditions. By estimating what wages would look like if Bangkok's temperature were 1°C cooler and weighing that figure against real wages, the study identifies how much pay is lost to heat. Findings show that a 1°C temperature rise shaves about 3.3 percent to 3.4 percent off worker productivity citywide. That drop adds up to a total annual wage loss of THB 44.7 billion, equal to 0.8 percent of Bangkok's GDP in 2019.[21] For comparison, this figure is higher than the opportunity loss caused by traffic jams[22] and air pollution[23] annually in Bangkok, combined (Figure 12).

FIGURE 12 COMPARISON OF PRODUCTIVITY LOSS DUE TO URBAN HEAT TO OTHER URBAN ISSUES



Source: World Bank staff calculation, Kasikorn Research Center (2016, 2019).

Similarly, the impact of rising temperatures varies across economic sectors, with some workers experiencing greater wage losses than others (Figure 13). These results may not align with the heat score, as productivity losses also depend on a sector's adaptability—such as access to cooling, flexible schedules, or reliance on cognitive rather than physical tasks. A high heat score doesn't always lead to proportional productivity declines if effective mitigation measures are in place. Those who work in the services sector—which includes finance, real estate, business services and others—are hit the hardest, with over a 5 percent hourly wage loss for each 1°C increase in temperature. Workers in electricity, gas, water, and trade, accommodation, and storage jobs also see big losses, around 4 percent. Manufacturing and construction workers lose about 2-3 percent of their wages. Interestingly, transportation workers are barely affected, possibly due to the experience of already long and consistent working hours, which is less affected by hikes in temperature.[24] Another explanation is increased consumer demand for transportation during hotter months, which offsets potential productivity losses. When temperatures soar, people are less inclined to walk or use non-motorized options, so more individuals turn to motorized transport.

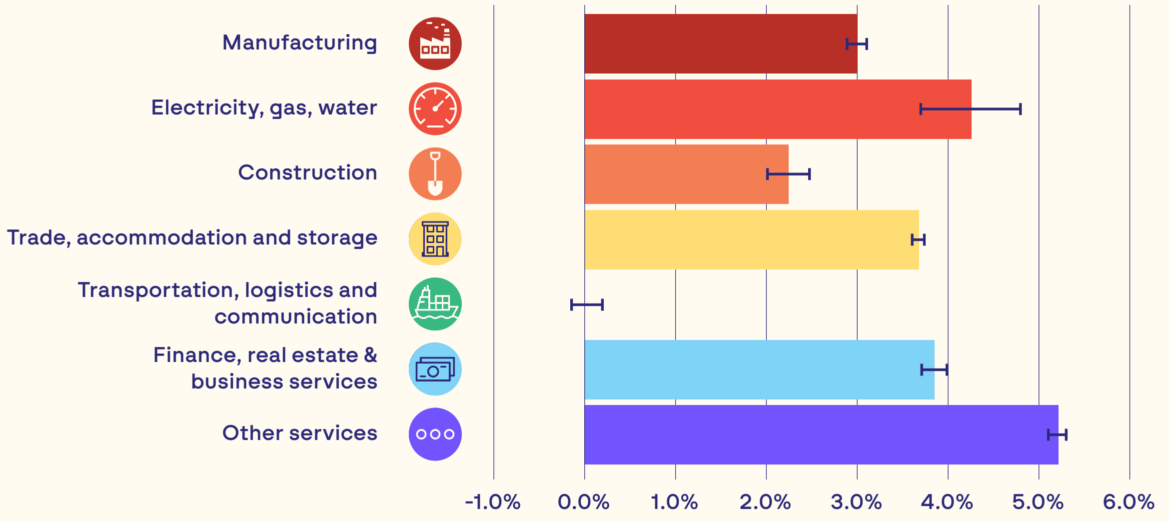
21 However, this estimate only covers about 70% of workers, as it is based on those with available hourly wage data in the TLFS. It excludes self-employed individuals and employers, who make up 30% of the workforce. Therefore, the true productivity loss due to urban heat is highly likely to be underestimated.

22 Kasikorn Research Center (2016).

23 Kasikorn Research Center (2019).

24 In the case of informal transportation workers such as tuk-tuk drivers, working hours statistics may not entirely reflect the time spent by workers on actually driving. Often, the working hours will include waiting time, which can be utilized by drivers to take rests in-between drives.

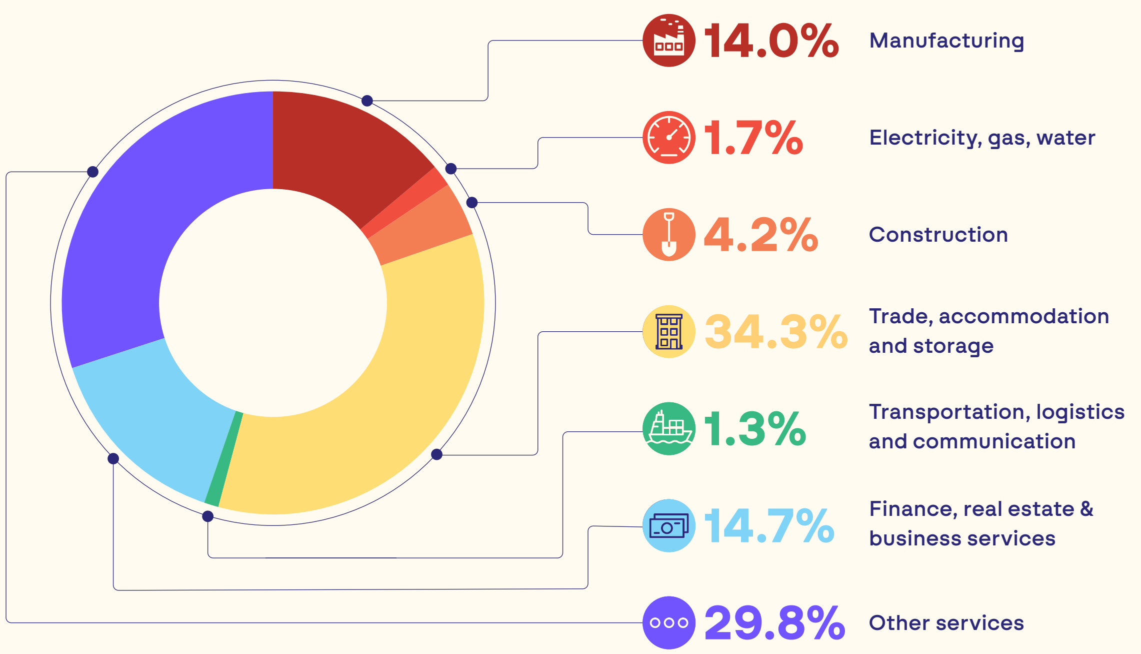
FIGURE 13 PERCENTAGE OF PRODUCTIVITY (HOURLY WAGE) LOSS PER 1°C INCREASE IN TEMPERATURE, BY SECTOR



Source: WB staff calculation based on Thailand Labor Force Survey (2019).

The majority of productivity losses due to heat in Bangkok come from the trade and services sectors, —the largest economic sector of Bangkok— which account for 34% and 30%, respectively, of the total THB 44.7 billion loss per 1°C increase in temperature (Figure 14). It is important to note that this estimate is derived from static figures based on 2019 data, without incorporating potential changes in Bangkok's demographics over time. Future research can explore these questions by incorporating dynamic data sources that capture shifts in population size, age distribution, migration patterns, and urban development to further refine the projections.

FIGURE 14 SECTORAL SHARE ON TOTAL PRODUCTIVITY LOSS PER 1°C INCREASE IN TEMPERATURE



Source: WB staff calculation based on Thailand Labor Force Survey (2019).

ENERGY USAGE FROM COOLING INCREASES CARBON EMISSIONS AND PUTS A FINANCIAL STRAIN ON LOW-INCOME HOUSEHOLDS

Understanding how heat affects livelihoods in Bangkok also requires examining its impact on energy use. This connection can be observed in two primary ways. First, an increase in temperature will lead to more demand for cooling, such as the use of air conditioning or fan. Second, electricity use is most efficient at a certain "comfort temperature," where minimal energy is needed for heating or cooling. When temperatures rise beyond this level, energy demand increases. In hot weather, air conditioning use spikes, and devices like refrigerators and computers become less efficient, leading to higher electricity consumption. This is especially true in cities like Bangkok, where the urban heat island effect makes temperatures even hotter.

Rising electricity use not only raises household bills but also increases carbon emissions. Since about 80 percent of Thailand's energy comes from fossil fuels[25], higher energy consumption leads to more CO_2 emissions, worsening air pollution and health problems like respiratory and heart diseases. It also puts pressure on Thailand's climate commitments, making it harder to reduce emissions and potentially increasing costs related to carbon credits. In the long run, this could slow progress on climate goals while adding economic and environmental challenges.

Bangkok's electricity consumption is notably high. In 2019, residents used an average of 498 kWh per month, more than double the national average of 231 kWh per month.[26] This highlights the need to understand how temperature affects electricity demand. By studying electricity use alongside temperature trends, this analysis shows how rising heat—especially in Bangkok's hot climate and UHI effect—leads to higher electricity consumption. A detailed description of the methodology used for this estimation is available on Annex 4.

The analysis found a strong link between temperature and electricity use. For every 1°C rise in temperature, monthly energy consumption per person increases by 6.8 percent, adding about 35.8 kWh to their electricity bill, an additional cost of around THB 144 per month. With an average household size of 3.1, Bangkok households are expected to face an increase of THB 447 per 1°C rise in temperature. As Bangkok's temperatures rise, especially in hotter months, energy demand surges due to increased cooling needs. With 10 million people in 2020, a 1°C increase is associated to an extra THB 1.44 billion in electricity costs per month, totaling THB 17.31 billion annually. This additional cost equals 0.34 percent of Bangkok's gross provincial product (GPP) in 2019, highlighting the financial burden of rising temperatures.

Lower-income households in Bangkok are especially vulnerable, as they already allocate a higher share of their budget to electricity. Among Bangkok residents, electricity bills account for about 2.5 percent of total monthly household spending on average, although this share varies by economic status. Data from the Thailand Socio Economic Survey indicate that lower-income Bangkok households—the bottom 20 percent of residents by income—allocate around 4 percent of their expenses to electricity, compared to just 2.3 percent for the top

25 International Energy Agency (n.d.).

26 Calculation based on energy data retrieved from the Energy Policy and Planning Office (2024), and population data from the National Statistical Office (2019).

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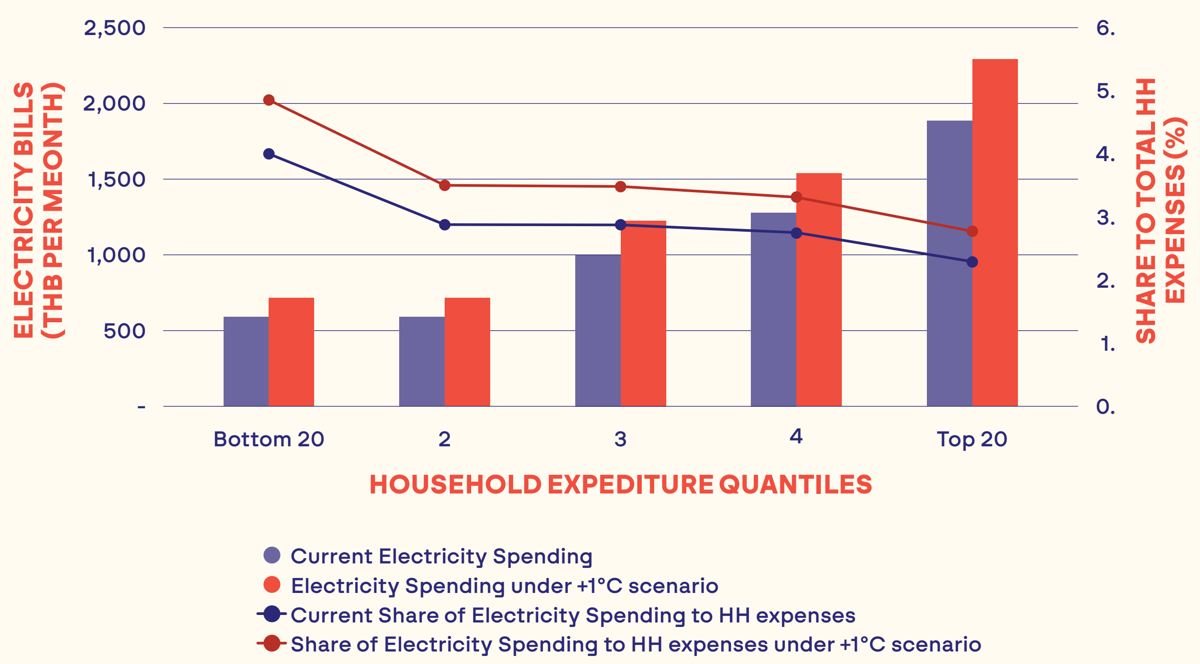
20 percent richest. In absolute terms, the citywide monthly average comes to THB 1,525 per household. A temperature increase of 1°C could cause this amount to jump by an average of THB 447, or roughly 29 percent overall. While the exact rise in energy use hinges on factors like the prevalence of AC and electronic devices, such a cost hike poses a greater burden for lower-income groups, who already spend a larger share of their income on electricity (Figure 15).

