MEKONG THOUGHT LEADERSHIP AND THINK TANKS NETWORK PROGRAM - FLAGSHIP RESEARCH STUDY

Urban Heat Resilience: Bridging Science, Policy, and Sustainable Design

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Urban Heat Resilience: Bridging Science, Policy, and Sustainable Design

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Preface

Urban heat is no longer a distant threat but it is a present and escalating crisis, particularly in rapidly growing cities of Southeast Asia. The summer heatwaves of 2023 and 2024 have laid bare the vulnerability of our cities and the urgent need for evidence-based, inclusive strategies to adapt and thrive in an increasingly warming world. Against this backdrop, this flagship report, Urban Heat Resilience: Bridging Science, Policy, and Sustainable Design, presents a timely and rigorous investigation into the drivers, impacts, and solutions to urban heat, with a special focus on Bangkok, Thailand, and second-tier cities in Southern Vietnam.

This research is the outcome of a collaborative effort under the Mekong Thought Leadership and Think Tanks Network Program, supported by the Department of Foreign Affairs and Trade (DFAT), Government of Australia. Drawing on the strengths of a diverse consortium including the Asian Disaster Preparedness Center (ADPC), Alluvium International, BKode, RMIT Vietnam, and the Thailand Environment Institute (TEI), the study blends advanced climate modeling, social vulnerability analysis, and spatial assessment to deliver practical insights for urban resilience planning.

At the heart of the report is a commitment to equitable and sustainable design. Nature-Based Solutions (NBS) emerge not only as effective buffers against heat but also as platforms for community-centered resilience. Recognizing the disproportionate burden of heat on the most vulnerable sections including women, children, the elderly, persons with disabilities, and low-income communities, the project embeds Gender Equality, Disability, and Social Inclusion (GEDSI) principles into its methodology and action plan.

By bridging scientific evidence with actionable policy pathways and design interventions, this report provides a comprehensive roadmap for cities seeking to adapt to a hotter future. While grounded in the context of the Mekong region, its findings and recommendations carry broader relevance for global urban climate resilience.

We hope this report will serve as both a wake-up call and a guidepost for decision-makers, urban planners, researchers, and community advocates working to build livable, inclusive, and heat-resilient cities.

Dr. Senaka Basnayake

Program Lead

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Glossary of terms

Adaptive Capacity: The ability of systems, institutions, humans, and other organisms to adjust to potential damage, take advantage of opportunities, or respond to consequences of climate change, particularly extreme heat events.

Air Temperature: The temperature of the air measured in the shade at a standard height (typically 1.5-2 meters above ground level), used as a baseline metric for assessing urban heat conditions and human thermal comfort.

Blue and Green Urban Infrastructure: Integrated network of natural and semi-natural water features (blue) and vegetation systems (green) designed to manage urban heat, stormwater, and provide ecosystem services while enhancing urban livability.

Building Codes and Materials: Regulatory standards and construction specifications that govern the thermal properties, energy efficiency, and heat mitigation capabilities of urban structures, including requirements for reflective surfaces, insulation, and ventilation systems.

Business-as-Usual (BAU) Scenario: A reference scenario that projects future conditions based on current trends and policies without additional climate mitigation or adaptation measures, used as a baseline for comparing intervention strategies.

Capacity Building: The process of developing and strengthening the skills, instincts, abilities, processes, and resources that organizations and communities need to survive, adapt, and thrive in addressing urban heat challenges.

Climate Adaptation Policies: Government strategies, regulations, and programs specifically designed to reduce vulnerability and build resilience to climate change impacts, including urban heat management and extreme temperature events.

Climate Change Adaptation Strategies: Comprehensive approaches and measures taken to adjust natural or human systems in response to actual or expected climatic stimuli, particularly focusing on heat-related risks and opportunities.

Climate-Resilient Urban Planning Policies: Planning frameworks and regulatory mechanisms that integrate climate risk considerations, particularly heat exposure, into urban development decisions and infrastructure investments.

Community Engagement: Participatory processes that involve local residents, stakeholders, and vulnerable populations in identifying heat-related challenges, developing solutions, and implementing urban heat resilience measures.

Cool Roofs: Roofing systems designed with high solar reflectance and thermal emittance properties to reduce heat absorption, lower building temperatures, and decrease the urban heat island effect.

Cooling Centers: Designated public facilities equipped with air conditioning and emergency services that provide temporary relief for residents during extreme heat events, particularly serving vulnerable populations.

Corporate Social Responsibility (CSR): Business practices and initiatives that address social and environmental challenges, including corporate contributions to urban heat mitigation through sustainable building practices and community cooling programs.

Critical Vulnerability: The highest level of susceptibility to heat-related harm, typically characterizing populations or areas with limited adaptive capacity, high exposure, and multiple socioeconomic stressors.

Early Warning Systems: Integrated communication networks and protocols that provide timely, accurate information about impending extreme heat events to enable protective actions by individuals, communities, and institutions.

Ecosystem-based Approaches: Climate adaptation strategies that utilize natural ecosystems and biodiversity to reduce urban heat through services such as evapotranspiration, shading, and microclimate regulation.

Economic Productivity: The efficiency of economic output, which can be significantly impacted by extreme heat through reduced worker performance, increased energy costs, and heat-related business disruptions.

Energy Consumption: The amount of energy used by buildings and urban systems, which typically increases during heat events due to cooling demands and can be reduced through heat mitigation strategies.

Energy Savings: Reductions in energy use achieved through urban heat mitigation measures, cool building technologies, and improved thermal comfort that decrease reliance on mechanical cooling systems.

Energy-Efficient Solutions: Technologies, designs, and practices that reduce energy consumption while maintaining or improving thermal comfort, including passive cooling strategies and high-performance building systems.

Evaporative Cooling: Natural or engineered processes that reduce air temperature through water evaporation, including transpiration from vegetation and mechanical evaporative cooling systems.

Extreme Heat Islands: Urban areas that experience significantly higher temperatures than surrounding regions during heat events, often characterized by dense development, limited vegetation, and extensive impervious surfaces.

Focus Groups: Qualitative research method involving structured discussions with selected community members to gather insights about heat experiences, adaptation needs, and preferences for resilience interventions.

Gender Equality, Disability, and Social Inclusion (GEDSI): Framework ensuring that urban heat resilience policies and programs address the specific needs and vulnerabilities of women, persons with disabilities, and marginalized communities.

Geographic and Temporal Scope: The spatial boundaries and time periods covered by urban heat studies, policies, or interventions, important for understanding heat patterns and planning appropriate responses.

Global Circulation Models (GCMs): Large-scale climate models that simulate Earth's atmospheric and oceanic circulation patterns to project future temperature and precipitation scenarios for climate planning.

Green Building Practices: Construction and design approaches that minimize environmental impact and maximize energy efficiency, including heat-reducing features such as cool roofs, efficient insulation, and natural ventilation.

Green Corridors: Connected networks of vegetated areas that provide continuous pathways for wildlife movement while creating cooling channels that reduce urban heat through shade and evapotranspiration.

Green Roofs: Rooftop systems covered with vegetation and growing medium that provide insulation, reduce stormwater runoff, and decrease building and ambient temperatures through evapotranspiration.

Green Space Ratio: The proportion of vegetated area within a defined urban zone, used as an indicator of heat mitigation potential and urban environmental quality.

Green Walls: Vertical growing systems on building facades that provide insulation, reduce surface temperatures, and contribute to urban cooling through transpiration and shading.

Heat Exposure: The degree to which individuals, communities, or assets come into contact with dangerous heat conditions, determined by geographic location, time spent outdoors, and access to cooling resources.

Heat Index: A measure of how hot it feels when relative humidity is factored in with actual air temperature, providing a more accurate assessment of heat stress risk to human health.

Heat Modeling: Computational techniques used to simulate and predict urban temperature patterns, heat island intensity, and the effectiveness of mitigation strategies using meteorological and urban morphology data.

Heat Stress: Physiological strain experienced by humans or other organisms when exposed to excessive heat conditions that challenge the body's ability to maintain normal temperature regulation.

Heatwave: A prolonged period of excessively hot weather, which may be accompanied by high humidity, defined by temperature thresholds and duration criteria specific to local climate conditions.

Heatwave Metrics: Quantitative measures used to characterize heat events, including intensity, duration, frequency, and timing, essential for risk assessment and early warning systems.

Heatwave Threshold: Temperature and duration criteria that define when heat conditions constitute a heatwave for a specific location, typically based on historical climate data and health impact studies.

Heat Vulnerability Index (HVI): Composite indicator that combines measures of heat exposure, sensitivity, and adaptive capacity to identify areas and populations at greatest risk from extreme heat events.

Heat-Health Action Plans (HHAPs): Coordinated emergency response protocols that outline specific actions for health systems, local governments, and communities before, during, and after extreme heat events.

Heat-Related Illness: Medical conditions caused by exposure to excessive heat, including heat exhaustion, heat stroke, dehydration, and exacerbation of chronic conditions such as cardiovascular and respiratory diseases.

Heat-Related Mortality: Deaths directly or indirectly caused by exposure to excessive heat, used as a critical indicator for assessing the health impacts of urban heat and the effectiveness of adaptation measures.

Housing Density: The concentration of residential units within a given area, which influences urban heat patterns through building thermal mass, reduced vegetation, and modified air circulation patterns.

Human Thermal Comfort: The condition of mind that expresses satisfaction with the thermal environment, influenced by air temperature, humidity, air movement, radiant temperature, clothing, and metabolic rate.

Impervious Surfaces: Built surfaces such as concrete, asphalt, and rooftops that prevent water infiltration and absorb and retain heat, contributing significantly to urban heat island effects.

Inclusive Participation: Engagement approaches that ensure meaningful involvement of all community members, particularly marginalized and vulnerable groups, in heat resilience planning and decision-making processes.

Individual Resilience: Personal capacity to prepare for, respond to, and recover from heat-related challenges through knowledge, resources, social networks, and adaptive behaviors.

Informal Settlement Residents: Populations living in unplanned urban areas with limited access to basic services, infrastructure, and formal housing, often experiencing heightened vulnerability to urban heat.

Integrated Urban Planning: Comprehensive planning approach that coordinates land use, transportation, infrastructure, and environmental considerations to address multiple urban challenges including heat management.

Intra-urban Heat Differences: Spatial variations in temperature within urban areas due to differences in land cover, building density, vegetation, and topography, creating patterns of heat exposure inequality.

Land Cover: The physical material covering the earth's surface, including vegetation, built structures, water bodies, and bare soil, which directly influences local temperature patterns and heat absorption.

Land Surface Temperature (LST): The temperature of the ground surface measured by satellite thermal sensors, providing spatially comprehensive data for urban heat analysis and heat island mapping.

Local Climate Zone (LCZ) Typology: Standardized classification system that categorizes urban areas based on surface cover, structure, and thermal properties to enable consistent urban heat studies across different cities.

Low-Emission Materials: Construction materials with reduced embodied carbon and improved thermal properties that contribute to both climate mitigation and heat reduction in urban environments.

Meteorological Data: Atmospheric measurements including temperature, humidity, wind speed, solar radiation, and precipitation used for climate analysis, heat modeling, and urban planning applications.

Microclimate: Local atmospheric conditions that differ from the broader regional climate due to specific geographic features, land use patterns, or built environment characteristics.

Min-Max Normalization: Statistical technique used to scale different variables to a common range (typically 0-1) for creating composite indices such as heat vulnerability assessments.

Morbidity: The incidence and prevalence of disease and illness in a population, including heat-related health conditions that increase during extreme heat events.

Monitoring, Evaluation, and Adaptive Management: Systematic approach to track implementation progress, assess effectiveness of heat resilience interventions, and adjust strategies based on performance and changing conditions.

Multi-disciplinary Approach: Integration of expertise from various fields including urban planning, public health, engineering, social sciences, and environmental science to address complex urban heat challenges.

Multi-hazard Impact-based Forecast and Warning Services: Integrated systems that provide warnings for multiple climate hazards including heat, considering their combined impacts on communities and infrastructure.

Multi-layered Adaptation Strategy: Comprehensive approach that implements heat resilience measures at multiple scales (individual, community, city) and sectors (health, infrastructure, environment) simultaneously.

Multi-stakeholder Approach: Collaborative framework involving government agencies, private sector, civil society, academia, and communities in developing and implementing urban heat resilience solutions.

Nationally Determined Contribution (NDC): Country commitments under the Paris Agreement that include both climate mitigation and adaptation measures, potentially encompassing urban heat resilience strategies.

Nature-Based Solutions (NBS): Interventions that use natural or semi-natural ecosystems to address urban challenges including heat mitigation while providing co-benefits for biodiversity, air quality, and human well-being.

Nature-Inspired Solutions: Engineered systems that mimic natural processes to provide cooling services, such as biomimetic building materials or artificial transpiration systems.

Nighttime Temperature Effects: The impact of elevated nighttime temperatures on human health, sleep quality, and recovery from daytime heat exposure, particularly important in urban heat island assessment.

Occupational Illnesses: Work-related health conditions exacerbated or caused by heat exposure, particularly affecting outdoor workers and those in non-air-conditioned environments.

Outdoor Workers: Employment groups with significant heat exposure including construction workers, agricultural laborers, delivery personnel, and emergency responders who require targeted protection measures.

Permeable Surfaces: Ground materials that allow water infiltration, reducing surface temperatures through evaporation and groundwater recharge while decreasing urban heat island effects.

Pervious Surfaces: Paved surfaces designed to allow water penetration, providing cooling benefits through evaporation while maintaining functionality for transportation and development.

Physiological Factors: Individual biological characteristics including age, health status, fitness level, and acclimatization that influence susceptibility to heat-related health impacts.

Physiological Risk: The likelihood of experiencing heat-related health effects based on individual physical characteristics and adaptive capacity for thermoregulation.

Public Health Benefits: Positive health outcomes achieved through urban heat mitigation, including reduced heat-related mortality and morbidity, improved air quality, and enhanced mental health and well-being.

Raingardens: Landscaped depressions designed to capture and infiltrate stormwater runoff while providing cooling benefits through vegetation and soil moisture evaporation.

Renewable Energy: Energy sources that naturally replenish and can power cooling systems without contributing to greenhouse gas emissions that drive urban heat challenges.

Sendai Framework for Disaster Risk Reduction (SFDRR): International framework that guides disaster risk reduction efforts, including heat-related hazards, through prevention, preparedness, response, and recovery strategies.

Shading: Physical obstruction of solar radiation through structures, vegetation, or designed elements that reduce direct heat exposure and improve thermal comfort in urban spaces.

Shared Socioeconomic Pathway (SSP): Scenarios describing alternative socioeconomic developments that influence greenhouse gas emissions and climate adaptation capacity, used in climate impact modeling.

Socioeconomic Factors: Social and economic characteristics including income, education, employment, housing quality, and social networks that influence vulnerability to heat and capacity for adaptation.

Socioeconomic Indicators: Measurable variables such as poverty rates, employment levels, and education attainment used to assess community vulnerability and adaptive capacity to heat risks.

Socioeconomic Losses: Economic and social costs associated with heat impacts, including healthcare expenses, lost productivity, infrastructure damage, and reduced quality of life.

Spatial Consistency: The degree to which heat patterns, interventions, or policies maintain coherence across different geographic scales and urban zones.

SSP2-4.5 Scenario: A moderate climate change scenario assuming intermediate greenhouse gas emissions and socioeconomic development, commonly used for urban heat impact assessments.

Stakeholder Mapping: Process of identifying and analyzing all parties with interests in urban heat resilience, including their roles, relationships, and influence on policy and implementation.

Strategic Planning: Long-term planning approach that sets priorities, allocates resources, and coordinates actions to achieve urban heat resilience goals over multiple time horizons.

Sustainable Development Goals (SDGs): United Nations framework that includes targets for climate action, sustainable cities, and health that align with urban heat resilience objectives.

Swales: Shallow channels designed to manage stormwater runoff while providing cooling benefits through vegetation and moisture retention in urban landscapes.

TARGET Urban Climate Model: Specific computational tool used to simulate urban climate conditions and assess the effectiveness of heat mitigation strategies at neighborhood and city scales.

Thermal Comfort: The state of thermal satisfaction with the environment, influenced by personal factors (clothing, activity) and environmental conditions (temperature, humidity, air movement, radiation).

Thermal Equities: Fair distribution of thermal comfort and heat exposure across different communities, addressing disparities in access to cooling resources and heat vulnerability.

Thermal Extremes: Temperature conditions that significantly exceed normal ranges and pose risks to human health, infrastructure performance, and ecosystem functioning.

Thermoregulation: Biological processes by which organisms maintain body temperature within optimal ranges, which can be compromised during extreme heat exposure.

Traditional Practices: Indigenous and local knowledge systems for heat management, including architectural techniques, behavioral adaptations, and community practices that provide culturally appropriate cooling strategies.

Tree Canopy Cover: The percentage of ground area covered by tree crowns when viewed from above, providing quantitative measures of urban forest cooling potential and coverage gaps.

Uchimizu (Sprinkling Water): Traditional Japanese practice of sprinkling water on streets and courtyards to create evaporative cooling, representing cultural approaches to urban heat management.

UNFCCC/Paris Agreement: International climate framework that establishes commitments for climate mitigation and adaptation, providing policy context for urban heat resilience strategies.

Urban Agriculture: Food production within urban areas that can provide cooling benefits through vegetation cover while enhancing food security and community resilience.

Urban Climate Model: Computational tools that simulate atmospheric conditions in urban environments, accounting for the effects of buildings, surfaces, and human activities on local climate patterns.

Urban Heat: Elevated temperatures in urban areas caused by human activities, modified land surfaces, and altered energy balances that create health risks and reduce livability.

Urban Heat Adaptation Strategies: Specific measures and approaches designed to reduce heat exposure, enhance cooling capacity, and build resilience to extreme heat in urban environments.

Urban Heat Island (UHI) Effect: Phenomenon where urban areas experience higher temperatures than surrounding rural areas due to human modifications of the landscape and energy use patterns.

Urban Heat Resilience: The capacity of urban systems, communities, and individuals to prepare for, respond to, and recover from heat-related challenges while maintaining essential functions.

Urban Heat Intensity: The magnitude of temperature difference between urban and rural areas, typically measured as the maximum temperature differential during heat events.

Urban Forests: Managed collections of trees and associated vegetation within urban areas that provide cooling services through shade, transpiration, and wind modification.

Urban Green Infrastructure (UGI): Network of natural and semi-natural features that provide ecosystem services including temperature regulation, stormwater management, and air quality improvement.

Urban Green Spaces: Parks, gardens, greenways, and other vegetated areas within cities that offer cooling benefits, recreation opportunities, and ecological services.

Urban Morphology: The spatial structure and form of urban areas, including building heights, street layouts, and open spaces that influence air circulation and heat distribution patterns.

Urban Overheating: Excessive heating of urban environments that exceeds comfortable or safe temperature thresholds, particularly during heat waves and in areas with limited cooling resources.

Vulnerable Communities/Populations: Groups with heightened susceptibility to heat-related harm due to social, economic, health, or geographic factors that limit their adaptive capacity.

Vulnerability Analysis: Systematic assessment of factors that make individuals, communities, or systems susceptible to heat-related harm, including exposure, sensitivity, and adaptive capacity components.

Vulnerability Drivers: Underlying factors that increase susceptibility to heat impacts, including poverty, social isolation, poor housing quality, chronic health conditions, and limited access to cooling resources.

Water Sensitive Urban Design: Planning and design approach that integrates water management with urban development to create cooling benefits through features such as wetlands, permeable surfaces, and water retention systems.

Waterways: Rivers, streams, canals, and other water bodies that provide cooling benefits through evaporation, humidity modification, and creation of cool microclimates in urban areas.

Wetlands: Natural or constructed areas with standing or flowing water that provide cooling services through evaporation while offering co-benefits for biodiversity and stormwater management.

Wet Bulb Globe Temperature (WBGT): Heat stress index that combines air temperature, humidity, wind speed, and solar radiation to assess thermal conditions for outdoor work and activities.

Worker Productivity: Economic output per worker, which typically decreases during extreme heat conditions due to reduced physical and cognitive performance and increased break requirements.

Zoning Regulations: Municipal laws that control land use, building density, and development patterns, which can be modified to reduce heat generation and improve urban cooling capacity.

1 Executive Summary

Bangkok, like many rapidly urbanizing cities in Southeast Asia, faces an escalating threat from extreme urban heat, exacerbated by the urban heat effect and global climate change. This challenge disproportionately affects vulnerable communities, including women, children, the elderly, persons with disabilities, low-income households, and informal settlement residents, who often lack adequate adaptive capacity and resources.

This report, drawing from the "**Urban Heat Resilience: Bridging Science, Policy, and Sustainable Design"** project, presents a comprehensive analysis of urban heat risks in Bangkok and the potential of Nature-Based Solutions (NBS) as a key mitigation strategy. Building on this, the report also incorporates specific findings and policy insights from the Vietnam Urban Heat Status report, detailing observed temperature shifts, urban heat island effects, health impacts, and policy landscapes within Vietnamese cities, offering learnings applicable to second-tier Mekong cities in Vietnam. Utilizing the **TARGET urban climate model**, simulations for both present-day (1985-2014) and projected mid-century conditions (2036–2065) demonstrate that central and western districts with high imperviousness experience the greatest heatwave burden, with up to **100 heatwave days per season, lasting weeks at a time, and with significant thermal intensity**. Without intervention, many districts could see an additional 40–60 heatwave days per year by mid-century.

Nature-Based Solutions (NBS), which involve widespread increases in pervious, green, and irrigated surfaces, particularly in highly impervious areas, are projected to significantly mitigate these impacts. The NBS scenario suggests a **reduction of up to 24 heatwave days in hotspots**, shorter heatwave events (over 30 days reduction in duration in some areas), and meaningful reductions in heatwave severity (up to 0.4°C during extreme events). These benefits are spatially consistent with intervention areas, highlighting the strong local cooling effects and spillover benefits of NBS.

Crucially, the project emphasizes a **Gender Equality, Disability, and Social Inclusion (GEDSI) Action Plan** to ensure that heat resilience efforts are inclusive and equitable. This plan integrates GEDSI principles into all project phases, from data collection and policy design to implementation and monitoring, prioritizing the needs of vulnerable populations.

While NBS offers a substantial buffer against climate-driven urban heat, it is not a standalone solution. A comprehensive, multi-layered adaptation strategy is required, combining NBS with broader systemic measures such as inclusive heat alert systems, cooling centers, hydration points, and integrated urban planning and policy that accounts for social equity. This project aims to bridge the gap between scientific understanding, policy frameworks, and practical implementation to build a more heat-resilient, equitable, and livable Bangkok, with learnings applicable to other Mekong cities in Vietnam.

2 Urban Heat Resilience: Project Overview

The **"Urban Heat Resilience: Bridging Science, Policy, and Sustainable Design"** is a flagship research study initiated in response to the unprecedented heatwaves experienced in Southeast Asia in 2023 and early 2024, particularly impacting Thailand and Vietnam. This study addresses the growing challenge of urban heat in Southeast Asia and aims to bridge the gap between scientific understanding, policy frameworks, and practical implementation of urban heat resilience strategies, with a particular focus on nature-based solutions and their potential to support vulnerable communities in the face of rising temperatures. The project is part of the **Mekong Thought Leadership and Think Tanks Network Program, supported by the Department of Foreign Affairs and Trade (DFAT), Government of Australia.**

2.1 About the Project

The project recognizes that heat is an increasingly pressing problem in cities, amplified by the urban heat effect. In Southeast Asia, the urban poor, especially those in informal settlements, are most at risk due to low-quality, overcrowded housing with poor ventilation and limited access to cooling. Research indicates that blue and green urban infrastructure (Nature-based Solutions, NbS) can lower temperatures, improving human thermal comfort and reducing heat stress. However, there is a scarcity of city and sub-city scale analyses in the Mekong Region to gauge the efficacy and cost-effectiveness of such interventions for long-term climate adaptation. This project aims to fill this gap by employing innovative heat modeling techniques to assess urban heat risks, bolstering Bangkok's resilience, and yielding insights applicable to other Mekong cities.

2.2 Mission and Key Objectives

The overarching mission of the project is to enhance urban heat resilience in Bangkok and Vietnamese cities through cutting-edge heat modeling, nature-based solutions, and inclusive policy development.

Key Objectives include:

- **Deploying innovative heat modeling techniques** to assess urban heat risks and create detailed heat risk maps in Bangkok.
- **Developing nature-based and green-blue infrastructure solutions**.
- **Supporting inclusive planning** to address thermal inequities, specifically identifying urban heat issues faced by vulnerable communities in Bangkok and assessing their applicability to other Mekong cities in Tien Giang Province.
- **Enabling multi-sector coordination and collaboration**.
- **Facilitating peer-to-peer knowledge exchange** with second-tier cities in Vietnam (in Tien Giang Province) to promote scalable solutions.

- **Enhancing local capacity** through training and education in urban heat resilience planning and implementation, particularly in heat modeling techniques and interpretation.
- **Providing evidence-based policy recommendations** for urban heat management.
- **Developing mechanisms** to disseminate knowledge and establish resources for application in diverse urban contexts.
- **Developing indicators** to assess proposed heat resilience solutions and establish a framework for long-term monitoring.

2.3 Geographic and Temporal Scope

The study has a primary geographic focus on **Bangkok, Thailand**, as a major metropolitan area, and a secondary focus on Second Tier cities in Vietnam, as representative second-tier Mekong cities.

For its temporal scope, the project utilizes **historical meteorological data from the ERA5-Land reanalysis product**[1] provided by ECMWF[2], for the present-day period of **1985-2014**. Future projections are centered around **2050 (years 2036-2065)**, using climate change data from the NASA Earth eXchange Downscaled Climate Projections (NEX-DCP30-CMIP6) dataset under the SSP 2.4-5 scenario. The analysis focuses on the hot season, specifically February to July.

The project will concentrate on developing and implementing nature-based solutions, offering a sustainable and potentially cost-effective approach to heat mitigation. This aligns with global trends in climate adaptation strategies and provides a framework that can be adapted across the broader Lower Mekong region. By focusing on both a major city and two second-tier urban areas, the project aims to provide insights and strategies applicable to various urban contexts within Southeast Asia, contributing to enhanced urban heat resilience across the region.

2.4 Consortium and Key Partners

The project is a collaborative effort led by the **Asian Disaster Preparedness Center (ADPC, Thailand)**, with consortium partners including **Alluvium (Australia), B-Kode (Belgium), RMIT University (Vietnam), and the Thailand Environment Institute (TEI)**.

2.5 Limitations

I. **Data Availability and Quality:** Reliance on existing datasets, which may have gaps or inconsistencies, and potential limitations in historical climate data for Bangkok

II. **Model Uncertainties:** Inherent uncertainties in climate projections and urban development scenarios, as well as limitations in the ability to model micro-climate variations within cities.

III. **Resource Constraints**: Time limitations for field studies and community engagement (12 months) and budget constraints limiting the extent of primary data collection.

IV. **Generalizability:** Findings from international research and models may not translate to tropical climates and the findings from Bangkok may not be fully applicable to all second-tier Mekong cities.

V. **Policy Implementation:** Study cannot ensure the adoption or implementation of recommended policies and solutions

VI. **Technological Limitations:** Constraints in the resolution and accuracy of available remote sensing data for heat mapping, and potential limitations in modeling complex urban geometries and their impact on heat distribution.

VII. **Stakeholder Engagement**: Engaging with all affected communities and dependence on representative sampling, Potential difficulties in reaching the most vulnerable groups due to access issues.

VIII. **Interdisciplinary Challenges:** Complexity in fully integrating insights from diverse fields (climatology, urban planning, social sciences, etc.) and potential gaps in translating scientific findings into actionable policy recommendations.