FIGURE 15 ELECTRICITY BILLS BY BANGKOK HOUSEHOLD EXPENDITURE QUANTILES



Source: WB staff calculation based on Thailand Socio Economic Survey (2019).

The rise in household electricity bills is only one visible effect of soaring urban temperatures. Less apparent, yet equally critical, is the surge in CO_2 emissions stemming from increased electricity use. In Thailand, each kilowatt-hour of electricity generates 0.477 kilograms of CO_2,[27] meaning that higher consumption during hotter periods translates into an extra 17 kilograms of CO_2 per person each month. In a city like Bangkok, which has around 10 million residents, this additional demand amounts to 170,000 metric tons of CO_2 every month—or about 2.04 million metric tons per year. When compared to Thailand's total CO_2 emissions of 265 million metric tons[28] in 2020, a 1°C rise in temperature leading to greater cooling needs could increase national emissions by about 0.7 percent. This highlights how urban heat not only places a financial strain on households through elevated electricity costs but also plays a substantial role in driving climate change.

27 Based on 2021 figures released by Energy Policy and Planning Office (n.d.).

28 World Resources Institute (2023) data presented in World Bank World Development Indicators (2024).

HEAT ADVERSELY AFFECTS EDUCATION OUTCOMES AND INFRASTRUCTURE SYSTEMS

This study primarily evaluates Bangkok's economic losses from urban heat through three major channels: heat-related mortality, reduced labor productivity, and increased electricity consumption. While these three elements are vital for measuring the impacts of heat, they represent only part of the city's broader vulnerability to extreme temperatures. Beyond these core issues, the report also acknowledges other significant ways in which urban heat can undermine Bangkok's societal and economic well-being. In reality, rising heat can affect society in less measurable ways—for example, reducing educational attainment among children unable to concentrate in overheated classrooms (Box 1), straining infrastructure systems that buckle under chronic heat (Box 2), and degrading overall urban liveability. Each of these outcomes, though difficult to quantify, carries real consequences for community well-being, long-term growth, and the city's capacity to adapt. While measuring each of these channels is beyond the scope of this report, this section draws on existing studies from various contexts to provide valuable insights for Bangkok.

BOX 1 EXTREME HEAT AND ITS IMPACT ON EDUCATION OUTCOMES

Heatwaves do more than just make classrooms uncomfortable—they can significantly undermine students' capacity to learn. In the United States, for instance, test-score data have consistently linked higher temperatures to poorer academic outcomes, underscoring how even developed regions with air-conditioning are not immune to the detrimental effects of extreme heat. Although these findings come from diverse geographic and socio-economic contexts, they converge on a key conclusion: excess heat during the school day can disrupt concentration, exacerbate fatigue, and impede overall cognitive performance.

Research by Roach and Whitney (2021) on elementary and middle school students highlights that each additional day above 32°C (90°F) can lead to a 1–1.5 percent drop in standardized test performance, depending on the student's baseline academic level. This effect manifests itself more acutely when schools lack adequate cooling technologies, implying that resource-poor districts bear the brunt of heat-driven learning deficits. By analyzing attendance records and detailed test results, the study also reveals that temperature spikes contribute to higher absence rates and a lower likelihood of completing homework, both of which compound the negative academic effects.

A separate study by Park et al (2020) takes a broader look across multiple states and school districts, finding that short-run temperature increases can directly impair students' math and reading scores. On average, each 1°C increase above seasonal norms yielded a 1 percent decline in performance for middle-grade learners. In particularly warm climates or places where classrooms lack air-conditioning, the dip in scores is often greater. The authors note that interventions like improved ventilation and shading can partially offset this effect.

Beyond immediate test-score implications, these learning gaps can have lasting consequences for student trajectories. Repeated disruptions during formative education years may translate into skill deficits and reduced long-term earnings potential. Moreover, the stress of trying to perform academically under adverse heat conditions has been associated with lower school satisfaction and higher dropout intentions, especially in under-resourced urban areas.

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BOX 2 HOW URBAN HEAT AFFECTS CITY INFRASTRUCTURE[29]

Rising temperatures can weaken vital components of a city's physical network, leading to sudden failures and mounting repair costs. According to the World Bank's *Unlivable* report, roads and rail tracks are often among the first casualties of extreme heat, as high pavement and track temperatures trigger buckling, cracking, and distortions. Urban highways in warm-climate cities can register surface temperatures up to 20°C above ambient air levels, hastening asphalt deterioration and demanding more frequent road maintenance. Likewise, rail systems can face speed restrictions, shutdowns, or safety hazards when steel rails expand beyond design tolerances.

Beyond transportation, heat also puts strain on water and waste management infrastructure. Hotter air and ground temperatures escalate evaporation rates, reducing reservoir levels and intensifying competition for water. In turn, pumping stations and treatment plants must consume more energy to maintain water pressure, resulting in higher operational costs. When drainage systems operate close to capacity under normal conditions, even a small elevation in temperature—often accompanied by more intense rainfall—can raise flood risk in low-lying or poorly ventilated areas of the city.

The report also emphasizes that hotter conditions accelerate aging in utility grids and power distribution networks, compounding the risk of brownouts or blackouts. Temperature spikes can reduce the efficiency of transformers and wiring, forcing them to handle the same load under greater strain. Air-conditioning surge demand during hot periods often tips supply systems into overload, undermining the reliability of daily services such as lighting, refrigeration, and electronic communications. Where backups or modernized grids are absent, blackouts can become more frequent, destabilizing economic activity and household routines.

Heat's impact on infrastructure is far-reaching and can span more subtle but costly areas as well. Older building materials can warp, pushing up the need for retrofitting, while high heat accelerates corrosion in structures already exposed to pollution or sea salt. These outcomes can add hidden repair costs over time, reinforcing the importance of heat-sensitive urban planning and policies. By taking into account projected temperature increases and their stress on infrastructure, city managers can prioritize preventive measures—such as cool pavements, heat-reflective coatings, expanded tree canopy, advice to passengers on staying well during hot weather, and proactive safety and maintenance protocols during heatwaves—to mitigate damages and reduce future spending on emergency fixes.

29 Roberts et al. (2023).

CHAPTER

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TAKING STOCK: CURRENT MEASURES FOR HEAT RESILIENCE

The Thailand National Adaptation Plan (NAP) 2023[30] highlights the increasing risks associated with heat stress, identifying over ten provinces, including Bangkok, as high-risk areas. Rising temperatures pose a growing challenge to urban areas, affecting public health, economic productivity, and overall quality of life. Addressing these challenges requires a comprehensive approach to climate adaptation and mitigation, integrating policies that enhance urban resilience while reducing greenhouse gas (GHG) emissions.

Bangkok has taken proactive steps in addressing climate change through a series of long-term strategies aimed at mitigating emissions and strengthening climate resilience. In 2007, the BMA launched its first climate initiative, the Global Warming Mitigation Action Plan (2007-2012), setting the foundation for a structured response to climate challenges. This early framework laid the groundwork for subsequent policies aimed at reducing emissions, promoting sustainable urban development, and improving environmental resilience.

Building on these efforts, BMA, in collaboration with the Japan International Cooperation Agency (JICA), developed the Bangkok Master Plan on Climate Change (2013-2023). This plan established a clear GHG reduction target of 13.6%[31] from a business-as-usual (BAU) scenario by 2020, with a focus on key emission sources, including transportation, energy, waste, and wastewater management. A 2021 assessment confirmed that Bangkok met its target, with emissions recorded at 40.75 million tons of CO_2 equivalent, compared to the projected 46.4 $MtCO_2e$ under a BAU scenario.

30 Ministry of Natural Resources and Environment of Thailand (2023).
31 Bangkok Metropolitan Administration (2015).

Recognizing the need for sustained climate action, BMA and JICA introduced the Bangkok Master Plan on Climate Change (2021-2030), expanding its focus to include sustainable transport, energy efficiency, waste management, and climate adaptation. The plan sets a GHG reduction target of 19% from BAU by 2030, reinforcing Bangkok's long-term vision to achieve net-zero emissions by 2050[32]. Climate adaptation measures have also been prioritized, recognizing the increasing risks posed by extreme weather events and rising temperatures. The integration of climate risk considerations into urban planning and infrastructure development is a key component of this approach, ensuring that future growth is both sustainable and resilient.

These efforts align with Thailand's broader national climate policies and international commitments to low-carbon development and urban resilience. Moving forward, strengthening institutional capacity, enhancing public-private collaboration, and increasing investment in climate-smart infrastructure will be critical in ensuring the successful implementation of Bangkok's climate action strategies. As urbanization accelerates, a coordinated, data-driven approach will be essential in achieving long-term climate goals and enhancing the city's ability to adapt to a changing climate.

In recent years, Bangkok has increasingly focused implementation of range of measures to both mitigate and adapt to urban heat, combining policies. Initiatives such as warning messages, heat-resilient city design, and nature-based solutions have emerged in response to rising temperatures and their associated health risks. While several initiatives have demonstrated impact, effective implementation requires stronger coordination between the BMA and national government agencies to enhance policy alignment, and resource allocation. Addressing challenges such as overlapping mandates and institutional coordination gaps will be key to scaling and sustaining urban heat adaptation efforts within Bangkok's broader climate resilience framework.

BMA'S HEAT-RELATED POLICIES AND URBAN HEAT MANAGEMENT FRAMEWORK

With temperatures rising annually, Thailand has experienced a steady increase in extreme heat events. In response, BMA has taken various steps in recent years to address rising temperatures and the adverse health and environmental impacts caused by urban heat. From adopting measures such as establishing cooling centers to introducing hydration station initiatives, these efforts aim to mitigate heat risks for Bangkok's diverse population. This section provides an overview of BMA's key policies and emerging Heat Action Plan.

In response to a string of recent heat waves, the BMA developed an Urban Heat Management Framework in 2024 to address rising temperatures in the city. The framework consists of two main components. The Year-Round Intervention Framework includes measures that are implemented continuously, regardless of the season. The Hot Season Intervention Framework consists of targeted interventions activated specifically during the hot season, with priority actions determined based on the heat index levels. The heat index, within this framework, is categorized into four phases. The Monitoring Phase (27°C – 32.9°C) focuses on regular

32 Bangkok Metropolitan Administration (2021).

temperature tracking and the dissemination of heat-related information. The Warning Phase (33°C – 41.9°C) emphasizes public awareness campaigns and advisories on heat risks. The Critical Phase (42°C – 51.9°C) involves the implementation of emergency response measures, including the preparedness of healthcare systems to manage heat-related illnesses. The Extreme Critical Phase (beyond 52°C) requires urgent interventions to safeguard public health and critical infrastructure. At each phase, the framework prioritizes continuous monitoring, timely dissemination of heat index data, and strengthening the healthcare system's capacity to respond to heat-related emergencies.