IX. **External Factors:** Unforeseen events like political changes or natural disasters may impact the study, and the global climate crisis may accelerate changes faster than the study can adapt

3 The Challenge of Urban Heat

Climate change is a pressing global issue that has significant impacts on the environment, economy, and society. One of the most visible manifestations of climate change is the increase in the frequency, intensity, and duration of heat waves [3]. Heat waves are prolonged periods of excessively hot weather, which can have detrimental effects on human health, agriculture, infrastructure, and ecosystems [4]. Understanding the science behind climate change and heat waves is crucial for developing effective policies and strategies to mitigate their impacts . Scientific research has shown that climate change is causing an increase in the frequency and intensity of heat waves. According to the Intergovernmental Panel on Climate Change (IPCC), the number of heat wave days has been increasing globally, and this trend is expected to continue in the future [5]. The geographical distribution of heat waves is also changing, with some regions experiencing more frequent and intense heat waves than others[6].

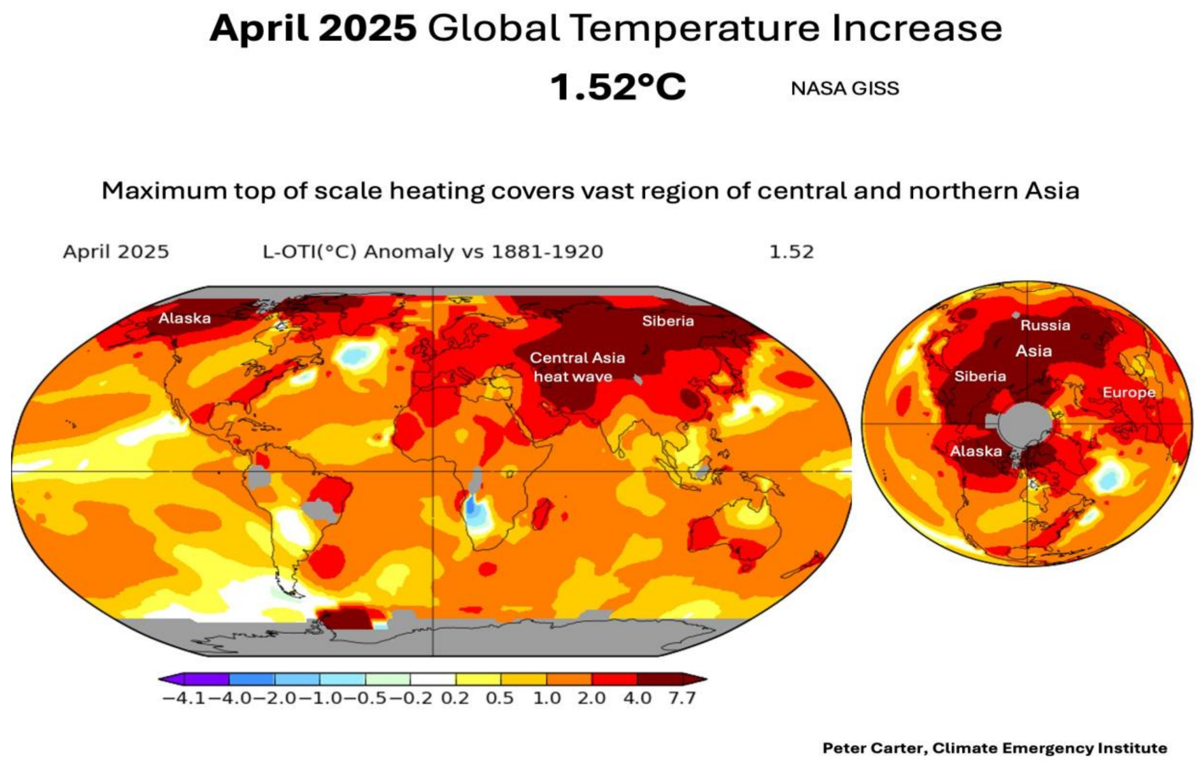


Figure 1 April 2025 Global temperature Increase (Peter Carter, Climate Emergency Institute, 2025)

High Temperatures in Urban areas has become a major issue in Southeast Asia, especially in fast-growing cities. Since 2024, the challenges of rising temperatures in urban areas have become more pronounced. Recent events have highlighted the urgency of addressing this problem. Heatwaves in 2023 and early 2024 brought extraordinarily high temperatures to Southeast Asia, particularly to Thailand and Vietnam[7]. These events were stark reminders of the region's vulnerability to intense heat, which according to climate change forecasts will only worsen in the future. Warming associated with urban development will be exacerbated in future years by temperature increases due to climate change[8] . This will adversely impacts the communities and the environment, affecting public health, economic productivity, energy consumption, and the overall quality of life for city residents. However, these effects are not distributed equally. Vulnerable populations are disproportionately affected. Living in poor quality housing, combined with limited or non-existing cooling, results in lower-income households suffering more from heat waves [9].

The 2013 study by Perkins and Alexander examines the complexities of defining and measuring heat waves, proposing three definitions based on climate science literature that focus on maximum and minimum temperatures as well as extreme heat factors. Using a multifaceted framework, the researchers assess aspects such as frequency, duration, participating days, and intensity. Key findings indicate that trends in heat wave definitions are more significant in the earlier period (1951-2008) compared to the later period (1971-2008). The availability of heat wave days affects the frequency of events, and the intensity of heat waves is increasing at a faster rate than their average magnitude[10].While land surface temperature and air temperatures are clearly different, mitigating high surface temperatures in cities is an appropriate target, as these reflect locations where both air temperature and absorbance of solar radiation is high, which impacts directly on human thermal comfort[11].

3.1 Characteristics of Urban Heat

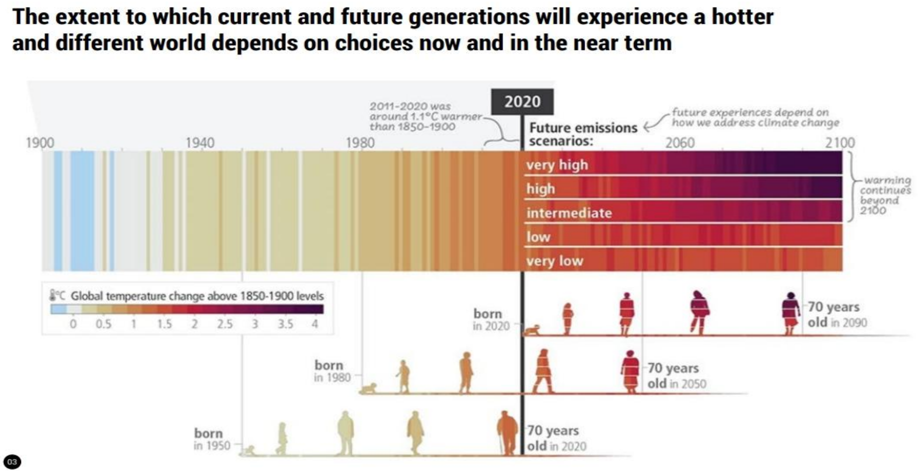


Figure 2 Emission Scenarios in future experienced by different generations (IPCC, 2023)

Spatial and Temporal Variations: Urban Heat intensity can vary depending on the time of day, season, and geographic location. For example, urban areas typically experience the highest temperature differences during nighttime and summer. [12]

Influence of Urbanization: The density of buildings, lack of vegetation, and extensive use of heat-absorbing materials contribute significantly to the increased Heat. Urban areas with more concrete and asphalt, fewer trees, and lower water bodies tend to have a more heat. [13]

Meteorological Influences: Weather conditions, such as wind speed and cloud cover, also influence the increased Urban Heat. Calm and clear nights tend to enhance the Urban Heat intensity, while windy or cloudy conditions diminish it. [14]

Impact on Climate and Health: Increased Urban Heat contributes to increased energy consumption for cooling, elevated emissions of air pollutants and greenhouse gases, and can affect human health by exacerbating heat stress and heat-related illnesses[15].

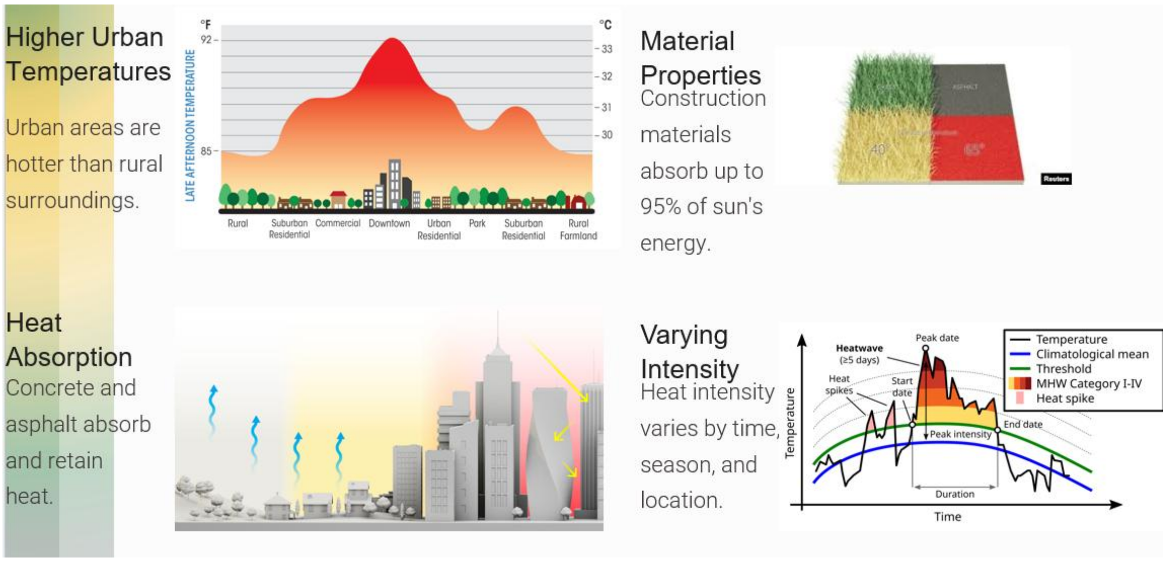


Figure 3 Causes of Urban Heat (Authors)

Urban Heat effect often creeps up on both large and small cities. Imagine cruising through the city on a scorching summer afternoon and feeling that it's noticeably hotter than the nearby rural areas. This phenomenon occurs because urban regions soak up and hold onto heat due to the abundance of concrete, asphalt, and structures. These materials trap warmth during the day and slowly release it after sunset, resulting in city temperatures that are consistently higher. While some permeable and moist surfaces, like grass or soil, absorb less heat, other construction materials like asphalt or concrete are capable of absorbing as much as 95% of the sun's energy, which is then radiated back into the surrounding atmosphere[16].

Li et al. (2015) conducted a review assessing the link between heat waves and morbidity, analyzing 33 studies to identify vulnerable populations and recommend public health interventions. Their findings indicate that heat waves negatively impact morbidity, particularly affecting the elderly, children, and males, as well as individuals with chronic conditions who require more medical care. Lower socioeconomic status also increases susceptibility to heat-related issues.The study highlights inconsistencies in methods and definitions of heat waves across research and advocates for targeted policies and guidelines to protect vulnerable groups, emphasizing the integration of morbidity indicators into heat wave early warning systems for effective public health action[17].

Research conducted by ZEW Mannheim and Frankfurt School of Finance & Management indicates that when a country's average temperature reaches at least 30°C, exports tend to decrease by an average of 3.4% per month due to heat waves. The study further suggests that the adverse impact of heat on exports is particularly noticeable in sectors where production processes are labor- intensive, implying that heat waves could potentially undermine the competitiveness of countries that heavily depend on labor as a comparative advantage[18].A report by the Atlantic Council (2021) disclosed that extreme heat drains billions in worker productivity each year from some of the world's largest cities. The report projected that unless greenhouse gas emissions are curtailed, annual worker productivity losses, which currently average $44 billion across the 12 cities studied, are expected to escalate to $84 billion by 2050. The report also cautioned that due to their rapid urbanization and population growth, cities in the Global South are likely to experience more severe impacts from worker productivity as a percentage of output[19]. For workers, exposure to extreme heat can cause occupational illnesses, increase risk of injury, and lower productivity through natural defence mechanisms such as slowing down, taking more frequent and longer breaks, or limiting working hours. For economies, it threatens their productivity. Regions such as Southeast Asia are expected to experience a reduction in working hours above the global average[20].

Understanding the science behind climate change and heat waves is crucial for addressing their economic impacts and promoting sustainable development. By studying the frequency, intensity, and duration of heat waves, as well as their geographical distribution, researchers can develop effective policies and strategies to mitigate their impacts. As the frequency and intensity of heat waves continue to increase, it is essential to prioritize research and policy efforts to address their economic impacts and promote sustainable development.