The Year-Round Intervention Framework focuses on two key areas: *strengthening healthcare capacity and mitigating urban heat impacts.* Efforts to enhance healthcare preparedness include training medical personnel on heat-related risks and integrating heat risk management into public health protocols. To mitigate urban heat impacts, the BMA is implementing long-term strategies such as expanding green spaces through initiatives like planting two million trees and establishing 15-minute parks to enhance urban cooling. Additionally, climate-sensitive urban planning measures are being introduced, including promoting open facades in high-rise buildings to improve ventilation, increasing blue spaces such as water bodies to moderate temperatures, and encouraging the use of heat-reflective materials in newly constructed buildings. Efforts to cool the physical environment place emphasis on green infrastructure and surface improvements. Projects like planting more trees and expanding green spaces seek to enhance shade and reduce ambient temperatures, while cool pavements and permeable surfaces aim to reflect more sunlight and improve water infiltration, thereby lowering surrounding heat levels. Similarly, integrating design features like urban ventilation corridors and water-based elements—such as fountains—into open areas contributes to localized cooling. These strategies are at various stages of implementation across Bangkok.

Complementary measures highlight the importance of consistent hydration and workplace adjustments. For hydration, the city has introduced initiatives such as installing additional water refill stations and fountains, aiming to make clean drinking water more readily accessible in public spaces. These efforts also include educational outreach to underscore the significance of adequate fluid intake in hot weather. Additionally, the BMA has encouraged modifying work schedules, especially for outdoor laborers, to reduce exposure during the hottest times of day. However, widespread adoption within the private sector remains limited because existing labor regulations do not explicitly address extreme heat conditions.

The Hot Season Intervention Framework focuses on status monitoring, health advisories, early warning systems, and providing guidance to the public on managing heat-related health risks by age group and health requirement group. This includes recommendations such as increasing fluid intake, staying in shaded areas, and wearing lightweight clothing. Early Warning Systems (EWS), for instance, have been implemented to provide timely alerts about impending heatwaves, helping residents and local agencies prepare in advance. Although the current EWS mostly relies on messaging applications, there are discussions to improve coverage and accessibility. Additionally, the framework emphasizes the preparation of cooling rooms in public hospitals to provide relief for those affected by extreme heat. The implementation of both intervention frameworks involve collaboration among key BMA departments, including the Health Department, City Planning Department, Environment Department, and Public Works Department. A summary of Bangkok's Intervention Framework is shown in Table 3.

TABLE 3 SUMMARY OF BANGKOK'S CURRENT HEAT ACTION PLAN	Year-long Measures	Monitoring Phase 27°C - 32.9°C	Warning Phase 33°C - 41.9°C	Critical Phase 42°C - 51.9°C	Extreme Phase beyond 52°C
Objective	Develop plans and guidelines, raise awareness, and monitor heat-related health risks.	Alert public and at-risk groups about potential heat impacts.	Issue warnings for heat risks and activate response plans.	Implement emergency measures to protect public health.	Enforce strict safety measures to prevent severe health impacts.
Measures	Educate communities, distribute protective equipment, enhance urban cooling strategies.	Daily monitoring of heat index, early alerts, and guidance on heat precautions.	Public advisories, activate cooling centers, and prepare emergency response units.	Emergency services on standby, restrict outdoor activities, ensure hydration points.	Full-scale emergency response, mandatory cooling shelters, continuous health monitoring.
Agencies	Environmental Office, Department of Health, Medical Department, Social Development Office	Environmental Office, Department of Health, Meteorological Department, Public Relations Office	Environmental Office, Medical Department, Public Relations Office, District Office	Medical Department, Department of Health, Emergency Operation Centers, District Office	Medical Department, Department of Health, Emergency Operation Centers, District Office

Source: Bangkok Metropolitan Administration (2024).

ONGOING INVESTMENTS IN BANGKOK'S HEAT RESILIENCE

Bangkok's current heat resilience efforts rely primarily on municipal budgets, private-sector investments, and ad-hoc project funding. The BMA allocates funds for green space expansion, cooling infrastructure, and heat action plans. However, these resources are often constrained by competing urban development priorities. While BMA's budget covers essential adaptation efforts—such as tree planting, hydration stations, and public awareness campaigns—larger-scale interventions like district cooling or extensive urban shading require additional funding sources. Despite these efforts, many initiatives depend on one-time project-based funding, making long-term sustainability uncertain. The city has yet to establish a dedicated heat resilience fund, which could help ensure consistent financing for heat mitigation projects.

BMA has undertaken public investments in heat adaptation, including early warning systems to alert residents about impending heatwaves. While current alert infrastructure relies heavily on mobile messaging applications, plans are underway to expand coverage and integrate it with platforms initially used for PM2.5 pollution alerts. These upgrades aim to improve inclusivity and timeliness, particularly for individuals without routine smartphone access. Additionally, BMA has supported cooling infrastructure projects, such as the Sabuy Square solar-powered bus stop and public hydration stations (Figure 16). Sabuy Square demonstrates the potential of low-energy, air-conditioned spaces to protect people from extreme heat while promoting energy conservation. Meanwhile, city-led hydration initiatives—such as additional refill stations and water fountains—enhance public health, reduce reliance on bottled water, and encourage sustainable daily habits. While these projects have largely been guided by BMA policies, private sponsors and Non-Governmental Organizations (NGOs) have contributed funds, materials, and expertise, particularly for certain pilot initiatives.

Green infrastructure has also been a key area of public-sector investment, often in collaboration with private donors. BMA has led extensive 1 million tree-planting campaigns, supported by corporate contributions. The Metro-Forest Project in Prawet district is an example of private sector-led investment to convert previously unused land into an ecological forest (also Figure 16). These efforts demonstrate the growing recognition that well-planned greenery can reduce local temperatures, support biodiversity, and offer recreational benefits to residents.

FIGURE 16 EXAMPLES OF URBAN HEAT-RELATED INVESTMENTS IN BANGKOK

A SABUY SQUARE BUS STATION

B METRO FOREST PROJECT

Image Source: Left (World Bank staff), Right (Shutterstock (link)).

Private-sector investments have played a crucial role in cooling initiatives, particularly in high-density commercial areas. In Ratchaprasong, for example, private funding from malls and building owners supports the development of shaded walkways connecting to the BTS Skytrain. These investments are driven by commercial incentives, as improved pedestrian comfort boosts foot traffic and retail activity. Privately led developments have also made significant strides in deploying advanced cooling technologies. Large-scale mixed-use projects like One Bangkok and Samyan Smart City have implemented district cooling systems, which provide efficient air conditioning while minimizing waste heat. These projects, primarily funded by private consortia, highlight the potential for collaboration between businesses and government, as favorable policies and incentives encourage firms to adopt energy-efficient cooling solutions. The result is lower operational costs for property owners and a reduced urban heat burden for surrounding communities.

While some public-private partnerships (PPPs) have emerged for heat mitigation, their implementation remains largely limited to high-income commercial zones. Expanding similar initiatives to other parts of the city—such as integrating covered walkways into transit-oriented developments or encouraging green facades on private buildings—would require clearer incentives and regulatory support. Currently, broader private investment in heat adaptation is hindered by the lack of density bonuses, tax incentives, or reduced permitting fees for heat-adaptive infrastructure.

INSTITUTIONAL AND GOVERNANCE CONSTRAINTS ON BANGKOK'S URBAN HEAT MANAGEMENT

While interventions such as those outlined in the Bangkok Heat Action Plan call for effective cross-collaboration among city agencies, the current governance arrangements have yet to fully incentivize cooperation. Limited channels for resource sharing, overlapping mandates, and a general limitation of holistic strategy reduce the coordination between national and sub-national departments to work together. This section discusses the backdrop of Bangkok's institution and the structural factors that shape how agencies coordinate heat management, highlighting the constraints preventing collaboration.

The BMA was formed in 1972 by merging the Bangkok and Thonburi municipalities into a single metropolitan authority, with the intention to streamline governance across the rapidly growing capital. Since its formation, the BMA has played a key role in the city's development, including the expansion of road networks, rail systems, and commercial areas. While the BMA has a broad mandate, many policy areas—such as land-use planning and environmental regulations—are also managed by national agencies, including the Ministry of the Interior, Ministry of Finance, and Ministry of Natural Resources and Environment. This shared responsibility means that certain city initiatives, such as efforts to strengthen land-use regulations and preserve green spaces, may require coordination with national policies and regulations, which can sometimes affect the pace of implementation.

As outlined in in the Bangkok Heat Action Plan, responsibilities relevant to urban heat management are distributed across multiple departments, such as the Department of City Planning, the Department of Environment, the Department of Public Works, and Department of Medical Service. While the plan emphasizes the importance of cross-institutional coordination, collaboration across these agencies can sometimes be challenging due to the diverse mandates and priorities of each entity. For example, district offices responsible for granting building permits may encounter difficulties in aligning enforcement with city-level regulations. Strengthening coordination mechanisms and ensuring adequate resources for heat resilience could further enhance a strategic response to Bangkok's heat challenge.

CHAPTER

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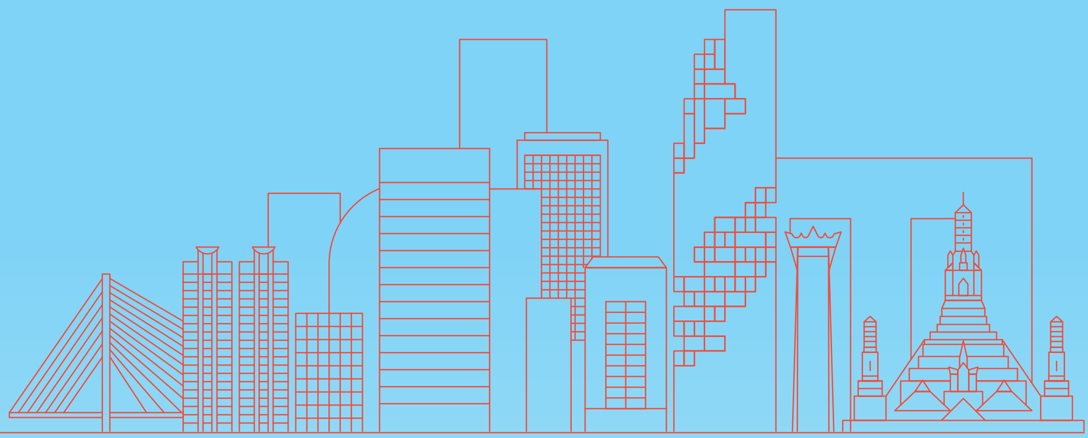

STRATEGIC ACTIONS FOR HEAT-RESILIENT BANGKOK

The BMA has made important progress on heat resilience which can be built upon by addressing key opportunities for strengthened governance frameworks and strategic action. To fully tackle the city's growing urban heat challenges, an integrated approach is essential.

The following analysis compares the BMA's current urban heat management efforts with an ideal framework built around "people, places, and institutions" (Box 3). By examining how well the city's existing policies protect vulnerable residents, address place-based heat challenges, and coordinate across agencies, this analysis highlights the most critical improvement opportunities in Bangkok's approach to rising temperatures.

BOX 3 THE PLACES, PEOPLE AND INSTITUTIONS FRAMEWORK

UHIs are tied closely to a city's physical environment—its buildings, pavements, and green spaces—all of which shape where and how heat accumulates. Targeting these specific "places" is essential: by identifying high-risk areas, such as neighborhoods dominated by dense concrete structures or limited vegetation, planners can apply precise interventions ranging from microclimate modeling to increased tree cover and reflective surfaces. This place-based approach must also consider the "people" who are most vulnerable—elderly residents, children, outdoor workers, and those with health conditions—by combining demographic and spatial data to prioritize resources where they will have the greatest impact. Fundamentally, the aim is to reduce heat-related health risks, including exhaustion and heat stroke, by ensuring these communities benefit from timely warnings, cooling centers, and adapted urban designs.