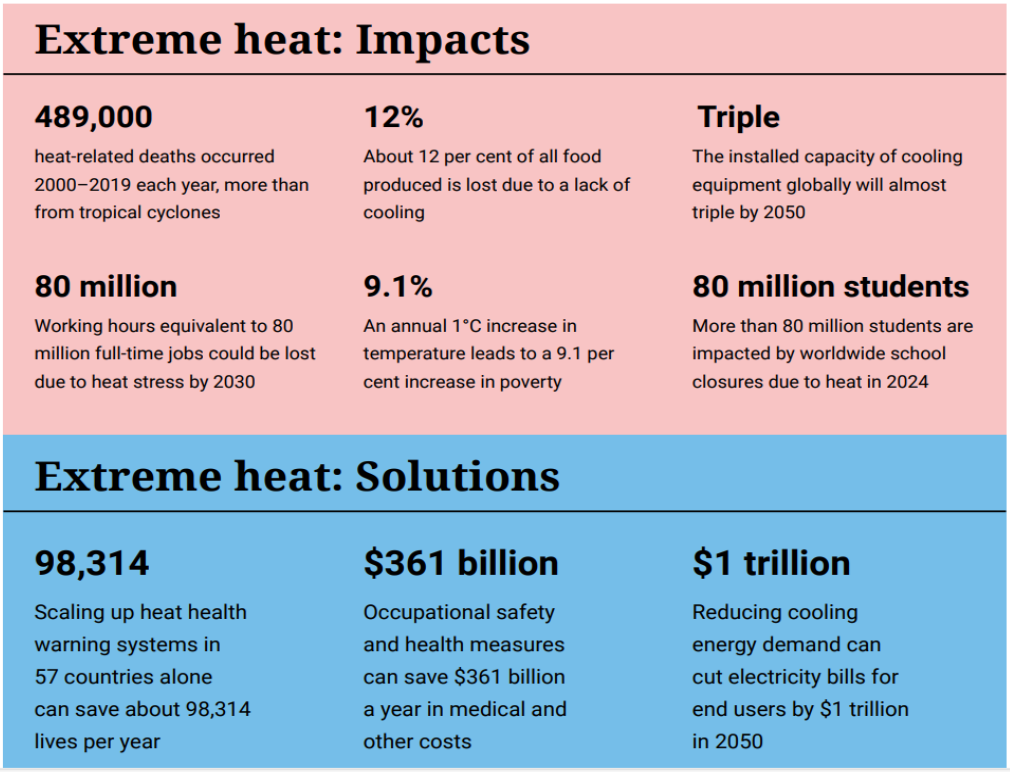


Figure 4 Extreme Heat Impacts (UN 2024) [21]

The challenges posed by urban heat have led to increased interest in the Nature-Based Solutions (NbS) as a way to mitigate its effects. Urban forests, green roofs, and water bodies are examples of blue and green urban infrastructure solutions that have been promising in reducing temperatures and enhancing human thermal comfort[22]. In the Mekong Region, there is a lack of comprehensive analysis at the city and sub-city scale to evaluate the effectiveness and cost-efficiency of such interventions for long-term climate adaptation [23]. The policy landscape surrounding urban heat resilience in Southeast Asia is both complex and evolving. Both Thailand and Vietnam have begun to incorporate heat resilience into their urban planning and climate adaptation strategies. Thailand National Adaptation Plan mentions the modelling of Heat stress scenarios in their National level climate modeling and also suggests to formulate Guidelines for responding to the impact on urban heat in large cities[24]. The National Action Plan of Vietnam also recognises the adverse impacts of increasing extreme temperature events on Health, livelihood, productivity, environment and Infrastructure[25]. However, the effectiveness of these policies, their implementation on the ground, the role of nature-based solutions as part of the suite of urban heat mitigation strategies and their ability to protect the most vulnerable populations remain areas requiring further investigation.

3.2 Current Trends and impacts in South East Asia

Southeast Asia, particularly Thailand and Vietnam, experienced unprecedented heatwaves in 2023 and early 2024, a trend projected to intensify with climate change. In 2024, Bangkok's temperatures were 1.75°C above the pre-industrial baseline, continuing a trend from 2023, which had already exceeded the 1.5°C threshold [26][27]. These back-to-back years brought record-breaking heatwaves to Bangkok, Thailand, Vietnam, and the broader Southeast Asian region, underscoring an escalating climate threat.

A study investigates the influence of landscape composition and pattern on land surface temperature (LST) in Southeast Asian megacities. Findings indicated that urban areas with less vegetation and higher built-up density exhibit significantly higher LST, contributing to the UHI effect. The study highlights the importance of urban planning and green infrastructure to mitigate UHI impacts [28].

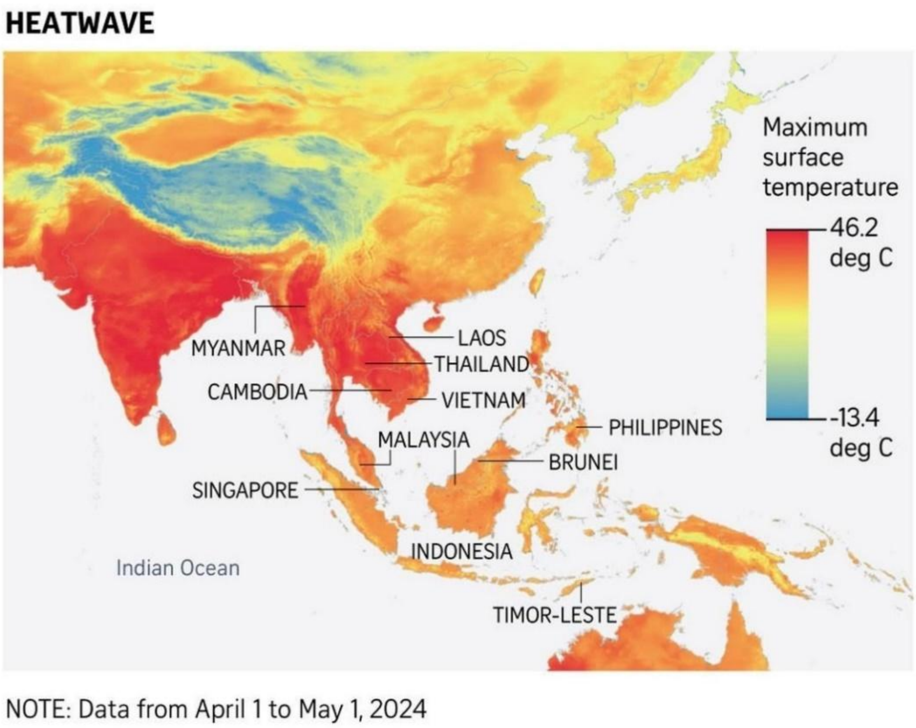


Figure 5 South East Asia's Heat Problem (UN, 2024)

The global climate crisis has led to an unprecedented increase in extreme heat events worldwide, with particularly severe impacts observed in Southeast Asian urban centres [29]. Many countries have experienced record-breaking summer temperatures in 2024. Scientists from NASA's Goddard Institute for Space Studies recently reported that May 2024, the hottest May in NASA's global surface temperature analysis, marked a full year of record-high monthly temperatures [30]. Likewise, NOAA recently reported that January through May 2024 ranked warmest on its 175-year temperature record [31]. On June 19, 2024, the Northern Hemisphere was running 1.1 degrees Celsius (1.9 degrees Fahrenheit) above normal [32].

Several Southeast Asian Countries experienced record-breaking extreme hot temperatures which led to several deaths and heat related illness cases. The heat wave has been attributed to a combination of causes, including climate change and El Niño[33]. The 2024 heat wave in Southeast Asia has hit Thailand and Vietnam particularly hard, causing significant challenges for both countries. In Thailand, At least 61 people have died so far this year from conditions linked to heat stroke, almost double that of all of 2023.[34] The high rate of urban expansion and economic growth in Bangkok has resulted in various environmental problems, especially city warming. The observations made by the department of meteorology of Bangkok show that the average maximum air temperature in Bangkok increased from approximately 32 °C in 1961 to nearly 34 °C in 2007.The number of days on which the temperature exceeded 35 °C increased from approximately 20 days in 1991 to approximately 110 days in 2007[35]. The extreme temperatures pushed electricity demand to record levels as people desperately try to stay cool. The heat is also exacerbating drought conditions, with water levels dropping sharply in key reservoirs and rivers. This has sparked fears of widespread water shortages. [36]

Meanwhile, Vietnam's southern region endured its longest heat wave in 30 years [37]. This prolonged period of extreme heat is having severe impacts on agriculture. Farmers in the crucial Mekong Delta region are reporting decreased crop yields, threatening livelihoods and food security [38].The environmental toll is also becoming apparent. In one shocking incident, mass fish deaths blanketed an entire 300-hectare reservoir in Đồng Nai province[39]. Local hospitals have reported a significant increase in heat-related illnesses such as heat exhaustion and heatstroke[40]. This devastating event was attributed to dwindling water levels caused by the intense heat. The situation has become so severe that several provinces have declared states of emergency due to the water crisis, land subsidence, and erosion [41].

Lower Mekong Region

The Lower Mekong River Basin, encompassing major cities like, Bangkok, Phnom Penh, and Ho Chi Minh City, is experiencing significant impacts from the ongoing heat wave. This region, covering approximately 571,000 km^2 across northeastern Thailand, Laos, Cambodia, and southern Vietnam, is considered one of the world's most vulnerable delta areas[42]

The 2024 heat wave has had far-reaching effects on both businesses and individuals in these urban centers. Many companies have been forced to adjust their operations, implementing flexible work arrangements or reduced hours to protect employees from extreme temperatures [43]. The heat has also put immense strain on power grids, with electricity demand reaching record levels as people seek relief from the scorching temperatures [44].

Vulnerable communities, including the elderly, young children, outdoor workers, and those with pre-existing health conditions, are particularly at risk. Heat-related illnesses have surged, with health facilities across the region reporting increased cases of heat exhaustion and heatstroke[45] [46]

The current situation aligns with long-term climate projections for the region. Based on Global Circulation Models (GCMs) and regional climate modeling, average maximum and minimum temperatures in the Mekong Basin are expected to increase by 1-3°C in the hot months (January to April) over the next 2-3 decades. The basin is also likely to experience longer dry seasons and shorter rainy seasons [47].

According to the ASEAN Specialised Meteorological Centre (ASMC), drier conditions engulfed almost the entire Lower Mekong Basin from late April to mid-May 2024 [48]. This combination of higher temperatures and reduced rainfall is projected to significantly impact agricultural activities, particularly rice production, further straining the livelihoods of people in the delta [49].

Looking ahead, by 2050, the Lower Mekong Basin is expected to face even more extreme climate conditions. These include higher temperatures, wetter wet seasons, drier dry seasons, and more frequent and intense flood events. Of particular concern are maximum daily temperatures exceeding 35°C, which are predicted to inhibit flowering and grain production in both rainfed and irrigated rice across many areas of the LMB, including the Mekong Delta [50].

As the region grapples with these immediate and long-term challenges, there is an urgent need for comprehensive adaptation strategies. These should address not only the agricultural and environmental impacts but also the social and economic consequences for the millions of people living and working in the Lower Mekong Basin's urban centers.

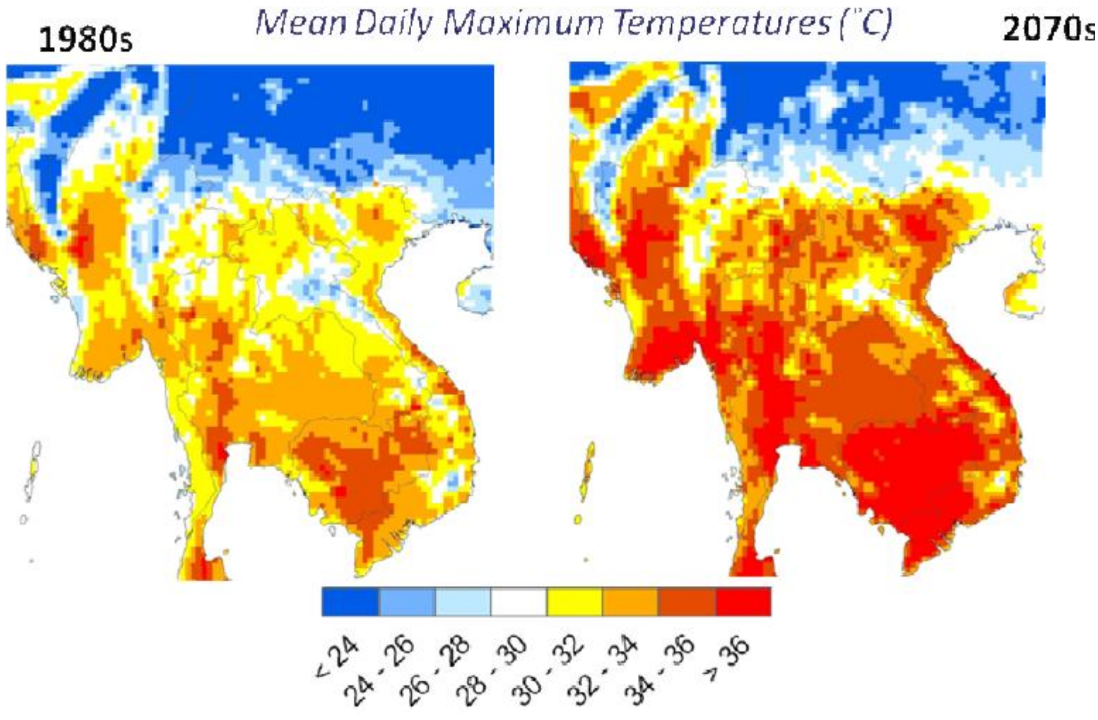
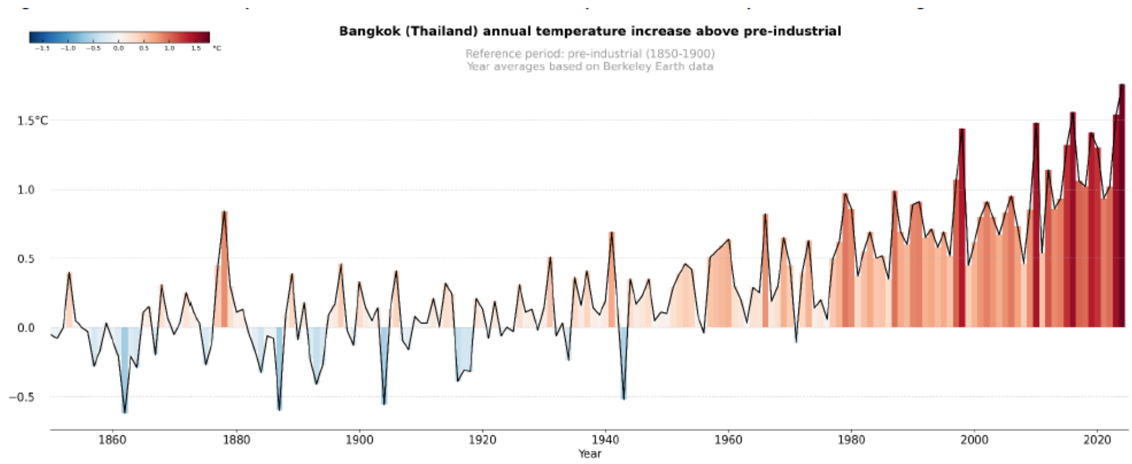


Figure 6 The projected change of mean daily maximum temperature in the Mekong Region since 1980s to 2070s (TTK & SEA START RC, 2009)

Bangkok Heat Waves

The heat wave in Bangkok during 2024 has had severe and wide-ranging impacts on the city and its residents. Record-breaking temperatures have pushed the urban heat effect to extreme levels. Bangkok's temperatures reach 40.1°C, but the heat index, or what the temperatures feel like, could reach 52°C when accounting for humidity [51]. At least 61 people have died so far in 2024 from conditions linked to heat stroke in Thailand, almost double that of all of 2023[52]. The 18 million residents of the Bangkok metropolitan area are among the 111 million people who suffered at least 60 days of dangerous heat in the first five months of this year[53]. Bangkok's heat problem is exacerbated by the urban heat island (UHI) effect, which can increase temperatures by up to 6-7°C in the densest areas [54]. The city's vulnerable populations, including the elderly, young children, and outdoor workers, have been particularly at risk. The high density of urban development in Bangkok increased temperatures in the city, with an average temperature increase of 0.6 ◦C over the past three decades [55] [56]. The same study also found that areas with high building density and low vegetation coverage have higher surface temperatures. Climate in Bangkok is heavily influenced by surrounding urban environment, with the Heat effects most acute in areas with high population density where vegetated lands were converted into urban infrastructure and impervious surface areas [57].



Source: B-Kode analysis based on Berkeley Earth data.

Figure 7 Annual Temperature increase above the pre-industrial period for Bangkok (B-Kode, 2025)

Factors contributing to the Urban Heat in Bangkok include[58]:

1. High vehicle emissions from an increasing number of cars
2. Widespread use of air conditioning, especially in malls and offices
3. Lack of incentives for green building practices
4. Minimal green space (1.47 sq m per capita vs WHO's recommended 9 sq m)

These impacts underscore the urgent need for effective urban heat management strategies in Bangkok, highlighting the importance of initiatives like the Urban Heat Resilience project in developing sustainable solutions to protect the city and its residents from future heat waves.

Table 1: Climate data for Bangkok Metropolis (1991–2020, extremes 1951–present)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	37.6 (99.7)	38.8 (101.8)	40.1 (104.2)	40.0 (104.0)	41.0 (105.8)	38.8 (101.8)	38.4 (101.1)	38.2 (100.8)	37.4 (99.3)	37.9 (100.2)	38.8 (101.8)	37.1 (98.8)	41.0 (105.8)
Mean daily maximum °C (°F)	32.7 (90.9)	33.7 (92.7)	34.7 (94.5)	35.7 (96.3)	35.1 (95.2)	34.1 (93.4)	33.5 (92.3)	33.3 (91.9)	33.2 (91.8)	33.3 (91.9)	33.1 (91.6)	32.3 (90.1)	33.7 (92.7)
Daily mean °C (°F)	27.4 (81.3)	28.6 (83.5)	29.7 (85.5)	30.7 (87.3)	30.3 (86.5)	29.7 (85.5)	29.2 (84.6)	29.2 (84.6)	28.6 (83.5)	28.4 (83.1)	28.4 (83.1)	27.3 (81.1)	28.9 (84.0)
Mean daily minimum °C (°F)	23.4 (74.1)	24.8 (76.6)	26.4 (79.5)	27.2 (81.0)	26.9 (80.4)	26.4 (79.5)	26.1 (79.0)	25.9 (78.6)	25.4 (77.7)	25.2 (77.4)	24.7 (76.5)	23.2 (73.8)	25.4 (77.7)
Record low °C (°F)	9.9 (49.8)	14.9 (58.8)	13.7 (56.7)	19.9 (67.8)	21.1 (70.0)	21.1 (70.0)	21.9 (71.4)	21.2 (70.2)	21.3 (70.3)	18.3 (64.9)	14.2 (57.6)	10.5 (50.9)	9.9 (49.8)
Average precipitation mm (inches)	23.6 (0.93)	21.4 (0.84)	51.0 (2.01)	93.3 (3.67)	216.8 (8.54)	198.5 (7.81)	189.7 (7.47)	227.1 (8.94)	335.9 (13.22)	288.7 (11.37)	44.6 (1.76)	11.6 (0.46)	1,702.1 (67.01)
Average precipitation days (≥ 1.0 mm)	1.9	1.9	3.4	5.4	12.4	13.4	14.1	15.6	18.0	14.4	3.8	1.0	105.3
Average relative humidity (%)	67.9	70.5	72.6	72.0	74.4	75.2	75.5	76.4	79.3	78.0	68.8	65.6	73.0
Average dew point °C (°F)	20.4 (68.7)	22.2 (72.0)	23.9 (75.0)	24.8 (76.6)	24.9 (76.8)	24.6 (76.3)	24.2 (75.6)	24.2 (75.6)	24.4 (75.9)	23.9 (75.0)	21.7 (71.1)	19.2 (66.6)	23.2 (73.8)
Mean monthly sunshine hours	216.0	215.8	234.2	226.6	196.2	158.4	140.7	128.9	129.6	157.5	194.8	213.5	2,212.2
Average ultraviolet index	10	12	12	12	12	12	12	12	12	11	10	9	11

Source 1: NOAA[59], Thai Meteorological Department (Feb–May record highs, 1951–2022[60]; Nov–Feb record lows, 1951–2021[61]), CNN (May record high)[62]

Vietnam Heat Waves

Vietnam has also experienced significant trends in observed temperature shifts and Urban Heat Island (UHI) effects across its urban areas. General Trends in Temperature Shift:

◦Studies have shown increasing trends in daily maximum temperature in most regions of Vietnam from 1961 to 2007, with five regions rising approximately 0.4°C per decade[63].

◦Analysis from 1961–2014 reported increasing trends in the highest maximum temperatures and frequency of hot days in northern Vietnam[64].

◦A nationwide warming trend of 0.11 to 0.32°C per decade was observed from 1981 to 2018, with stronger warming in areas like the North Delta and eastern Southern Vietnam[65].

◦For Hanoi, projections suggest the heat index could rise by 0.0777°C per year under the RCP 4.5 scenario and 0.08°C per year under RCP 8.5, with danger-level heat weeks potentially increasing to 5.5 to 6 weeks per 5 years[66]

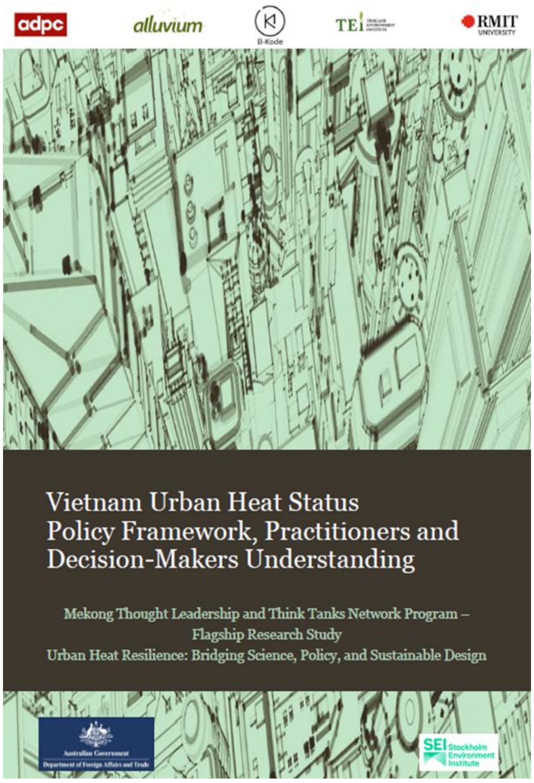


Figure 8 Vietnam Urban Heat Status- RMIT

Urban Heat effect in Vietnamese cities

Heat exposure in Vietnam has primarily been explored through the urban heat island (UHI) effect, climate projection, and scenarios assessment. A significant gap exists in projecting the combined impacts of UHI and climate change on temperature and heat stress beyond 2030, which likely underestimates future urban heat hazards. Existing evidence suggests that while greening strategies are crucial for adaptation, their cooling potential alone is insufficient to offset compounded impacts or fully protect populations.Crucially, no studies to date assess the potential socio-economic impacts and damages of extreme heat in Vietnam over the coming decades, highlighting a significant research gap. This requires understanding direct and indirect impact channels such as health, productivity, income, agriculture, and infrastructure, and their interaction with vulnerabilities. Overall, while extreme heat is gaining public attention, awareness among the general population remains low, and few experimental early warning systems are mentioned (RMIT Vietnam Literature Study)

- Da Nang City and Quang Nam Province (Central Vietnam) saw built-up areas expand from 77.24 km^2 to 96.92 km^2 and 183 km^2 to 226 km^2 respectively between 2000 and 2020. During this period, maximum temperatures increased at rates of 0.16°C/decade in Da Nang and 0.30°C/decade in Tam Ky, suggesting a strengthening UHI effect[67].

- In Can Tho City (Mekong Delta), the UHI effect was found to cover about 26% of the city, with urban land surface temperatures (LST) exceeding surrounding rural areas by more than 5°C. Industrial and public/special use zones showed the most intense UHI effects[68 69].
- In Hue City (North-Central Vietnam), simulations of greening strategies indicated that tree-based interventions were most effective in reducing pedestrian-level heat stress through shading, but had a limited effect on air temperature (maximum 1.3°C) and were insufficient alone against climate change impacts[70].
- In Ninh Thuan, increased respiratory-related admissions were observed during heat events, though a negative association for cardiovascular hospitalizations was seen in Ca Mau during similar conditions[71].

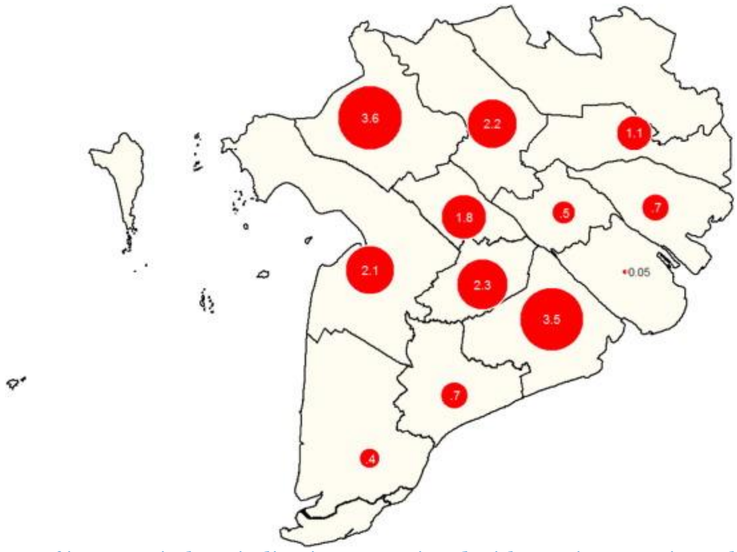


Figure 9 Percentage of increase in hospitalizations associated with 1 °C increase in Mekong delta (for all associated causes)[72]

Tien Giang Province Vietnam

In the Mekong Delta Region (2002-2014), a 1°C increase in daily average temperature was associated with a 1.3% rise in all-cause hospital admissions, 2.2% for infectious diseases, and 1.1% for respiratory diseases. The effect varied by province, from 0.05% in Tra Vinh to 3.6% in An Giang. A study found that a 5°C increase in average temperature corresponded to a 6.1% increase in hospital admissions across the Mekong Delta[73]. During extremely hot weather in 2024 , unexpected power outages in My Tho, a second-tier city in Tien Giang Province Vietnam, significantly disrupted daily life. The outages made indoor air very stuffy, prompting many family to use pools and ponds, seeking refuge in supermarkets during outages, which lasted 2-3 hours each time. The outages were due to a sudden increase in electricity demand, causing overloads. The electricity company had to cut power to replace equipment and increase capacity[74]. According to the Tien Giang Provincial Hydrometeorological Station, on April 29,2024, the highest temperature at My Tho Meteorological Station at 1 p.m. was 37.9 degrees Celsius (exceeding the historical record of April 28, 2024 by 0.1 degrees Celsius)[75].

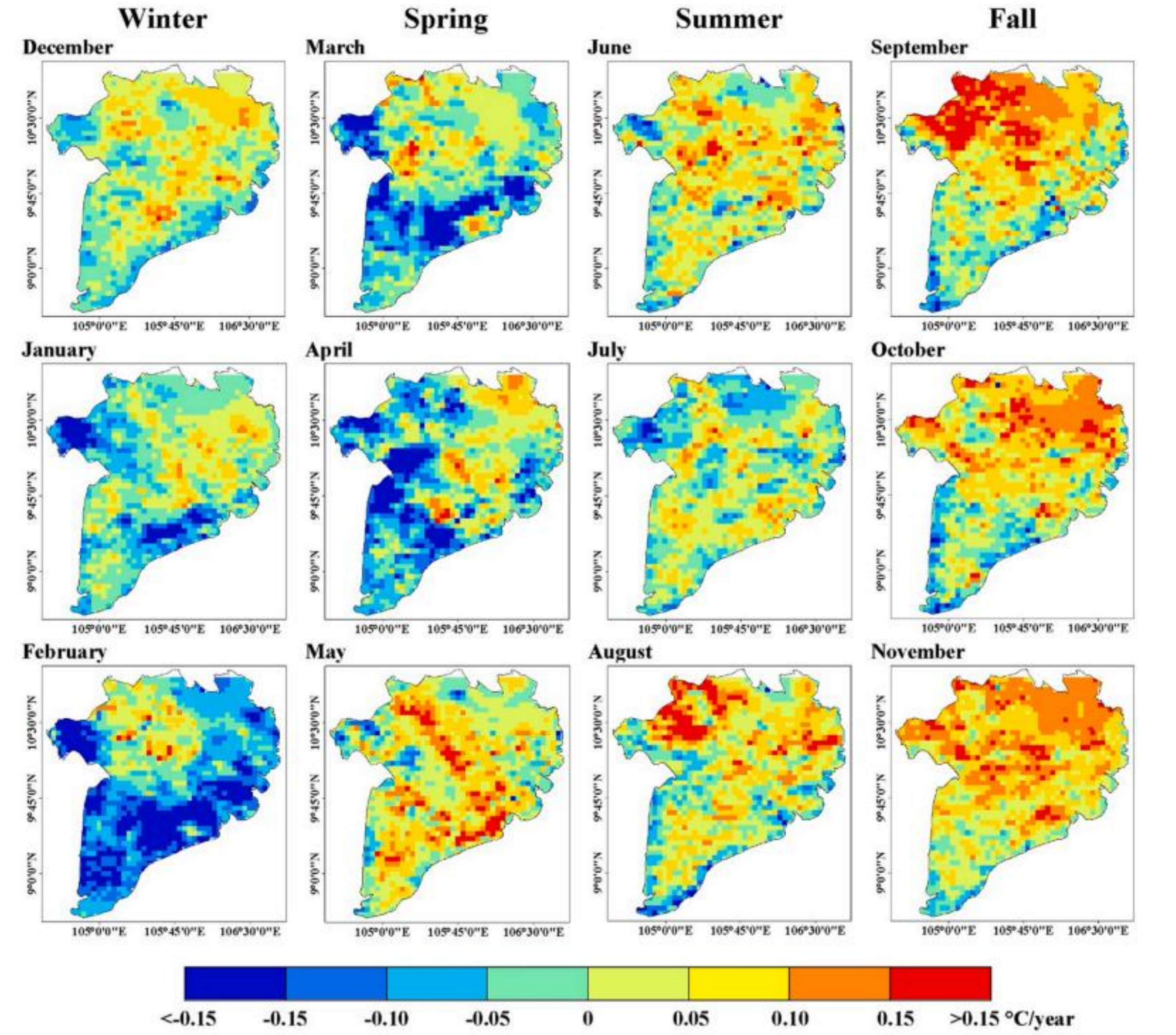


Figure 10 Distribution of mean land surface temperature (LST) in the day time (monthly and seasonal) from MODIS data from 2000 to 2018 (19years) for Vietnamese Mekong Delta.In particular, the warming associated with the spring (March-May) shows warm areas of daytime LST in the northwest and the southeast portions of VMD that are greater than 34 ◦C. [76]