Equally important is the role of "institutions," which coordinate the many dimensions of urban heat management. Cities need robust governance structures—such as a dedicated heat task force—that bring together government departments, health services, professional groups, and civil society. Clear mandates, resource mapping, and transparent communication form the backbone of effective institutional coordination. By integrating heat resilience measures into daily operations—through building codes, early warning systems, and strategic outreach—Bangkok can proactively reduce heat's negative impacts on both public health and the local economy. This holistic framework, centered on people, places, and institutions (Figure 17), ensures that efforts to combat urban heat remain both equitable and sustainable.

FIGURE 17 THE "PLACES, PEOPLE, INSTITUTIONS" FRAMEWORK FOR URBAN HEAT RESILIENCE

PLACES

- → Advance urban greening through strategic planning
- → Cool city spaces through wind, shade and design
- → Engage building owners to tackle indoor heat

PEOPLE

- → Save lives through heatwave early warnings
- → Protect heat-exposed workers

INSTITUTIONS

- → Mainstream heat mitigation into city strategies and operations

Source: Roberts et al. (2023).

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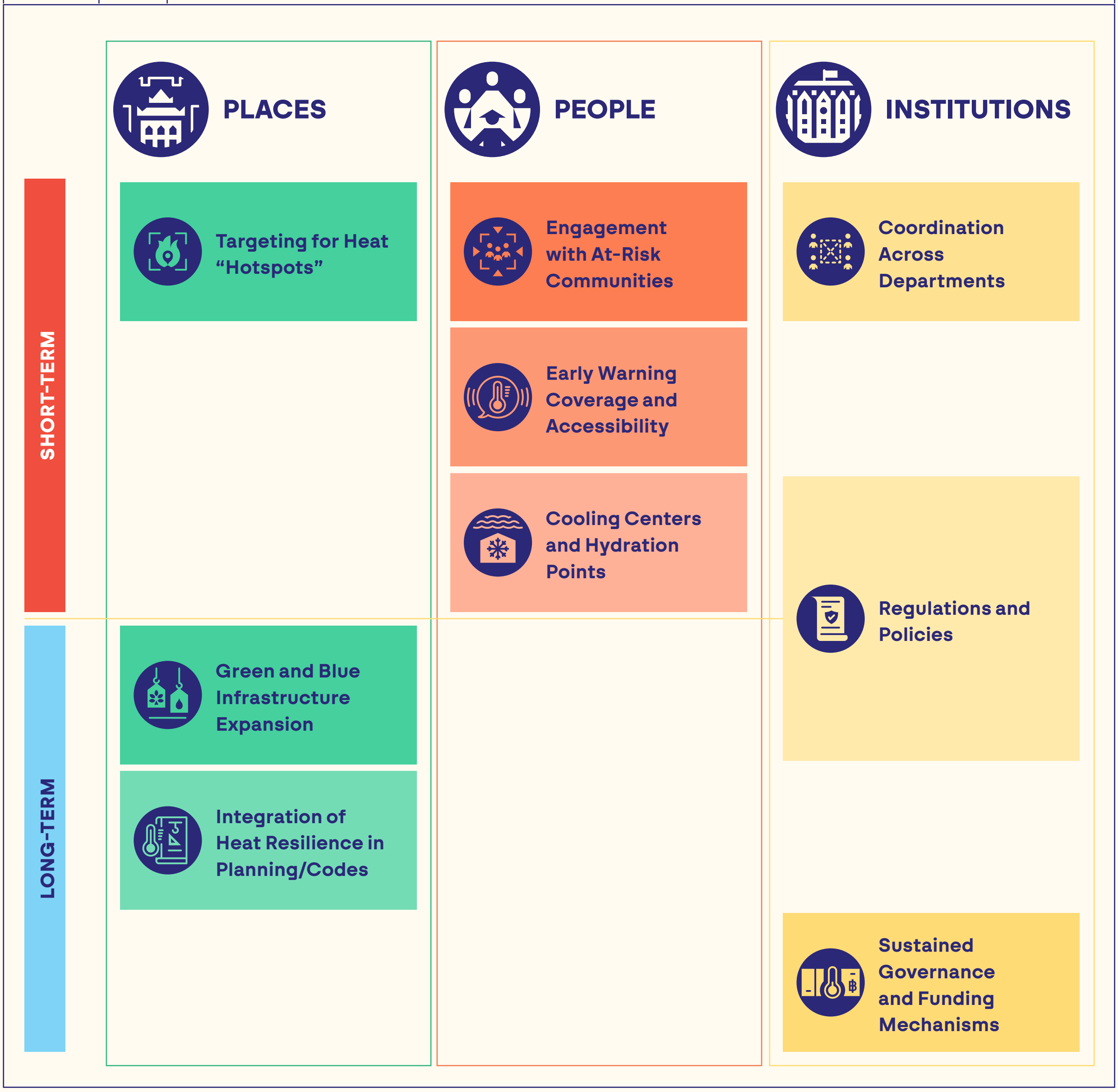
This analysis highlights both immediate and long-term challenges in BMA's Heat Action Plan, requiring distinct approaches tailored to each timeframe (Figure 18). Bangkok's short-term challenges in heat management—such as limited early warning systems, insufficient cooling centers, and limited inter-departmental coordination—can be addressed through policy adjustments and targeted resource allocation. These immediate measures, including opening safe cooling spaces and enhancing alert systems, can provide direct relief and help save lives during upcoming heatwaves.

Meanwhile, longer-term requirements—integrating heat resilience into urban planning, reforming regulations, and establishing stable funding and governance—require ongoing efforts and potentially structural adjustment, which may not yield immediate results but are vital to achieving systemic resilience. A balanced approach that advances both short- and long-term strategies will help safeguard vulnerable populations in Bangkok while supporting the city's ability to adapt to rising temperatures over time.

FIGURE 18 IMPROVEMENT OPPORTUNITIES FOR BANGKOK HEAT RESILIENCE POLICIES



Source: WB elaboration.

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PLACES

Photo by Nick van den Berg on Unsplash

TARGETING FOR HEAT "HOTSPOTS"

Bangkok has an opportunity to enhance its urban heat strategies by prioritizing the neighborhoods most affected by extreme temperatures. Integrating detailed heat mapping and micro-level climate modeling into decision-making can help ensure that tree planting and cooling initiatives are directed toward the areas that need them most. By focusing on dense, lower-income communities—where studies show urban heat island intensity is highest—the city can provide targeted support and build resilience for those at greater risk.

Prioritizing these neighborhoods offers co-benefits that extend beyond heat mitigation. Planting trees or establishing pocket parks in underserved hotspots can enhance air quality by filtering pollutants, reduce stormwater runoff through permeable soils, and create attractive public spaces that foster community gatherings, further enhancing quality of life in underserved communities. Even small interventions like shading bus stops can encourage more residents to opt for public transit in previously unattractive locations, potentially easing congestion while improving the comfort of daily commutes. Over time, these localized improvements help revitalize vulnerable districts, attracting new businesses and instilling a sense of pride among residents, thus further embedding sustainability and inclusivity into Bangkok's urban framework.

Many global cities have already integrated microclimate data into their planning: New York City's "Cool Neighborhoods NYC" program, for example, combined satellite thermal imagery with demographic information to pinpoint block-level hotspots, guiding the expansion of reflective roof coatings and targeted tree planting. Likewise, Los Angeles leveraged NASA satellite data to identify neighborhoods suffering from high daytime temperatures and low canopy coverage, allowing officials to concentrate cooling strategies—like "cool pavements" and shade structures—in the most affected areas.

In the future, the city could enhance its targeting programs by employing high-resolution heat data—using satellite imagery or local climate zone models—to pinpoint these "hotspot" districts and concentrate mitigation efforts there, such as urban greening, cool roofs, and misting stations. In the short term, the BMA could undertake a city-wide heat-mapping exercise, if not already in progress, and quickly deploy cost-effective solutions in identified

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hotspots, for example by installing shade canopies at bus stops, scheduling water sprinkling on heat-retaining roads, or painting roofs white. These immediate, localized interventions can help alleviate conditions while a more comprehensive microclimate model is developed. Over time, embedding this data-driven approach into urban planning will ensure new projects in high-risk zones incorporate robust heat-mitigation measures from the outset.

GREEN AND BLUE INFRASTRUCTURE EXPANSION

Bangkok has made meaningful strides in expanding its green and blue infrastructure, with initiatives such as tree planting, park development, and water conservation. The BMA successfully met its ambitious goal of planting one million trees ahead of schedule and is actively introducing small "pocket parks" in underutilized spaces to enhance urban greenery. At the same time, BMA also had plans on exchanging development incentives (e.g., Floor Area Ratio bonuses) for meeting or exceeding green coverage targets. While these efforts contribute positively to the city's livability, there is an opportunity to build on this progress by developing a comprehensive, long-term strategy that integrates green and blue infrastructure on a larger scale. Strengthening plans to preserve canals, create ponds, and incorporate water features could further enhance the city's natural cooling capacity and resilience to extreme heat. Equally important, investing in larger-scale wetlands or "sponge" designs can not only reduce urban heat, but this also bring co-benefits via helping capture rainwater, thereby reducing flood risks and easing pressure on drainage systems. Such expansions in greenery and water features can also create vibrant recreational areas, encouraging greater public use while supporting biodiversity.

Ideally, a decade-spanning strategic plan would set measurable targets for expanding greenery to meet international standards and include additional water features for evaporative cooling, backed by clear funding, agency responsibilities, and maintenance protocols. Many global cities have embraced this approach: for instance, Singapore has integrated "sky-rise greenery" requirements[33] into its urban planning, obliging new developments to include vertical or rooftop greenery proportional to the building's footprint. Meanwhile, Berlin's "Biotope Area Factor" compels property owners to set aside a minimum portion of their sites for green or permeable surfaces,[34] significantly increasing vegetation citywide. Seattle uses a "Green Factor" scoring system that assigns points to different types of green infrastructure—like trees, rain gardens, or green roofs—and requires developers to meet a minimum threshold based on project scale.

In the interim, the BMA could incorporate tree-planting and park development initiatives into broader urban or climate action plans, supported by dedicated budgets, and incentivize private developers to create green spaces or install green roofs through tax breaks or development bonuses. At the same time, "blue" solutions such as restoring ponds in parks, constructing urban wetlands, or establishing rooftop rain gardens should be advanced. Achieving these goals will require sustained, multi-year investments—potentially through public-private partnerships and community stewardship programs—to ensure that these nature-based solutions are both scaled up and maintained over time.

33 Behm et al (2012).
34 Naumann et al (2020).

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BOX 4 LEVERAGING GREEN AND BLUE INFRASTRUCTURE TO COUNTER IMPACT FROM URBAN HEAT IN GUANGZHOU

Green and blue infrastructure encompasses urban strategies such as integrating green spaces, water features, and passive building cooling designs to reduce city temperatures. These methods, inspired by historical practices such as light-colored roofs and airflow-promoting architecture, can lower indoor temperatures by 3–5°C[35] and decrease cooling energy demand by up to 20%[36]. Cities worldwide are adopting these solutions.

For the new China-Singapore Guangzhou Knowledge City is a large new town development on the outskirts of Guangzhou. As a future high-tech district, it provided a "blank slate" to plan for sustainability from the start. The pilot project focused on a 12.6 km^2 area around Jiulong Lake within this development, aiming to create a low-carbon, green, and cool ecological district[37]. Guangzhou's planners used this case to integrate nature-based cooling into urban design at the master-plan level.

Green & Blue Strategies: In Knowledge City, the strategy was to "design in" cooling features across the whole urban layout. Extensive green infrastructure was planned: large parks, tree-lined avenues, and a network of ecological corridors linking green spaces were laid out to break up heat islands. Notably, planners leveraged the existing Jiulong Lake (blue infrastructure) by shaping it and the surrounding parkland as a "green ventilation corridor" – the lake and open space channel cooler breezes into built-up areas. The street grid and building arrangement were optimized for wind flow; for example, major streets align with prevailing winds to serve as breezeways, and building heights step down toward the lake to funnel air movement. New buildings are required to have green roofs or sky gardens and light-colored, reflective materials to reduce heat absorption. In short, nature-based solutions (parks, water, greenery) were woven into the *urban fabric* from the beginning, rather than added later.

35 Shickman, Kurt & Rogers, Martha (2020).
36 Lehmann (2021).
37 Wang et al. (2022).

INTEGRATION OF HEAT RESILIENCE IN PLANNING/ CODES

Bangkok has an opportunity to enhance its urban planning and building regulations to better integrate heat resilience. While previous city plans have primarily focused on broader development goals, there is growing potential to incorporate strategies that preserve open spaces and reduce urban temperatures. Updating building codes to include incentives for heat-mitigating features, such as green infrastructure and reflective materials, can help ensure that future developments balance urban growth with climate adaptation. Introducing rooftop gardens or living walls, for instance, can not only provide shade as relief to urban heat, but also serve as mini habitats for urban wildlife, enriching the local ecosystem. Such efforts can reduce air-conditioning demand in buildings, translating into lower energy bills and carbon emissions.

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Ideally, urban planning regulations and building codes would embed heat resilience from the start—for instance, by mandating a minimum percentage of green cover in new projects, requiring reflective or green roofs for larger buildings, ensuring shaded parking areas, and incorporating building orientation and ventilation standards that reduce heat gain. The preservation of green space would also be enforced through comprehensive land-use policies.

To bridge the gap, the BMA, in partnership with national authorities, could revise building codes to include specific measures against the UHI effect, such as making cool or green roofs standard for new large structures and providing retrofit guidelines for existing buildings. Incentives—like fast-track permitting or tax benefits—could encourage developers to adopt additional greenery and reflective materials. Over the long term, stronger enforcement of these requirements, including penalties for noncompliance, will be essential. By systematically integrating heat considerations into building and planning regulations, Bangkok can gradually develop a cooler urban environment.

BOX 5 PARIS: COOLING THE CITY THROUGH BUILDING CODES AND REGULATIONS

Paris's dense infrastructure, historically built with concrete and asphalt, has contributed to a significant UHI effect[38]. Climate change has further intensified this challenge. Parisian residents have experienced multiple heat waves, most notably the deadly 2003 event, which resulted in approximately 1,100 fatalities. These extreme events have driven the city to integrate heat resilience into its building codes and urban planning[39].

In 2015, Paris implemented mandatory green roofs on new commercial buildings, requiring either vegetation or solar panels to mitigate heat and enhance urban cooling[40].

The city's climate-adaptive building standards (RE2020) enforce summer comfort measures, mandating passive cooling techniques such as high-performance insulation, natural ventilation, and reflective materials to minimize reliance on air conditioning[41].

Additionally, the Bioclimatic Urban Plan[42] integrates heat resilience into zoning laws by requiring 50–65% green space in large developments, de-paving 40% of city surfaces by 2050, and protecting 100,000 street trees to expand urban shade. Paris is also transforming public spaces through initiatives like the OASIS Schoolyard program, converting asphalt playgrounds into green, permeable, and shaded areas that act as cooling hubs for communities. These combined strategies reduce urban heat while enhancing sustainability and livability.

38 C40 Cities (2015).
39 Climate-ADAPT European Climate Adaptation Platform (2022).
40 C40 Cities (2015).
41 Lahet et al (2024).
42 City of Paris (2024).

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Photo by Tom Bixler on Unsplash

ENGAGEMENT WITH AT-RISK COMMUNITIES

Bangkok has made progress in addressing extreme heat, but strengthening efforts to protect vulnerable groups—such as the elderly, children, outdoor laborers, and low-income communities—remains a key opportunity. Expanding tailored programs and specialized outreach can enhance the city's Heat Action Plan, ensuring that those without air conditioning or safe cooling options receive targeted support. Priority interventions could include home visits for older residents, school-based heat-safety programs, and mobile cooling units for high-risk areas. In the short term, the BMA can collaborate with community leaders and health agencies to identify at-risk populations and provide them with practical guidance. For outdoor laborers, enforcing heat safety measures—such as mandated rest breaks, shaded workspaces, and adjusted work schedules—can provide immediate relief while laying the groundwork for more comprehensive labor protections.

A major opportunity to improve BMA's heat resilience strategy is to develop a unified, accessible public education on heat risks. The BMA can bridge this by streamlining messaging across billboards, social media, district outreach, and radio or television spots in multiple languages. Cities like New York[43] and Ahmedabad have successfully implemented public heat-awareness campaigns, using multilingual outreach and community volunteers to educate residents on simple but life-saving strategies. Bangkok could adopt similar initiatives, ensuring that safety tips, cooling resources, and policy updates reach underserved communities through trusted local networks.

A community-centered approach is essential to building long-term resilience. Partnering with local NGOs and volunteers can help ensure that vulnerable individuals, especially older or isolated residents, receive timely assistance during heatwaves. Inspired by Chicago's "buddy system,"[44] Bangkok could encourage neighborhood-based safety checks while promoting

43 See an example leaflets in English and Spanish.
44 City of Chicago (n.d.).

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citywide participation, from employers rearranging work shifts to individuals volunteering at cooling centers. Public engagement strategies—such as a dedicated social media hashtag or an annual "Heat Awareness Week"—could further reinforce awareness and preparedness.

EARLY WARNING COVERAGE AND ACCESSIBILITY

Bangkok's early warning system for heat effectively utilizes smartphone apps and online messaging to reach many residents. Beyond simply issuing heat notifications, diversifying these alerts can yield other benefits as well: for instance, a robust multi-channel network could be used to share information about flooding, pollution spikes, or public health advisories, thereby strengthening the city's overall crisis readiness. Building wider channels of communication also encourages community engagement, as residents who receive updates through local radio or loudspeaker systems may become more invested in neighborhood safety efforts. In the process, Bangkok can bridge linguistic or technological divides, further enhancing social cohesion across neighborhoods.

The key objective of a heat early warning system is to save lives. France introduced a Heat Health Watch Warning System following a heatwave that caused 15,000 deaths across the country[45]. Three years later, mortality during an equally severe heatwave was 84 percent lower than expected based on past heat-mortality relationships – reflecting success at warning vulnerable residents and prompting them to stay safe during heat extremes. In Ahmedabad, India, introducing a 'traffic light' system of yellow, orange and red heart alerts helped save an estimated 1,100 lives per year in the years immediately following its introduction (Box 6)[46]. Following these precedents, the BMA could further refine the alert system with the strategic goal of preventing avoidable deaths during hot season. Key principles for an effective warning system are to communicate effectively to the public, promote simple behavior change such as drinking water and avoiding heat exposure, prioritize vulnerable population groups such as elderly people and workers in heat-exposed occupations, and convey health messages developed by medical professionals.Expanding accessibility through additional channels, such as broad emergency alerts, could ensure even greater inclusivity, reaching those without smartphones or reliable internet access. Ideally, coverage should reach everyone through methods such as SMS cell broadcasts, public loudspeakers, community radio, and television announcements in multiple languages. In the short term, the BMA can enhance its alert infrastructure by integrating multiple channels—such as the SMS-based system already used for air quality—so that timely warnings also reach individuals without smartphones. To enhance reach, the BMA can partner with telecom providers to implement a multi-channel system—such as cell broadcast SMS for all mobile phones, community radio broadcasts, and public loudspeakers in informal neighbourhoods. Engaging communities in preventing death and illness during heatwaves can yield important benefits. In Ahmedabad, for instance, text alerts are coupled with radio announcements and on-the-ground community volunteers who pass along warnings in slum areas. Local networks including neighborhood leaders and health volunteers help disseminate heat alerts and practical safety advice directly to vulnerable households, especially in informal settlements and among older residents who may not use digital media.

45 Pascal et al (2006).
46 Hess et al (2018).

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To further develop the early warning system, two key priorities are to refine the targeting of alerts and measure their effectiveness. The BMA could partner with public health researchers to develop a model to predict heat-related excess deaths. Such a model could provide a valuable basis to inform the alerting system and to trigger other protective actions at times when serious health impacts are impending. Secondly, an annual monitoring cycle for the early warning system and Heat Action Plan could be formalized. Senior officials could chair a pre-seasonal preparedness planning meeting and chair a post-season review. A heat-health monitoring system can be established – with local partners such as university researchers – to provide data for this cycle. The post-season reviews could monitor key indicators such as the estimated number of heat-related deaths and illnesses by district and demographic group; evaluate the performance of actions such as alert issuance and cooling center provision towards strategic goals; and refine preparedness and response plans for the following year. By building an annual cycle of monitoring and improvement, heat-related death and illness can progressively be reduced.

BOX 6 SAVINGS LIVES THROUGH EARLY WARNINGS AND HEAT ACTION PLANNING – AHMEDABAD'S EXPERIENCE

In Ahmedabad, one of India's hottest cities, a severe heatwave in 2010 provided a wake-up call for city leaders. Researchers at the city's public health university reviewed daily death counts during the heatwave and found that all-cause mortality – in other words, the number of deaths per day across the city from any cause – spiked to three times its usual level at the peak of the heatwave. City leaders proceeded to implement South Asia's first Heat Action Plan.

The Ahmedabad Heat Action Plan combines long-term investments to make city spaces cooler with short-term measures to warn and protect residents during heat emergencies. The thresholds for warning issuance were designed based on the correlation of daily deaths from all causes with air temperature on the same day. Citizens received yellow, orange and red alerts when temperatures exceed 41°C, 43°C and 45°C respectively.

On days when warnings are issued, an inter-agency emergency management plan is put into operation, with each participating stakeholder having an assigned role to play on yellow, orange or red alert days. In the health sector, alerts are linked to practical actions such as activating heatstroke treatment stations in hospitals and equipping ambulances with ice packs. Safety-at-work protocols for heat-exposed workers are also activated. Drinking water is distributed and public gardens stay open later to provide residents with a space to cool down.

The Heat Action Plan, with the traffic-light alert system at its core, has been credited with helping to avoid around 1,100 deaths per year in the years immediately following its introduction[47].

47 Hess et al (2018).

COOLING CENTERS AND HYDRATION POINTS

Bangkok is taking important steps to expand public cooling spaces, recognizing the urgent need for heat relief in a rapidly warming city. The Sabuy Square solar-powered, air-conditioned bus stop serves as a promising pilot project, demonstrating the potential for sustainable cooling solutions. Additionally, the BMA is prioritizing hydration accessibility by installing drinking fountains across the city, ensuring residents have access to clean, refreshing water during extreme heat. Besides reducing the risk of heat-related illness, cooling centers can double as community hubs where residents gather, share information, and foster stronger neighborhood bonds. Public hydration stations help cut down on disposable plastic usage, promoting a cleaner environment while ensuring everyone has reliable access to safe drinking water. While these efforts mark progress, a broader strategy is necessary to provide widespread, equitable relief, especially for vulnerable populations.

One effective approach is repurposing existing air-conditioned facilities, such as schools, community centers, libraries, and malls, into designated cooling centers during heatwaves. Many global cities have adopted similar strategies: Chicago extends library and park district building hours, Toronto uses a mobile app to help residents locate cooling centers, and Phoenix employs multilingual flyers to reach low-income and immigrant communities (see Box 7”—S” for more information). Bangkok can build on these models by collaborating with district offices to ensure an even distribution of cooling centers in high-risk areas, implementing clear signage, and extending operational hours to accommodate those most affected by extreme heat. Making these centers highly visible and accessible—particularly to those without private transportation—will maximize their impact.

To further enhance accessibility, the BMA can develop a public mapping tool or mobile app to help residents quickly locate nearby cooling centers and drinking fountains. Promoting this information through multilingual outreach efforts and engaging local community leaders will ensure widespread awareness. In the long term, while BMA already mentions cooling centers into its disaster response protocols, treating them as essential infrastructure with prioritized resource allocation during the city’s increasingly frequent heatwaves could enhance its effectiveness in the future events of heatwaves.

BOX 7 TRANSFORMING PUBLIC FACILITIES INTO COOLING CENTERS: STRATEGIES AND SUCCESS FACTORS

Implementing cooling centres by repurposing existing public facilities has proven effective in mitigating the adverse effects of extreme heat in urban areas. Several cities have transformed schools, libraries, and community centres into accessible cooling centres, providing residents with safe havens during heatwaves.