Impacts of Extreme Heat in South East Asia

- **Mortality and Illness:** Heatwaves pose serious threats to public health, increasing risks of heat-related illness and mortality. In Bangkok, heat-related mortality is lowest around 28°C, but a mean daily temperature of 35°C could increase heat-related deaths by nearly 28%. At least 61 people have died in Thailand from heatstroke-linked conditions in 2024, almost double that of all of 2023.
- **Vulnerable Populations:** Children (~880,000) and elderly (~1,000,000 over 65) in Bangkok are especially heat-vulnerable. Women bear extra burdens as caregivers and face higher heat-related illness rates. People with disabilities face unique barriers during heatwaves, including mobility and communication challenges. Low-income households and informal settlement residents (e.g., in Klong Toey) suffer extreme indoor heat and lack cooling infrastructure.
- **Economic Impacts:** Extreme heat drains billions in worker productivity annually. Approximately 1.3 million outdoor workers in Bangkok (nearly 25% of the workforce) suffered major productivity and wage losses when heat intensified in 2019. Globally, working hours equivalent to 80 million full-time jobs could be lost due to heat stress by 2030. When a country's average temperature reaches at least 30°C, exports tend to decrease by an average of 3.4% per month, particularly in labor-intensive sectors.
- **Infrastructure and Energy Demand:** Extreme temperatures push electricity demand to record levels as people try to stay cool. This can lead to power outages, as seen in Mỹ Tho, Vietnam, where outages disrupted daily life during hot weather due to increased electricity demand causing overloads.
- **Environmental Toll:** The heat exacerbates drought conditions, leading to sharply dropping water levels in reservoirs and rivers and fears of widespread water shortages. Mass fish deaths have occurred in Vietnam due to dwindling water levels from intense heat

Figure 11 A busy street on a Hot day- Street vendors use colorful umbrellas and canopies to create shade along a busy urban thoroughfare in Vietnam, demonstrating grassroots adaptation to intense urban heat amid high-rise development and heavy motorcycle traffic. Credits- ADPC

4 Methodology for Urban Heat Assessment

The project employs a **comprehensive mixed-methods approach** to address the increasing challenge of urban heat in Southeast Asia, particularly focusing on Bangkok and sharing insights with second-tier cities in Vietnam. This dual strategy is essential for understanding both the measurable factors of urban heat and the contextual, subjective aspects like policy, social inclusion, and stakeholder perspectives.

The methodology integrates **quantitative and qualitative research techniques** to develop evidence-based policy recommendations and practical implementation guidelines.

Figure 12 Methodology (Authors)

4.1 Methodology Overview

The project's analytical framework is typically structured across several phases, including:

- **Phase 1: Inception and Planning**
- **Phase 2: Research, Analysis, and Design** (or Data Collection, Analysis Framework)
- **Phase 3: Implementation and Piloting** (or Dissemination, Engagement, and Policy Change)
- **Phase 4: Monitoring, Evaluation, and Consolidation**

This structured approach ensures comprehensive data collection, rigorous analysis, and the development of actionable, inclusive solutions.

4.2 Quantitative Components

The quantitative component primarily focuses on **advanced heat modeling** by B-Kode.

- **Urban Heat Modeling with TARGET:** The **Air-temperature Response to Green/blue-infrastructure Evaluation Tool (TARGET[77])**, a lightweight, efficient, and robust urban climate model, is utilized to evaluate how urban heat exposure evolves in space and time within the Bangkok Metropolitan Area (BMA).
    - **Model Inputs:** TARGET requires two main types of information: **meteorological time series** (air temperature, humidity, wind speed, air pressure, incoming radiation) and **land cover information** (fractions of roof, paved, vegetation, and water).
    - **Heatwave Definition:** A heatwave is defined as a period of at least three consecutive days where daily mean temperatures exceed the 95th percentile of the historical temperature distribution in the city's coolest district during the February to July period from 1985 to 2014, a threshold corresponding to **29.8°C daily mean temperature**. (B-Kode Analysis, 2025)
    - **Heatwave Metrics:** The analysis specifically focuses on three dimensions of heatwave risk: **frequency** (number of heatwave days), **persistence** (average heatwave duration), and **intensity** (temperature exceedance above the heatwave threshold).
    - **Simulations:** Simulations are conducted for both **present-day conditions (1985-2014)** and **projected mid-century conditions (2036–2065)**.
- **Meteorological and Climate Change Data:**
    - **Historical Data:** Historical meteorological data for 1985-2014 is extracted from the **ERA5-Land reanalysis product[78]** provided by ECMWF[79], offering hourly, gap-free coverage of all necessary variables at a ~9 km grid spacing. This reanalysis product integrates observational and modeling sources for a comprehensive climate representation.

- **Future Projections:** Climate change data is derived from **CMIP6 models**[80], specifically using the **shared socioeconomic pathway (SSP) 2.4-5 scenario**, which represents a moderate climate change mitigation effort where global mean temperatures are projected to rise by approximately 3°C above pre-industrial levels by 2100[81]. The climate change signal from CMIP6 (future minus historical) is added to the historical ERA5-Land data using a morphing method to create high-resolution weather data for TARGET. Monthly temperature increases show consistent warming, with the highest increases in January and December (over 1.8°C for Tmin and Tmean) and smallest in July to September (1.2–1.3°C for Tmax and Tmean) (B-Kode, 2025).

- **Urban Land Cover Characteristics:**
  - **Local Climate Zone (LCZ) Typology[82]:** Land cover for Bangkok is described using the **LCZ typology**, a holistic approach that classifies landscapes based on surface structure (buildings, trees) and cover (pervious/impervious) influencing temperature. This includes 10 built LCZ classes, each associated with urban canopy parameters (B-Kode, 2025).
  - **Scenarios:** Two contrasting land cover scenarios are simulated: a **business-as-usual (BAU) trajectory** and a **high-impact nature-based solution (NBS) intervention scenario** (B-Kode, 2025)..
  - **NBS Scenario Design:** The NBS scenario envisions a widespread increase in pervious, green, and irrigated surfaces, specifically targeting highly impervious districts. This involves increasing **tree canopy cover**, retaining water through **water sensitive urban design** (represented by irrigated grass and water surfaces), and a shift from impervious to pervious surfaces. Examples from Australian urban heat mitigation strategies (e.g., Parramatta Heat Strategy[83], Western Sydney's Turn Down the Heat Strategy[84], NSW Urban Design Guide[85], Canberra's Living Infrastructure Plan[86]) informed the development of location-specific NBS targets for Bangkok.

4.3 Qualitative Components

The qualitative methods involve **policy review, stakeholder mapping, and vulnerability assessments**, focusing on urban poor communities in Bangkok and Vietnamese cities.

- **Policy Review and Analysis:** This involves examining peer-reviewed articles, policy documents, and urban planning reports from both Thailand and Vietnam to identify **policy gaps** and understand **systemic barriers and opportunities** for integrating heat resilience into urban planning. The project assesses how current policies address urban heat, particularly in the context of women, persons with disabilities, and marginalized communities.
- **Stakeholder Mapping and Engagement:**
  - **Multi-stakeholder Approach:** The project employs a **multi-stakeholder engagement process** to ensure social inclusion and foster collaborative solutions. Key stakeholders include government agencies (e.g., Bangkok Metropolitan

Administration, Ministry of Health), private sector entities, civil society organizations, and vulnerable population advocacy groups.

- **Participatory Workshops and Surveys: Participatory workshops and surveys** are mandated to ensure representation from diverse groups, including **women, the elderly, youth, and persons with disabilities**, enabling the co-design of solutions. These workshops encourage sharing experiences on how heat affects different households.
- **Focus Groups: Focus groups** are conducted with key populations to identify **barriers, needs, and local solutions**. Discussions with provincial policymakers, academic researchers, and international experts in Vietnam have already taken place to discuss urban heat challenges in Vietnamese cities like My Tho.
- **Targeted Outreach and Communication:** Tailored communication campaigns using local media, social media, community meetings, and places of worship are launched to disseminate heat-safety information. Materials are developed in **multiple languages and formats** (e.g., Thai, English, Vietnamese) to ensure inclusivity.

- **Vulnerability Assessment:** A comprehensive assessment framework is developed, incorporating three primary weighted factors to identify the most vulnerable districts in Bangkok. This approach recognizes that vulnerability is not solely defined by heat intensity but also by social and behavioral factors.
  - **Framework Components:**
    1. **Heat Exposure (40% weight):** Evaluates heatwave frequency, severity, and duration as indicators of daily heat conditions and nighttime temperature effects.
    2. **Heat Vulnerability (40% weight):** Focuses on population and built environment characteristics.
       - **Demographic Vulnerability (60% of this component):** Indicators include **population density**, **birth rate** (as a proxy for young children), and **female percentage** (due to higher heat risks for women).
       - **Built Environment Vulnerability (40% of this component):** Indicators include **housing density** and **green space ratio** (inverse).
    3. **Behavioural Exposure (20% weight):** Considers resources and systems enabling coping with heat stress, using **school density** (inverse) and **teacher-student ratio** as proxies for educational resources and access to cooling/awareness.
  - **Data Collection:** This analysis uses available **district-level data for Bangkok**. All activities aim to generate **gender-disaggregated and disability-inclusive data**. Community volunteers, including women and youth, are engaged to assist with data logging.
- **Field Observations and Site Visits:** Priority hotspots identified from modeling results undergo fieldwork to **validate heat impacts, assess NbS suitability, and gather**

community input. This includes examining informal settlements to gain insights into the lived experiences of vulnerable populations.

4.4 Integration and Synthesis

The project integrates findings through a **multi-criteria analysis (MCA)**, combining technical, social, and economic factors to ensure proposed interventions are not only technically sound but also socially equitable, economically viable, and politically feasible. This leads to the development of **evidence-based policy recommendations** and practical implementation guidelines for urban heat management.

4.5 Quality Assurance and Deliverables

- **Quality Assurance:** The methodology includes **cross-verification of data sources**, **peer-reviewing findings**, and conducting **sensitivity and uncertainty assessments** to ensure robustness. **Stakeholder validation workshops** are organized to present results and ensure community voices inform final policy recommendations.
- **Deliverables:** Key outputs include a **flagship report**, **journal articles**, and various **communication products** (e.g., policy briefs and fact sheets) designed to guide the use of Nature-based Solutions (NbS) in Bangkok and the broader Mekong region. A dedicated **GEDSI Implementation Plan** is a core deliverable, ensuring inclusion throughout the project.