For instance, Baltimore opens community and senior centres throughout the city during extreme heat events, offering transportation for seniors to ensure they can access these facilities. Similarly, Maricopa County, which also includes Phoenix city in Arizona, has established a comprehensive system with over fifty cooling centres serving a population of nearly 5.5 million. These centres are strategically located to provide refuge from the heat for residents without adequate cooling at home.[48]

Key success factors in these initiatives include strategic location selection, ensuring that cooling centres are situated in areas with high social vulnerability and limited access to air conditioning. Equitable placement ensures that vulnerable populations, such as low-income households and the elderly, can easily reach these centres.[49] Additionally, clear communication about the availability and location of cooling centres is crucial. Cities have utilized various channels, including local news outlets and dedicated hotlines, to disseminate this information effectively.

Another critical aspect is community engagement. Partnering with local organizations and leaders helps in tailoring services to meet the specific needs of the community. For example, involving community members in the planning and operation of cooling centres can enhance trust and encourage greater utilization of these facilities. Moreover, providing amenities such as drinking water, comfortable seating, and entertainment can make cooling centres more inviting, thereby increasing attendance.

Operational considerations, such as extending hours during peak heat periods and ensuring accessibility for individuals with disabilities, are also vital. Training staff to recognize signs of heat-related illnesses and respond appropriately can further enhance the effectiveness of cooling centres. By focusing on these key factors—strategic placement, effective communication, community involvement, and thoughtful operations—cities can successfully implement cooling centres that safeguard public health during extreme heat events.

48 Bedi et al (2022).
49 Adams et al (2023).

INSTITUTIONS

Photo by Uwe Schwarzbach on Flickr

COORDINATION ACROSS DEPARTMENTS

Bangkok's heat management efforts have the potential to be significantly strengthened through improved coordination among various BMA departments, including environment, health, and city planning (Box 8). By enhancing collaboration, the city can ensure that initiatives are more aligned and mutually reinforcing. For instance, integrating urban design approvals with heat mitigation strategies would create a more cohesive approach, allowing efforts such as promoting heat awareness and sustainable urban planning to work in synergy for a greater overall impact.

A well-coordinated governance structure—perhaps led by a cross-departmental task force or a "Chief Heat Officer"—would unify agencies such as urban planning, parks, public works, health, and disaster management under a single Urban Heat Management Framework. This approach would ensure that interventions ranging from tree planting to issuing heat alerts work in tandem. In the short term, BMA could establish a formal mechanism, such as a monthly inter-departmental meeting on extreme heat, led by a senior official, to streamline roles and address overlaps. Even modest improvements—like sharing hospital heat-illness data with urban planners or providing heat hotspot maps to utilities and parks departments—would help synchronize efforts. Such coordination, while primarily administrative, can be quickly initiated by mayoral directive and would significantly enhance Bangkok's ability to implement effective heat policies.

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BOX 8 STAKEHOLDERS FOR ADDRESSING URBAN HEAT MANAGEMENT

Initiatives	Current BMA Agencies	National Agencies for Collaboration and Support
Identify and Targeting for Heat "Hotspot"	City Planning Department Environment Department	Department of Town and Country Planning, Ministry of Interior Department of Climate Change and Environment, Ministry of Natural Resources and Environment
Green and Blue Infrastructure Expansion	City Planning Department Environment Department Sewerage and Drainage Department	Department of Town and Country Planning, Ministry of Interior Department of Treasury, Ministry of Finance SRTA and MRTA, Ministry of Transport
Integration of Heat Resilience in Planning/Codes	City Planning Department Public Works Department Environment Department	Department of Town and Country Planning, Ministry of Interior
Engagement with At-Risk Communities	Health Department Medical Service Department	Department of Health Service, Ministry of Public Health Ministry of Social Development and Human Security
Early Warning Coverage and Accessibility	Health Department Medical Service Department Environment Department	Thai Meteorological Department Department of Health Service, Ministry of Public Health Ministry of Social Development and Human Security
Cooling Centers and Hydration Points	City Planning Department Environment Department Public Works Department	Department of Health Service, Ministry of Public Health Ministry of Social Development and Human Security

REGULATIONS AND POLICIES

Bangkok's heat adaptation efforts have significant opportunities for enhancement through stronger regulatory frameworks. One key area for improvement is the development of city ordinances that ensure outdoor workers have access to breaks, shade, and hydration during extreme heat, helping to safeguard their well-being. Additionally, empowering BMA departments with greater legal authority would enable them to move beyond recommendations and actively implement measures such as building efficiency improvements and expanded urban greenery. By establishing comprehensive legal frameworks—both at the city and national levels—Bangkok can strengthen worker protections, enhance enforcement of

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building and zoning codes, and provide BMA agencies with the necessary mandate to advance heat resilience initiatives effectively.

In the short term, BMA can issue voluntary guidelines or emergency directives, such as advising adjusted work hours during heatwaves, and collaborate with the Labor Ministry to encourage employers to adopt safer practices. Existing legal provisions, like those under public health or disaster risk laws, can also be used to enforce heat precautions where feasible. Over the longer term, policy reforms—both at city and national levels—are needed. By advocating for updated labor laws that include heat protections, and enhancing local ordinances (for instance, requiring large new developments to include heat mitigation plans), Bangkok can gradually build a stronger regulatory framework and reduce the institutional barriers currently impeding heat resilience.

SUSTAINED GOVERNANCE AND FUNDING MECHANISMS

Bangkok has made significant progress in addressing urban heat through initiatives like tree planting and cool-roof pilot projects. While these efforts have primarily relied on external grants and intermittent funding, they have successfully raised awareness and catalyzed action. To ensure long-term sustainability, Bangkok must institutionalize heat resilience by integrating it into the city's development plans, annual budgets, and governance structures. This could include appointing a dedicated heat adaptation unit, securing multi-year funding from public and private sources, and embedding extreme heat mitigation into broader urban resilience strategies. By taking these steps, Bangkok can shift from short-term projects to a sustained, city-wide commitment.

A crucial part of this strategy is establishing a formal heat resilience fund that pools resources from municipal budgets, private donors, and international grants. Many cities have adopted similar models; for example, Los Angeles' "Cool LA" initiative combines municipal funding with private-sector contributions to finance shade tree programs and reflective road coatings. Bangkok can follow suit by creating a transparent funding mechanism that prioritizes high-impact projects, such as public cooling infrastructure and neighborhood greening, particularly in low-income communities most vulnerable to extreme heat. Ensuring consistent financing will prevent reliance on sporadic grants and help maintain efforts even amid shifts in political leadership or public attention.

At the same time, a long-term intervention plan would benefit greatly from a systemic, periodic evaluation of all heat-related policies. Regular monitoring of heat-related policies and projects are essential for understanding their effectiveness and optimizing resource allocation. By conducting annual or biennial evaluations, the BMA can review vital metrics such as EWS performance, cooling centre utilization, tree survival rates, and adherence to updated building codes. These audits should be made public to build trust, enhance transparency, and disseminate successful strategies that merit replication. This can be in a form of publishing an Annual Heat Resilience Report. By following this cycle of evaluation and feedback, city departments can reallocate resources toward the most impactful measures, ensuring that interventions remain both relevant and cost-effective.

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To sustain long-term impact, Bangkok must also focus on tracking and demonstrating measurable results. Implementing a structured evaluation framework—such as monitoring fund utilization rates, completed neighborhood projects, reductions in street-level temperatures, and reduction in heat-related mortality—can reinforce confidence among stakeholders and justify continued investment. Clear, data-backed evidence of success will strengthen political will, attract further funding, and embed heat resilience as a core pillar of urban planning. By adopting a structured, well-financed, and results-driven approach, Bangkok can build a long-lasting urban heat management strategy that ensures protection for all residents, especially the most vulnerable, for decades to come.

BOX 9 LEGISLATION, GOVERNANCE AND PARTNERSHIPS FOR A COOLER SINGAPORE

Since independence in 1965, Singapore urban cooling initiatives have demonstrated the value that cross-agency governance arrangements coupled with strategic use of partnerships and legislation can offer when it comes to beating the heat.

Tree planting to increase green cover has been a key strategy to control urban temperatures. The government first launched a tree planting campaign in 1963, and this was incorporated into the “Garden City” vision launched by Prime Minister Lee Kuan Yew in 1967. More recently, the National Parks Board has since 2015 extended the Garden City vision to plant climbers and shrubs on bus shelter roofs, covered walkways, railway stations and noise barriers.

Covered walkways have been a key feature since at least the Town Plan of 1822. Today, the Urban Redevelopment Authority mandates that all commercial and mixed developments “shall provide covered walkways along the periphery of the building facing roads and pedestrian routes,” with design specifications around roof height and minimum width.

In 2017, the government launched ‘Cooling Singapore’, a major research program that leveraged the skills of university researchers to inform actions for improved thermal comfort. The project team tested and simulated alternative building designs, conducted surveys of residents’ experiences and preferences, and developed a “digital twin” model to inform planning decisions based on thermal comfort considerations.

In 2019, an interagency working group led by the Ministry of Sustainability and the Environment (MSE) and the URA was launched to implement initiatives to mitigate UHI effects in Singapore. It identified key strategies including expanding the network of climate sensors in the country to collect data; assessing mitigation strategies using collected data and simulations; partnering with industry and the public to implement heat mitigation actions including application of cool paint on building facades and expansion of district cooling networks. The coordinated efforts, rooted in legislation and cross-sectoral partnerships, were instrumental at advancing urban cooling in Singapore.

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ANNEX

ANNEX 1. ESTIMATING URBAN HEAT ISLAND INTENSITY

UHI MODELLING APPROACH

The impact of urban heat in the BMA was investigated using WRF, version 4.2, a mesoscale climate model coupled with a multi-layer canopy model Building Effect Parametrization (BEP) (Martilli, 2002) and a Building Energy model (BEM) (Salamanca et al., 2010). Natural ventilation, the transmission of heat through walls, roofs and floors, the radiation exchanged between indoor surfaces, the generation of heat due to occupants and equipment, and energy consumption due to AC systems are considered by using the BEM embedded in WRF climate model.

The numerical climate models rely heavily on the surface energy budget. In this sense, the dynamic and thermal interaction in urban canopy environment is represented by the NOAH land surface model (LSM) coupled to WRF model (Wang et al., 2018). The heat surface fluxes from pervious areas (natural areas) are provided by NOAH LSM while those from the impervious regions (urban areas) are provided by improved WRF and BEP/BEM model coupling. Thanks to this modelling framework the calculation of surface heat fluxes (sensible heat flux and latent heat flux) is improved, and the near-surface air temperature estimation is expected to be more accurate.

CLIMATE SIMULATION SETUP

To understand the impact of urbanization in the urban heat, the three climate seasons (see previous section) in Bangkok were considered: the cool and dry season, the hot and dry season and the wet season. In each season, the urban climate was simulated for one month, December 2019, March 2020 and July 2020 respectively. The year of simulations were selected based on a neutral intensity of the El Nino Southern Oscillation (ENSO) phenomenon. The WRF model grid configuration included three nested domains from D1 to D3, as shown in Figure 19 with grid size of 112x112, 112x112 and 235x350 and a spatial resolution of 3km, 1km, and ~0.3 km, respectively.

The LCZ land use scheme for Bangkok was downloaded from the World Urban Database and Access Port Tools (WUDAPT) platform (Bechtel et al, 2019) and used in the current study (Figure 20).

FIGURE 19 WRF GRID CONFIGURATION FOR EACH SIMULATION

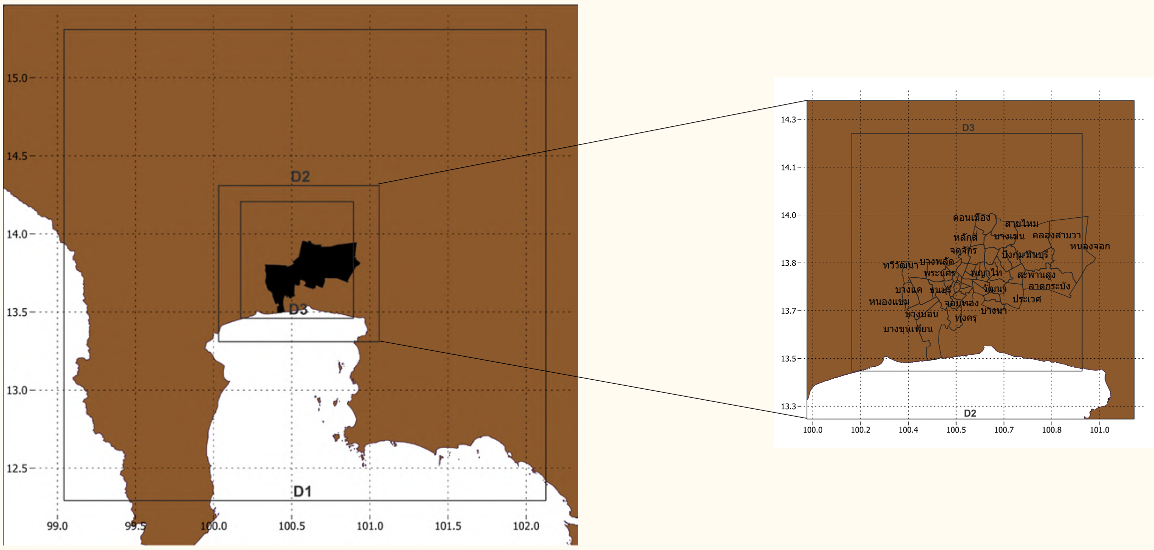
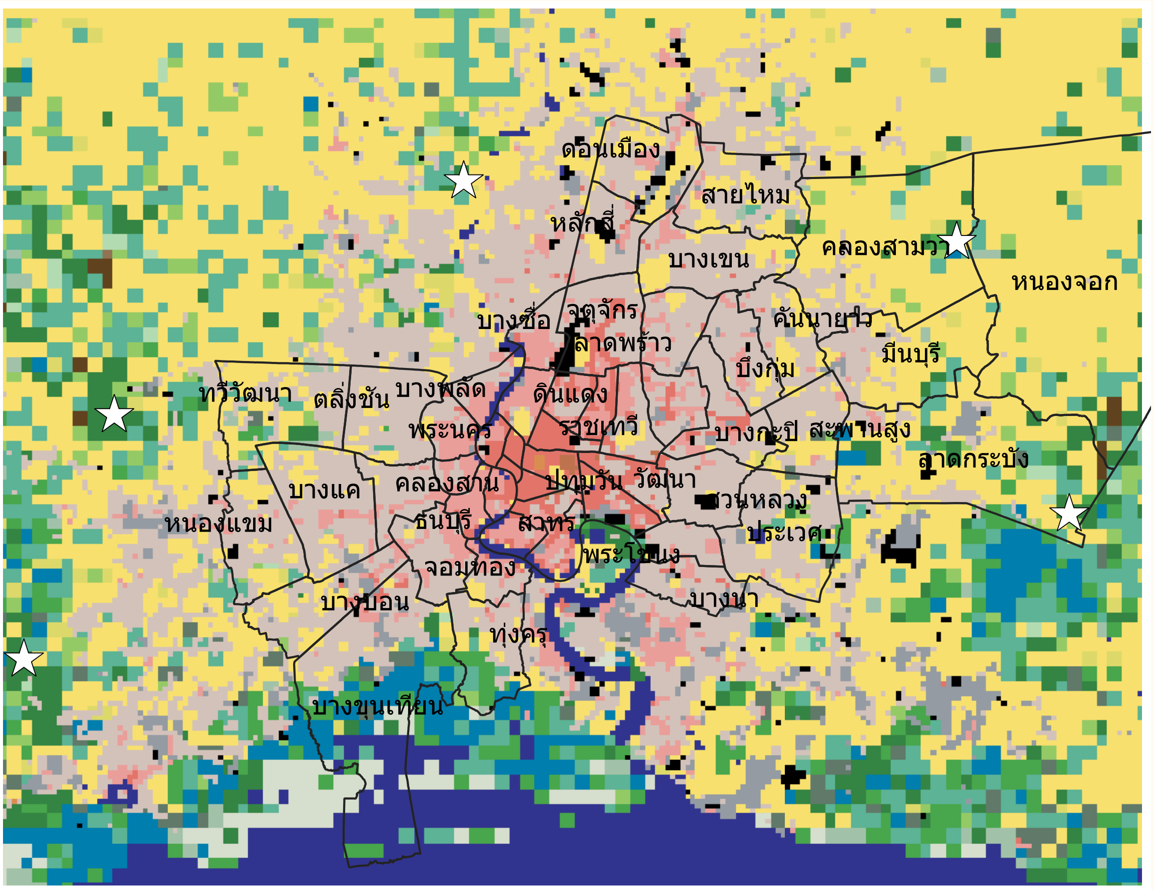


FIGURE 20 BANGKOK LAND USE/LAND COVER MAP INCLUDED IN THE WRF SIMULATIONS



LOCAL CLIMATE ZONES (LCZ)

- Evergreen Needleleaf Forest
- Evergreen Broadleaf Forest
- Deciduous Broadleaf Forest
- Mixed Forests
- Closed Shrublands
- Open Shrublands
- Woody Savannas
- Savannas
- Grasslands
- Permanent wetlands
- Croplands
- Cropland/Natural Vegetation Mosaic
- Barren or Sparsely Vegetated
- Water
- Compact high-rise
- Compact mid-rise
- Compact low-rise
- Open high-rise
- Open mid-rise
- Open low-rise
- Large low-rise
- Heavy Industry
- ☆ Rural Location

Source: WUDAPT (2019).

Note: The five star marks in the map indicate the location of rural reference points.

DESIGN OF THE EXPERIMENTS

The impact of the urban heat in BMA has been evaluated at 2 meters above the surface level, to consider the height where human thermal comfort is evaluated.

The outputs of the model were extracted at 5 reference/rural locations and were used as rural locations. These sites were selected in evergreen broadleaf forest areas. The UHI intensity, defined as the temperature difference between urban and rural areas, was evaluated by subtracting the reference locations to the outputs of the model:

$$UHII = T_{a_{simul}} - T_{a_{ref}}$$

Where Ta_{simul} are the outputs of the model at each grid point and Ta_{ref} are the rural locations. The spatial and temporal UHI intensity is analysed in 3 different months, each representative of a climatic season in Bangkok. Levels of UHI intensity are evaluated in the whole Bangkok Metropolitan Area and specifically for different land use categories. Similarly, the alteration of the regional climatic values (daily maximum temperature, Tmax, and daily minimum temperature, Tmin) are also presented.

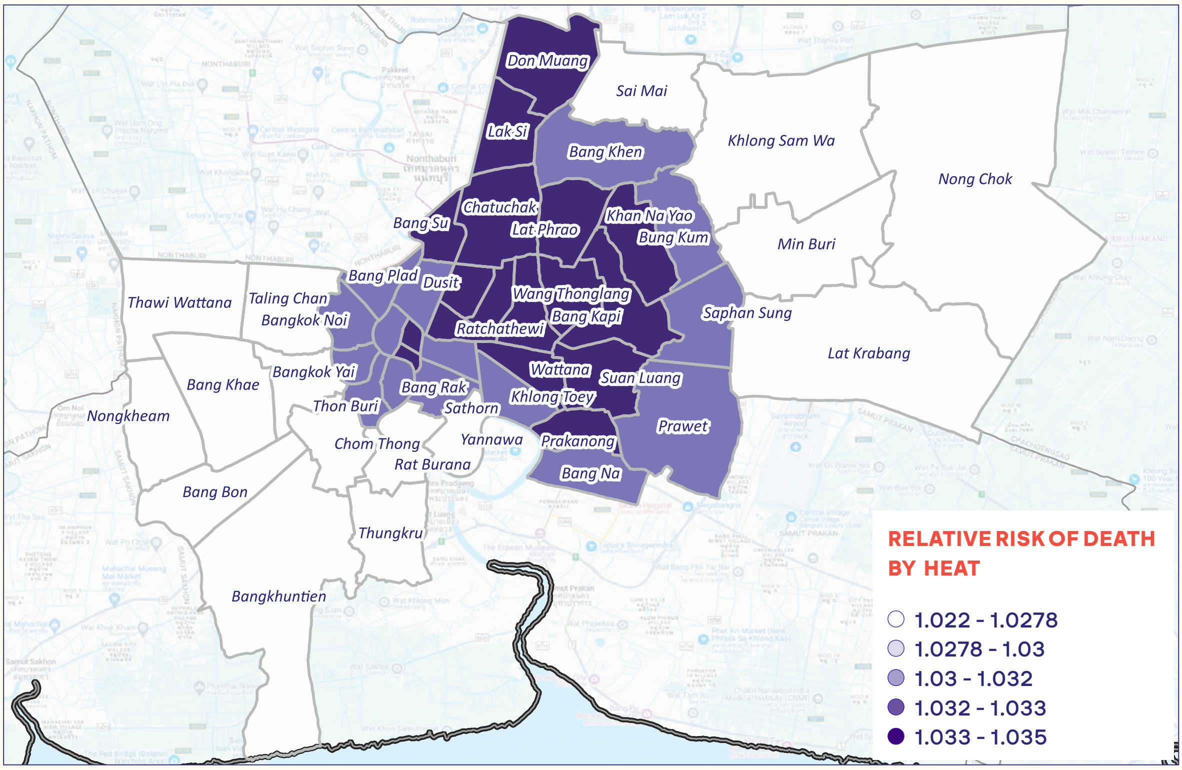
ANNEX 2. ESTIMATING EXCESS MORTALITY DUE TO HEAT

For practical reasons, estimation of excess mortality due to heat in this study borrows on parameters found in existing studies, particularly on the relative risk and value of statistical life. The methodology for estimating excess mortality due to heat in Bangkok uses a two-step approach:

STEP 1: CALCULATING THE NUMBER OF DEATHS DUE TO TEMPERATURES BEYOND MINIMUM MORTALITY TEMPERATURE

In the first step, the analysis estimates the number of deaths linked to temperatures above a minimum mortality baseline, including UHI (Figure 21). This involves applying epidemiological models that quantify how mortality rates rise in response to higher temperatures. Since each district in Bangkok experiences varying levels of heat exposure, the relative risk of heat-related mortality also differs by district. Accordingly, the study assigns a relative risk value for each district based on its local temperature data, using parameters drawn from Denpetkul and Phosri (2021). This value of relative risk equals to 1 when the district experiences at the minimum mortality temperature of 27.7°C and increases non-linearly above that.

FIGURE 21 DISTRICT-LEVEL RELATIVE RISK OF DEATH DUE TO HIGHER-THAN-OPTIMAL TEMPERATURE, 2019



World Bank elaboration based on Denpetkul and Phosri (2021).

Specifically, the number of excess deaths for each district is estimated by following formula:

$$Excess\ deaths_i = \frac{RR_i - 1}{RR_i} \times Pop_i \times DR$$

Where RR_i denotes the relative risk of death of district *i* given its level of temperature, Pop_i denotes population count at district *i*, and *DR* is the national all-cause mortality rate, which we assume to be equal across all districts.[50] This formula implies that when a district temperature equals to the minimum mortality temperature, no excess deaths due to heat risk is present.

Once the excess deaths at current temperatures are determined, the next step involves simulating a scenario where each district's temperature increases by 1°C. In this higher-temperature scenario, each district's relative risk of heat-related mortality rises accordingly. The additional deaths attributable to the 1°C increase are then calculated by comparing the new total (under the higher temperature) with the original excess deaths at the current temperature. Finally, excess heat for the entire metro for the year 2019 is calculated as the sum of monthly excess mortality across 50 districts. For the districts with the mean monthly temperature below the minimum mortality temperature, this study assumes that the relative risk equals one, meaning no excess death attributed to excess heat.