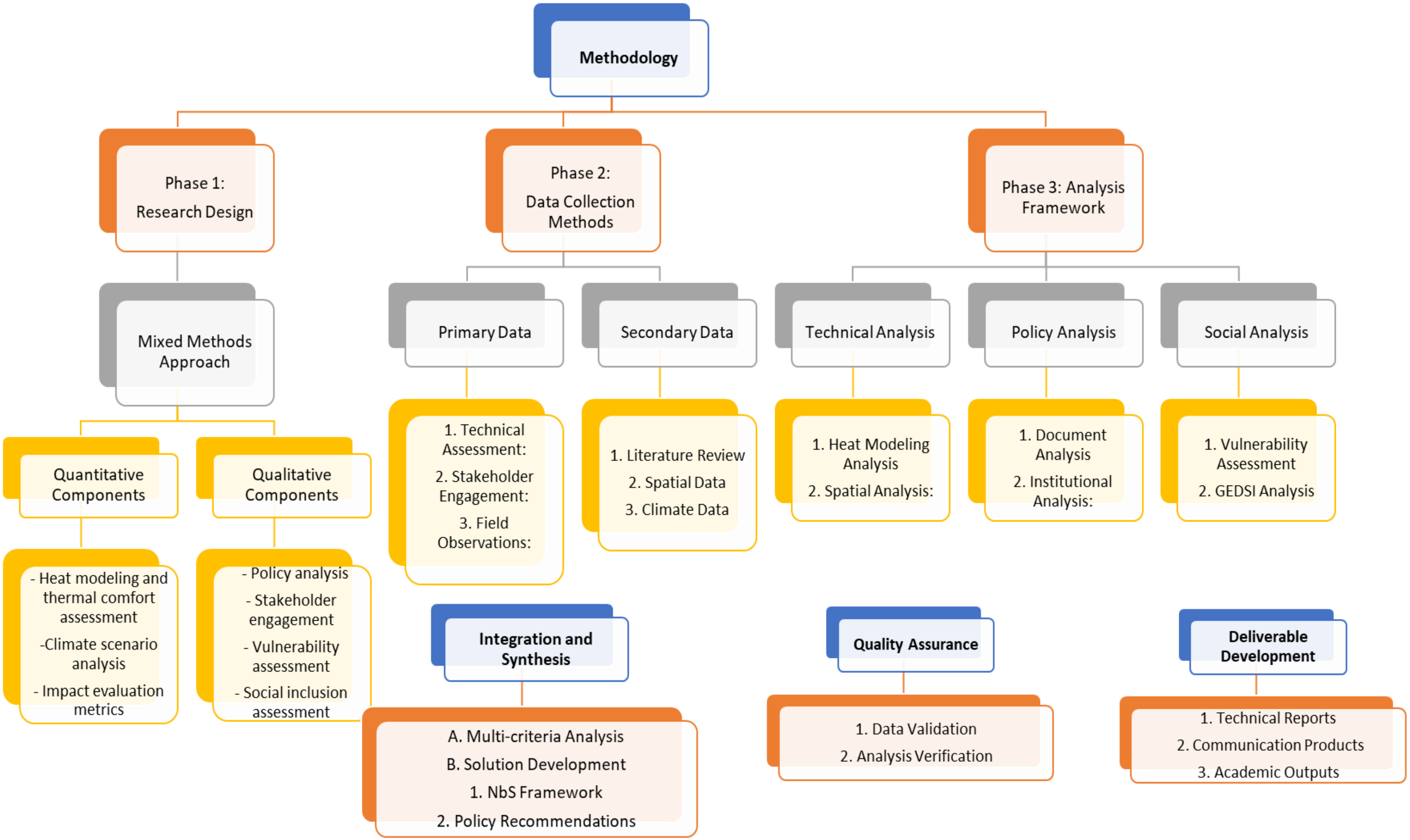


Figure 13 Detailed Methodology (Authors)

5 Urban Heat Modeling Results for Bangkok

The modeling results from B-Kode confirm significant intra-urban heat differences in Bangkok, both historically and in future projections. This technical analysis evaluates urban heat exposure and the potential of nature-based solutions (NBS) to mitigate heat stress in Bangkok Metropolitan Area. Using the TARGET urban climate model, researchers examined present-day conditions (1985-2014) and projected mid-century scenarios (2036-2065) under two land cover approaches: business-as-usual (BAU) development and high-impact nature-based interventions.

Figure 14 Urban Heat Modeling and NBS scenarios Technical report and communication Leaflet developed under the project

5.1 Past and Present Heatwave Trends (1985-2014)

- **Pronounced Urban Overheating:** Central and densely built-up districts in the Bangkok Metropolitan Area (BMA) exhibit the highest temperatures, often exceeding 30°C during the hot season (February to July). In contrast, peripheral and less urbanized areas are significantly cooler, averaging 27–28°C.
- **Intra-urban Variability:** Central districts can be up to 3°C warmer than the average of the five coolest peripheral districts, indicating substantial heat exposure disparities linked to land use, surface cover, and urban morphology.
- **Heatwave Burden:** Central districts consistently experience the highest heatwave burden. These areas face up to **100 heatwave days per season**, with events lasting up to **40 consecutive days** in some districts, and greater severity, with average daily mean temperature exceedances reaching **2°C above the heatwave threshold**.
- **Peripheral Contrast:** Peripheral districts generally record fewer heatwave days (below 20), shorter durations (below 10 days), and less intense events (exceedances below 0.9°C).

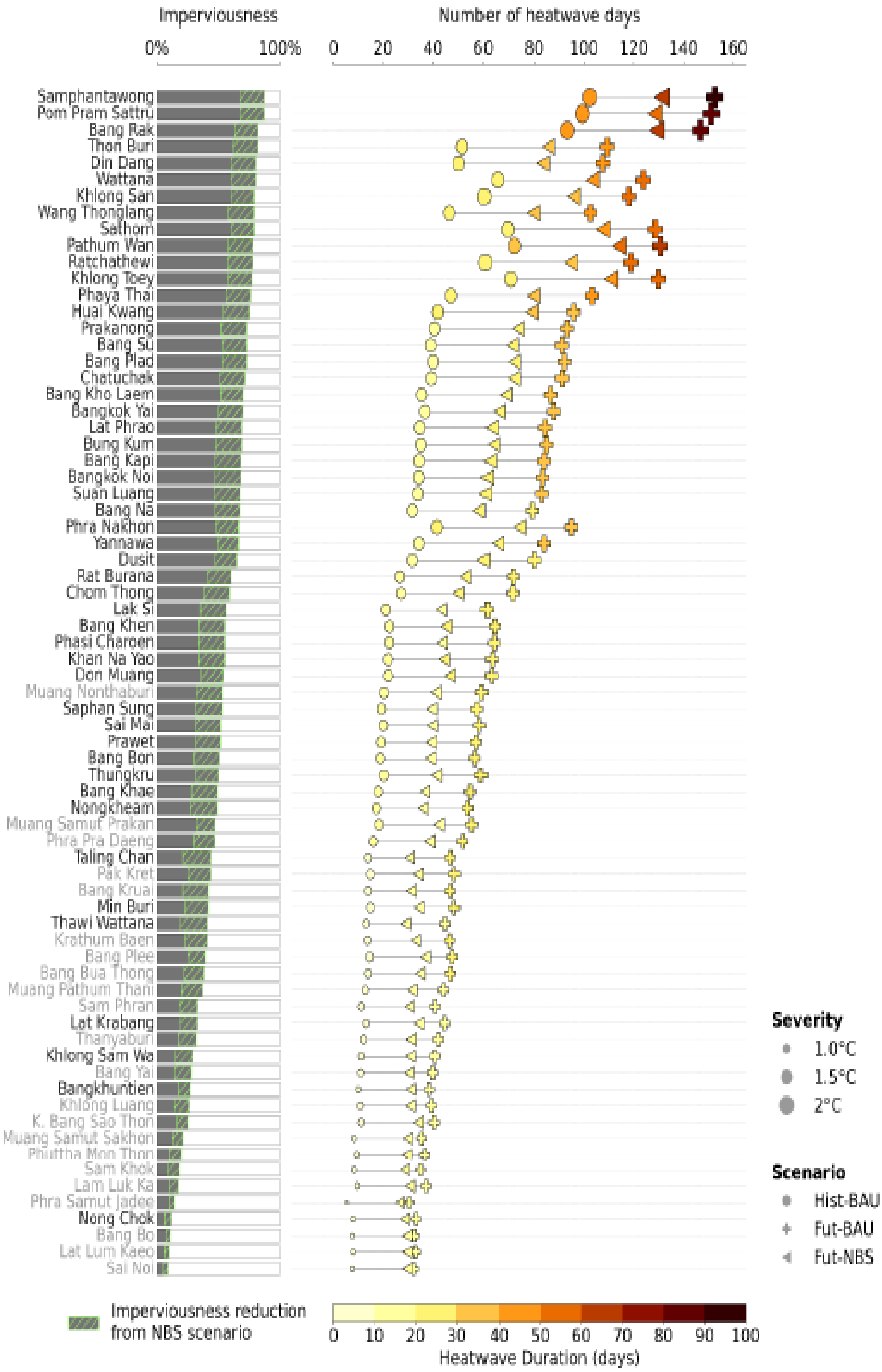


Figure 15 . Heatwave trends in Bangkok: past, future, and the NbS impact.(B-Kode, 2025)

Future Heatwave Projections (2036-2065, Business-as-Usual Scenario)

Under a business-as-usual (BAU) land cover scenario and the SSP2-4.5 moderate emissions scenario, Bangkok is projected to warm by another **1.4°C by mid-century** relative to the 1985–2014 baseline. This will lead to a substantial intensification of urban heat stress.

- **Increased Frequency:** The number of heatwave days is expected to increase dramatically, with central districts experiencing up to **55 additional days per season**. This intensification is concentrated in core urban areas already burdened by heat.
- **Extended Duration:** The average duration of heatwave events is projected to rise significantly, with some areas experiencing up to **45 more consecutive heatwave days**, indicating a shift towards longer and more persistent extreme heat episodes.
- **Increased Severity at Urban Fringe:** While central districts show relatively modest increases in temperature exceedance during heatwaves (due to already high baselines), many peripheral districts are expected to experience sharper increases, sometimes exceeding **0.5°C above their historical averages**. This highlights that heatwave intensity will become more pronounced at the urban fringe.
- **Overall Impact:** Without intervention, many districts may see an additional **40–60 heatwave days per year by mid-century**.

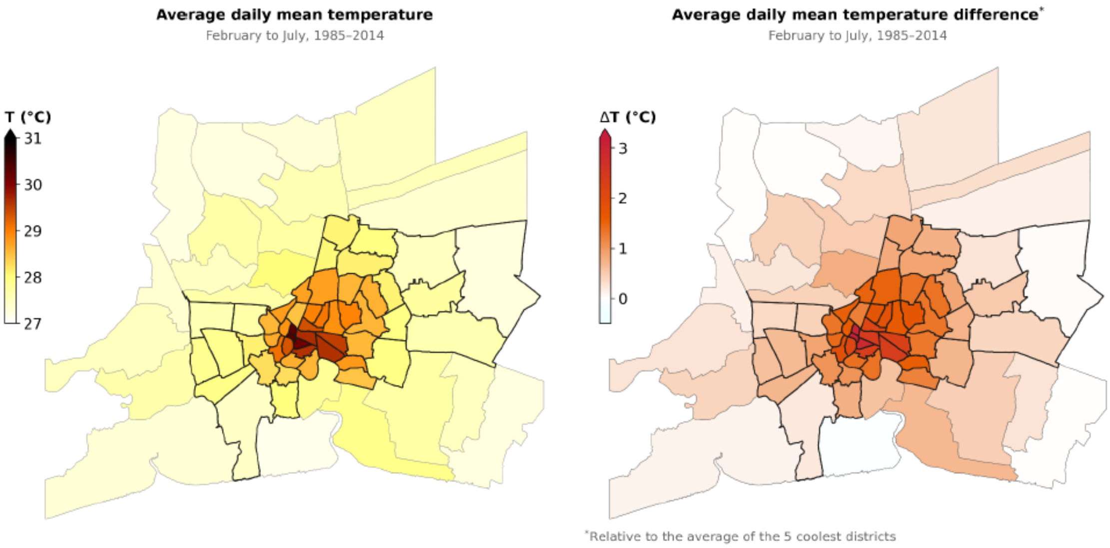
5.2 Key Findings

Current Heat Patterns

Bangkok displays pronounced intra-urban temperature variations, with central and western districts experiencing significantly higher temperatures than peripheral areas. The analysis reveals:

- **Temperature disparities**: Central districts average temperatures exceeding 30°C, while peripheral areas remain around 27-28°C
- **Heat island intensity**: Central districts experience temperatures up to 3°C warmer than the city's coolest areas
- **Heatwave burden**: Dense urban cores face up to 100 heatwave days per season, with events lasting up to 40 consecutive days

A HEATWAVE IS DEFINED IN THIS ANALYSIS (B-KODE) AS A PERIOD OF AT LEAST THREE CONSECUTIVE DAYS WHERE DAILY MEAN TEMPERATURES EXCEED THE 95TH PERCENTILE OF THE HISTORICAL TEMPERATURE DISTRIBUTION IN THE CITY'S COOLEST DISTRICT DURING FEBRUARY-JULY (1985-2014). THIS THRESHOLD CORRESPONDS TO A DAILY MEAN TEMPERATURE OF 29.8°C.



Notes: The five coolest districts are white-colored in the right panel, and are Sai Noi (THA.36.6_1), Lat Lum Kaeo (THA.37.3_1), Phra Samut Jadee (THA.57.6_1), Bang Bo (THA.57.1_1), Nong Chok (THA.3.28_1). Values in brackets refer to the GID_2 id from the gadm database.
Source: B-Kode analysis based on TARGET simulations.

Figure 16 Central districts within the Bangkok Metropolitan area exhibit significantly higher temperatures compared to their surrounding less urbanised districts (B-Kode, 2025

Key metrics for evaluating heatwave risk include:

- **Frequency:** Number of heatwave days.
- **Persistence (Duration):** Average heatwave duration, or the length of the longest annual heatwave.
- **Intensity (Severity):** Temperature exceedance above the heatwave threshold.

Climate Change Projections

Under moderate emissions scenarios (SSP2-4.5), Bangkok faces substantial warming by mid-century:

- **Temperature increase**: Projected 1.4°C rise in annual average temperatures by 2050
- **Intensified extremes**: Central districts may experience up to 55 additional heatwave days per season
- **Extended duration**: Heatwave events projected to last up to 45 more consecutive days
- **Spatial expansion**: Peripheral districts expected to experience sharper increases in heatwave severity

CENTRAL DISTRICTS IN BANGKOK CONSISTENTLY EXPERIENCE THE HIGHEST HEATWAVE BURDEN, WITH UP TO 100 HEATWAVE DAYS PER SEASON, EVENTS LASTING UP TO 40 CONSECUTIVE DAYS, AND SEVERITY REACHING 2°C ABOVE THE THRESHOLD. PERIPHERAL DISTRICTS ARE COOLER, WITH FEWER HEATWAVE DAYS (BELOW 20), SHORTER DURATIONS (BELOW 10 DAYS), AND LESS INTENSITY (EXCEEDANCES BELOW 0.9°C).