STEP 2: TRANSLATE NUMBER OF DEATHS INTO MONETARY TERMS

The second part of the methodology involves translating the number of differences in excess deaths into monetary terms using the VSL methodology. The VSL estimates the economic value that society places on reducing the risk of death, and it is often used in cost-benefit analyses for public policy. In this case, it converts the number of excess deaths into an economic cost. For this study, the VSL parameter is borrowed from study done by Witvorapong & Komonpaisarn (2020). This study uses hedonic wage approach on estimating VSL, which analyses how wages vary with job-related fatality risks, allowing for an implicit valuation of life by workers. This VSL is first converted to 2011-THB using the 2011 USD to THB exchange rate. To account for inflation, the ratio of the Thailand consumer price index (CPI) in 2019 compared to that in 2011 is applied:

$$VSL_{2019\text{-}THB} = VSL_{2011\text{-}USD} \times \frac{2019THB}{2011USD} \times \frac{CPI_{2019\text{-}THB}}{CPI_{2011\text{-}THB}}$$

This results with VSL is between 0.66 to 1.21 million 2011 USD. Multiplying this with difference in excess deaths will provide rough estimate on social cost due to mortality for each 1°C increase in temperature.

50 In this estimate, we use Thailand's 2019 crude all-cause mortality rate, which is at 7 deaths per 1000 inhabitants. Source: UN World Population Prospects, 2022 revision. Link to data in World Bank Databank.

CAVEATS AND LIMITATIONS

This study makes several key assumptions due to data limitations. Since data for temperatures above 36.6°C were unavailable, the relative risks at higher temperatures are assumed to be the same as those at 36.6°C. The latest district-level mortality data available at the time of analysis was from 2018, so the study assumes that the number of deaths remained unchanged in 2019. When calculating monthly crude death rates, it is also assumed that annual deaths were evenly distributed across all 12 months of 2019. Additionally, based on findings from Denpetkul and Phosri (2021), which indicate that the impact of high temperatures on mortality peaks within a 0–7 day lag before declining, this study adopts relative risk estimates based on a 7-day lag rather than longer periods.

The VSL approach can be highly sensitive to the specific monetary value assigned, which varies based on factors like a country's economic context, average income levels, and the demographic composition of its population. By using a singular estimate, the methodology may inadvertently obscure differences between younger and older individuals, or between those in poor health versus those who are fit, as it treats every life as having the same economic worth. Moreover, national or regional disparities in living standards can further complicate the direct application of one VSL figure across different communities within the same city, leading to a skewed understanding of the broader societal cost of heat-related deaths.

An additional limitation lies in the VSL approach's sole focus on mortality, overlooking the myriad non-lethal effects of extreme heat. These include both short-term and chronic health impacts—ranging from heat exhaustion and respiratory ailments to cardiovascular strain—as well as reduced quality of life for those who must endure prolonged heat indoors or out. Similarly, it leaves out long-term economic repercussions such as decreased workforce productivity, infrastructure damage, or increased healthcare expenditures for heat-related illnesses. By concentrating exclusively on lives lost, the VSL method may underestimate the full extent of harm caused by escalating temperatures in urban environments.

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ANNEX 3. ESTIMATING PRODUCTIVITY LOSS DUE TO HEAT VIA LABOR SURVEY DATA

Given that the TLFS does not provide district-level identifiers, the analysis is conducted at the Bangkok Metropolitan Area level as a whole. This approach helps quantify the productivity losses due to heat, focusing on how different sectors and occupations are impacted by rising temperatures, particularly in an urban environment like Bangkok where the urban heat island effect intensifies heat exposure for many workers. This is done by 4 steps:

STEP 1: MEASURING PRODUCTIVITY

The first step in assessing the impact of urban heat on worker productivity involves obtaining wage data from the TLFS. For this analysis, hourly wage data (or an equivalent of[51]) is extracted from three specific periods: Q4 2019, Q1 2020, and Q2 2020. These periods represent distinct seasons, allowing us to observe potential fluctuations in wages and productivity as they relate to varying seasonal temperatures. Hourly wages serve as a proxy for labor productivity, where a decrease in wages may reflect lower productivity due to external factors like heat exposure. The TLFS provides a comprehensive dataset on worker demographics and earnings, making it a reliable source for analyzing productivity trends in the Bangkok Metropolitan Area.

STEP 2: ASSIGN HEAT EXPOSURE

In this step, each worker in Bangkok is assigned a heat exposure score based on their occupation. This heat score is derived from occupational data found in the O*NET database, which provides detailed information on the work environment and conditions specific to each job category. Workers in outdoor and physically demanding jobs, such as construction or transportation, are assigned higher heat exposure scores, while those in indoor or air-conditioned environments, like office workers, receive lower scores. This heat exposure score is used as a mediating variable in the subsequent analysis to determine how workers' exposure to high temperatures affects their productivity. The score ranges from 0 to 1, with 0 represents no exposure at all and 1 as full exposure.

STEP 3: ASSIGN TEMPERATURE VARIATION

Next, the average temperature for each of the three seasons—cool, hot, and wet—is assigned to the TLFS wage data for Q4 2019, Q1 2020, and Q2 2020. This allows us to link wage data with the specific temperature conditions workers experienced during each survey period. By assigning seasonal temperature variations to each wave of TLFS data, we can explore the extent to which changes in temperature correlate with changes in productivity. This step is crucial for identifying the direct impact of urban heat on labor productivity, as it establishes

51 As different type of employment are paid in different scheme, this study calculate hourly wage as total monthly income divided by total working hours. For full time workers, working hours are assumed to 40 hours per week, or 160 hours per months. Other type of workers have their actual working hours reported in the TFLS.

the relationship between the environmental temperature and worker performance.

STEP 4: ESTIMATION

In the final step, a statistical model is developed to estimate the relationship between temperature and productivity, using the heat exposure score as a mediating variable. This involves running regression analyses that examine how variations in temperature affect hourly wages, controlling for worker characteristics such as occupation, education level, and age. The data from three survey waves are treated as pooled cross-section data. Specifically, the link between temperature and productivity is estimated using a regression approach with the following specification:

$$hwage_{it} = \beta_0 + \alpha T_t + \beta X_{it} + \gamma HS_{it} + \delta X_{it} HS_{ii} + \zeta X_{it} T_{it} + \eta HS_i T_{it} + \theta X_{it} HS_i T_{it} + \varepsilon$$

Where $hwage_{it}$ represents the hourly wage of worker i in TLFS quarter t, T_t is temperature in quarter t, X_{it} is vector of worker i's characteristics in quarter t, and HS_{it} represent heat score of worker i in quarter t. The interaction between these three terms ensure that the estimated impact is obtained after controlling for observable worker characteristics such as age, gender, occupation, sector and education level. The result from this regression is then used to 1) predict the level of wage under the current temperature for each worker, and 2) predict the level of wage conditional to temperature being reduced by 1°C. The differences between (1) and (2) would reflect the productivity loss experienced by each worker for each of 1°C temperature increase.

CAVEATS AND LIMITATIONS

A key limitation is that the analysis draws on only three distinct waves of temperature and UHI data, each tied to a single season, without capturing potential year-round or multi-year trends. This constraint means the model may confound heat impacts with unrelated seasonal factors—for instance, shifts in consumer demand or tourist arrivals that also influence incomes. Additionally, wages might not respond fully or immediately to changing weather conditions, since nominal wages can be sticky. Many workers in Bangkok have predetermined monthly or daily pay, limiting the extent to which their earnings visibly change with short-term temperature spikes or drops.

Another significant caveat is that about 30 percent of the workforce—self-employed individuals and employers—remains outside the scope of the TLFS wage dataset, likely causing the current methodology to underestimate the full impact of urban heat on productivity. Even among covered workers, those receiving piece-rate or per-service payments may experience earnings fluctuations that don't fully reflect day-by-day temperature variations. Finally, the analysis takes a correlational approach, linking wages to observed temperatures without fully accounting for individual coping strategies. Each of these limitations indicates that the findings, while informative, represent a conservative baseline rather than a comprehensive measure of Bangkok's heat-induced productivity losses.

ANNEX 4. ESTIMATING THE RELATIONSHIP BETWEEN TEMPERATURE AND ENERGY USE IN BANGKOK'S CONTEXT

The analysis aims to investigate the relationship between electricity consumption per capita and temperature across Bangkok's districts. However, the economic development of each district may influence the degree to which this relationship manifests. Wealthier districts with more advanced infrastructure and higher income per capita may exhibit different patterns of electricity usage compared to less developed areas. Therefore, in establishing this relationship, it is important to control for economic variables like GDP and GDP per capita to ensure that the findings reflect the impact of temperature on electricity consumption, independent of the district's economic level. The estimation of relationship between temperature and energy use, in the context of Bangkok, follows the three following steps:

STEP 1: OBTAIN ELECTRICITY CONSUMPTION DATA

The first step involves gathering data on electricity consumption in Bangkok. Electricity consumption data is available from the Energy Policy and Planning Office (EPPO) and the Metropolitan Electricity Authority (MEA), but it is only provided as aggregate annual consumption figures for the entire city. This presents a challenge because to understand how urban heat affects energy use, we need a more granular dataset that breaks down electricity consumption by district within Bangkok. Therefore, further steps are needed to redistribute the total city-wide electricity consumption across its various districts.

STEP 2: REDISTRIBUTE ELECTRICITY CONSUMPTION BY DISTRICT VIA SATELLITE NIGHTTIME LIGHTS

Since district-level electricity consumption data is not directly available, the analysis uses satellite data to estimate it. Specifically, nighttime lights data from the Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB) is used as a proxy for electricity usage at the district level. Nighttime lights provide an indication of urban activity, and areas with brighter nighttime lights are assumed to consume more electricity. The total electricity consumption for Bangkok, as reported by EPPO and MEA[52], is then redistributed to individual districts based on their share of nighttime lights intensity. This method allows for the creation of an estimated dataset of electricity consumption for each district, which can be used in the subsequent analysis. The temperature data used in this analysis was based on Zhang and Zhou's (2022) method, which calculates average temperature for each district over the same period (2013-2019). Figure X shows the distribution of the variable of interests by district in year 2019.

52 https://www.eppo.go.th/index.php/en/en-energystatistics/electricity-statistic

STEP 3: CALCULATE STATISTICAL RELATIONSHIP, CONDITIONAL ON GDP PER CAPITA

Once electricity consumption has been estimated for each district, the next step involves conducting an econometric analysis to explore the relationship between temperature and electricity usage. This analysis is performed using data from 2013 to 2019, using the following regression specification:

$$\ln(ECcap_{it}) = \beta_0 + \beta_1 \ln(GDPpc_{it}) + \beta_2 \ln(GDPpc^2_{it}) + \gamma T_{it} + \theta_i + \varepsilon$$

Where ln($ECcap_{it}$) represents log of electricity use (kWh) per capita in district i in year t, ln($GDPpc_{it}$) represents GDP per capita, and T_{it} denotes district i's temperature in year t. Unobservable, time invariant district characteristics are controlled via district-level fixed effects (θ_i). The goal is to assess how changes in temperature affect electricity consumption, while accounting for the influence of economic development.

CAVEATS AND LIMITATIONS

A primary limitation in estimating the relationship between temperature and energy use in Bangkok is that the analysis relies on aggregate-level, spatial data rather than detailed information on individual households or businesses. This means it does not capture specific coping strategies—such as adjusting air-conditioner settings, changing usage schedules, or investing in more efficient cooling devices—which can differ widely across households or firms. As a result, the model's outcomes reflect an overall pattern for the city rather than the nuanced responses of smaller population segments, possibly overlooking significant variability in energy habits.

Furthermore, the econometric approach employed does not establish causality; it simply explores the observed association between temperature and electricity consumption. This lack of causality is particularly relevant given that energy use itself can contribute to higher urban temperatures, such as through waste heat emitted by air conditioners or machinery, raising the possibility of reverse causality. In other words, while higher temperatures can drive up energy usage, that very energy usage can, in turn, compound the heat problem.

SHAPING A COOLER BANGKOK:

Tackling Urban Heat for a More Livable City