Nature-Based Solutions Impact

The NBS scenario demonstrates significant cooling potential through strategic interventions:

Surface Transformation

- Reduction of impervious surfaces by up to 25% in central and western districts
- Increased tree canopy cover targeting 20-35% depending on land use type
- Enhanced water-sensitive design features including rainwater tanks, gardens, and wetlands

Heat Mitigation Benefits

- **Frequency reduction**: Up to 24 fewer heatwave days in urban hotspots
- **Duration shortening**: Average heatwave duration reduced by over 30 days in some districts
- **Intensity dampening**: Temperature reductions of up to 0.4°C during extreme events
- **Spatial consistency**: Greatest benefits align with areas of highest intervention

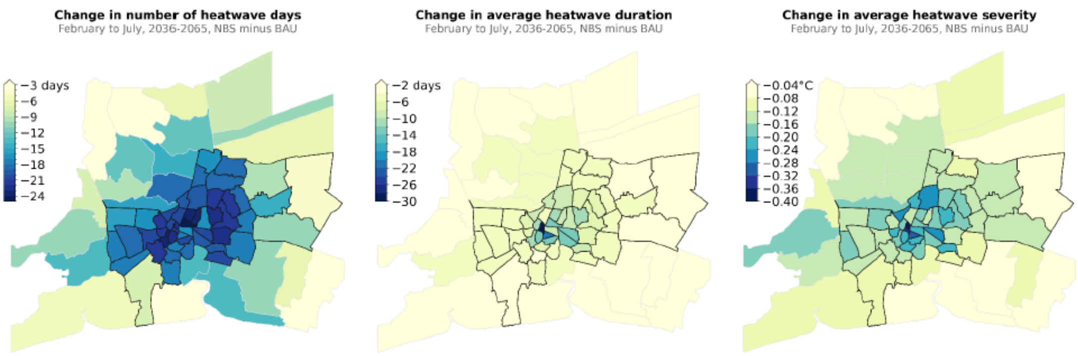


Figure 17 Extreme heatwave characteristics dampened by nature-based solutions (BKode, 2025)

5.3 Implications

While NBS interventions provide substantial cooling benefits, they cannot entirely offset projected climate warming. The analysis suggests that even with ambitious greening strategies, future heat conditions will likely exceed current levels in many districts. This underscores the need for comprehensive adaptation strategies combining NBS with complementary measures such as heat alert systems, cooling centers, and climate-resilient urban planning policies.

The spatially targeted nature of NBS benefits supports prioritizing interventions in high-imperviousness districts where cooling effects are most pronounced, while recognizing that peripheral areas will require attention as heat risks expand citywide under continued warming.

6 Vulnerability Analysis

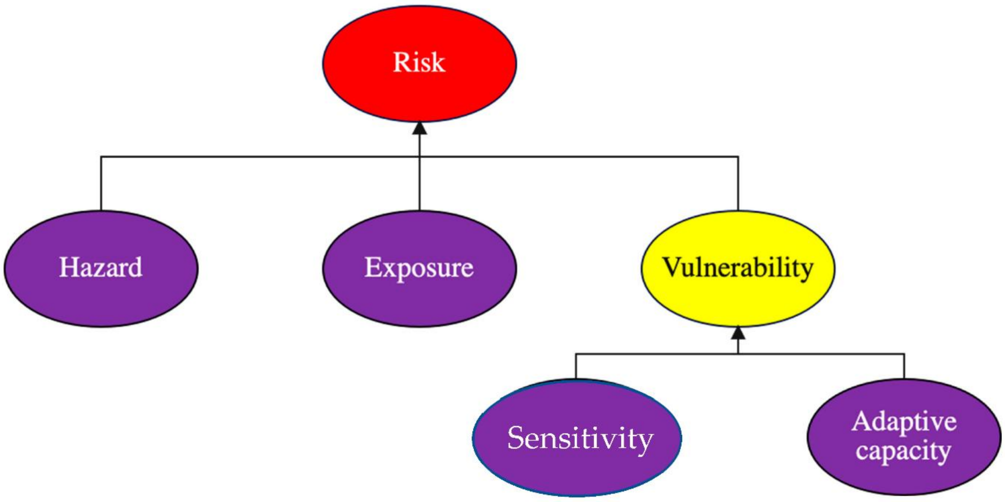


Figure 18 The IPCC's risk assessment framework Source: IPCC. Climate Change (IPCC, 2014)

Vulnerability analysis is essential for comprehending the susceptibility and resilience of communities facing urban heat .By examining social, economic, and environmental factors, this assessment provides valuable insights into the particular vulnerabilities experienced by different areas and populations[87] [88]. According to the Intergovernmental Panel on Climate Change (IPCC), a greater adaptive capacity to urban heat induced by climate change can significantly mitigate socioeconomic losses. This enhanced capacity not only contributes to reducing these losses but also fosters greater individual resilience during extreme heat events.[89]

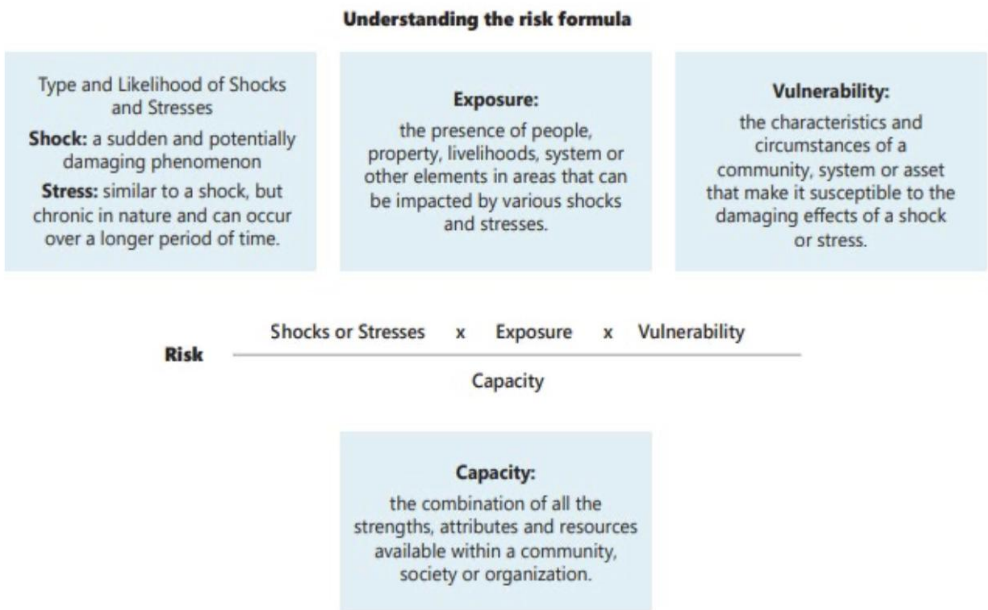


Figure 19 Understanding the relationship between risk, vulnerability and capacity (National Institute of Disaster Management India, 2005)

While most studies have primarily concentrated on analyzing the relationship between current and future heat-related mortality, there has been a notable lack of attention to the personal factors that contribute to the social vulnerability of citizens. Consequently, this dimension of vulnerability remains insufficiently recognized in urban adaptation measures and policies[90] [91].

In response to the growing concerns about urban heat vulnerability in Bangkok, we developed a comprehensive assessment framework that incorporates three primary weighted factors: Heat Exposure (40%), Heat Vulnerability (40%), and Behavioural Exposure (20%). The exposure component evaluates heat wave frequency, severity, and duration as indicators of daily heat conditions and nighttime temperature effects, while vulnerability focuses on demographic vulnerabilities including population density, birth rates as proxies for young age groups, and death rates as indicators of elderly populations and pre-existing health conditions. This analysis is based on a comprehensive methodology for assessing heat vulnerability across Bangkok's districts using available district-level data[92]. The analysis aims to identify the most vulnerable districts to urban heat effects, enabling targeted policy interventions. The current methodology adapts established heat vulnerability frameworks to Bangkok's specific context and data limitations.

Figure 20 Motorcyclists stop in the shade of a skytrain line on a hot day in Bangkok, Thailand, Friday, May 3, 2024 (Sakchai Lalit / AP.93)

6.1 Framework Development and Rationale

In response to the growing concerns about urban heat vulnerability in Bangkok, we developed a comprehensive assessment framework that incorporates three primary weighted factors: Heat

Exposure (40%), Heat Vulnerability (40%), and Behavioural Exposure (20%). The exposure component evaluates heat wave frequency, severity, and duration as indicators of daily heat conditions and nighttime temperature effects, while vulnerability focuses on demographic vulnerabilities including population density, birth rates as proxies for young age groups, and death rates as indicators of elderly populations and pre-existing health conditions.

6.2 Purpose and Scope

This analysis:
• Evaluates heat vulnerability at the district level across Bangkok
• Utilizes officially available data sources
• Identifies priority areas for heat mitigation interventions
• Provides an evidence base for policy decisions and resource allocation

Data Availability and Limitations

The methodology has been specifically tailored to use only data points confirmed to be available at the district level for Bangkok. Many traditional vulnerability indicators are unavailable, necessitating a modified approach. Specifically, the analysis lacks: • Socioeconomic indicators (income levels, poverty rates) • Detailed age distribution (only birth counts available as proxy) • Health infrastructure and heat-related illness data • Air conditioning prevalence

6.3 Methodology

Conceptual Framework

The analysis follows a three-component vulnerability framework:

1. **Heat Exposure (40%)**: Physical heat conditions experienced
2. **Vulnerability (40%)**: Population and built environment characteristics that influence vulnerability
3. **Behavioural Exposure (20%)**: Resources and systems that enable coping with heat stress

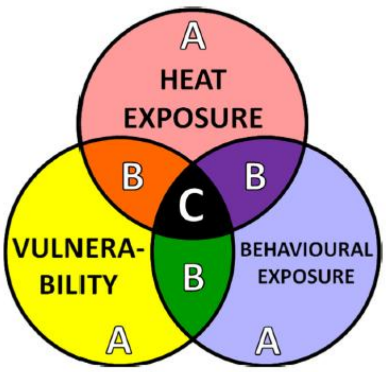


Figure 21. Factors required to identify neighbourhoods of high (C), medium (B) and moderate (A) priority for nature-based solutions implementation for surface temperature heat mitigation94

Indicator Selection and Justification

Component 1: Heat Exposure (40%)

Table 2: Heat Exposure			
Indicator	**Weight**	**Justification**	**Data Source**
Heat wave frequency (HWF)	35%	Measures how often heat waves occur, directly indicating exposure threat	B-kode calculations
Heat wave severity (HWS)	35%	Quantifies the intensity of heat events above threshold temperatures	B-kode calculations
Heat wave duration (HWD)	30%	Longer heat waves increase cumulative health impacts	B-kode calculations

Justification: These three indicators provide a comprehensive picture of the heat hazard itself, capturing frequency, intensity, and duration of extreme heat events—all critical dimensions of heat exposure.

Component 2: Heat Vulnerability (40%)

2A: Demographic Vulnerability (60%)

Table 3: Demographic Vulnerability			
Indicator	**Weight**	**Justification**	**Data Source**
Population density	40%	Higher density areas experience greater urban heat island effects and complicate heat dissipation	Total population 2022 / District area- BMA
Birth rate	30%	Proxy for presence of infants and young children who are physiologically vulnerable to heat	Total births 2022 / Total population 2022-BMA
Female percentage	30%	Research shows gender disparities in heat vulnerability, with females often experiencing higher risks[95]	Female population 2022 / Total population 2022-BMA

Justification: These demographic factors capture population concentration and composition characteristics known to influence heat vulnerability. Birth rate serves as a proxy for the presence of infants and young children, who are among the most physiologically vulnerable to heat stress.

2B: Built Environment Vulnerability (40%)

Table 4: Built Environment Vulnerability			
Indicator	**Weight**	**Justification**	**Data Source**
Housing density	60%	Higher density of structures contributes to heat retention and urban heat island effects	Total houses 2022 / District area- BMA
Green space ratio (inverse)	40%	Lack of green space increases heat retention; included as inverse (1-ratio) so higher values indicate higher vulnerability	Area of green spaces / District area- BMA

Justification: These indicators capture key built environment factors that contribute to heat vulnerability. Housing density represents urban development intensity, while green space ratio (inverted) captures the lack of natural cooling features.

Component 3: Behavioural Exposure (20%)

Table 5: Behavioural Exposure

Indicator	Weight	Justification	Data Source
School density (inverse)	50%	Schools often serve as cooling centers and education hubs; higher density indicates better access (hence inverse relationship to vulnerability)	Number of schools / District area- BMA
Teacher-student ratio	50%	Proxy for educational resources that can translate to heat awareness and response capacity	Number of teachers / Number of students- BMA

Justification: Without direct data on income, air conditioning prevalence, or health services, educational resources serve as a proxy for behavioural exposure. Schools often function as cooling centers during heat events, and educational resources correlate with better information access and response capabilities.

Note: For school density, we use inverse normalization since higher density means better access (lower vulnerability).

Calculation Method

All indicators are normalized using min-max normalization:

Normalized Value = (X - Xmin) / (Xmax - Xmin)

Component scores are calculated as weighted averages of their respective normalized indicators. The final Heat Vulnerability Index (HVI) is calculated as:

HVI = (0.4 × Heat_Exposure_Score) + (0.4 × Vulnerability_Score) + (0.2 × Behavioural_Exposure_Score)

Higher HVI values indicate greater vulnerability.

6.4 Results

District Heat Vulnerability Rankings

Based on the calculated Heat Vulnerability Index (HVI), Bangkok's districts show significant variations in their vulnerability to heat stress. The top 10 most vulnerable districts are:

Table 6: Most Vulnerable Districts

Rank	District	Heat Vulnerability Index	Heat Exposure Score	Vulnerability Score	Behavioural Exposure Score
1	Samphantawong	0.750	1.000	0.626	0.500
2	Pom Pram Sattru	0.720	0.981	0.731	0.177
3	Bang Rak	0.635	0.930	0.487	0.343
4	Pathum Wan	0.592	0.680	0.529	0.540
5	Khlong Toey	0.560	0.673	0.458	0.540
6	Ratchathewi	0.554	0.603	0.585	0.396
7	Din Dang	0.536	0.513	0.545	0.565
8	Sathorn	0.519	0.663	0.391	0.489
9	Khlong San	0.519	0.594	0.606	0.195
10	Wattana	0.509	0.639	0.442	0.381

Conversely, the least vulnerable districts include:

Table 7: Least Vulnerable Districts

Rank	District	Heat Vulnerability Index	Heat Exposure Score	Vulnerability Score	Behavioural Exposure Score
50	Bangkhuntien	0.165	0.015	0.149	0.497
49	Nong Chok	0.201	0.000	0.228	0.551
48	Khlong Sam Wa	0.228	0.052	0.270	0.499
47	Lat Krabang	0.245	0.079	0.273	0.522
46	Min Buri	0.268	0.117	0.308	0.490
45	Taling Chan	0.271	0.099	0.305	0.547

Heat Vulnerability ranking- Bangkok Districts

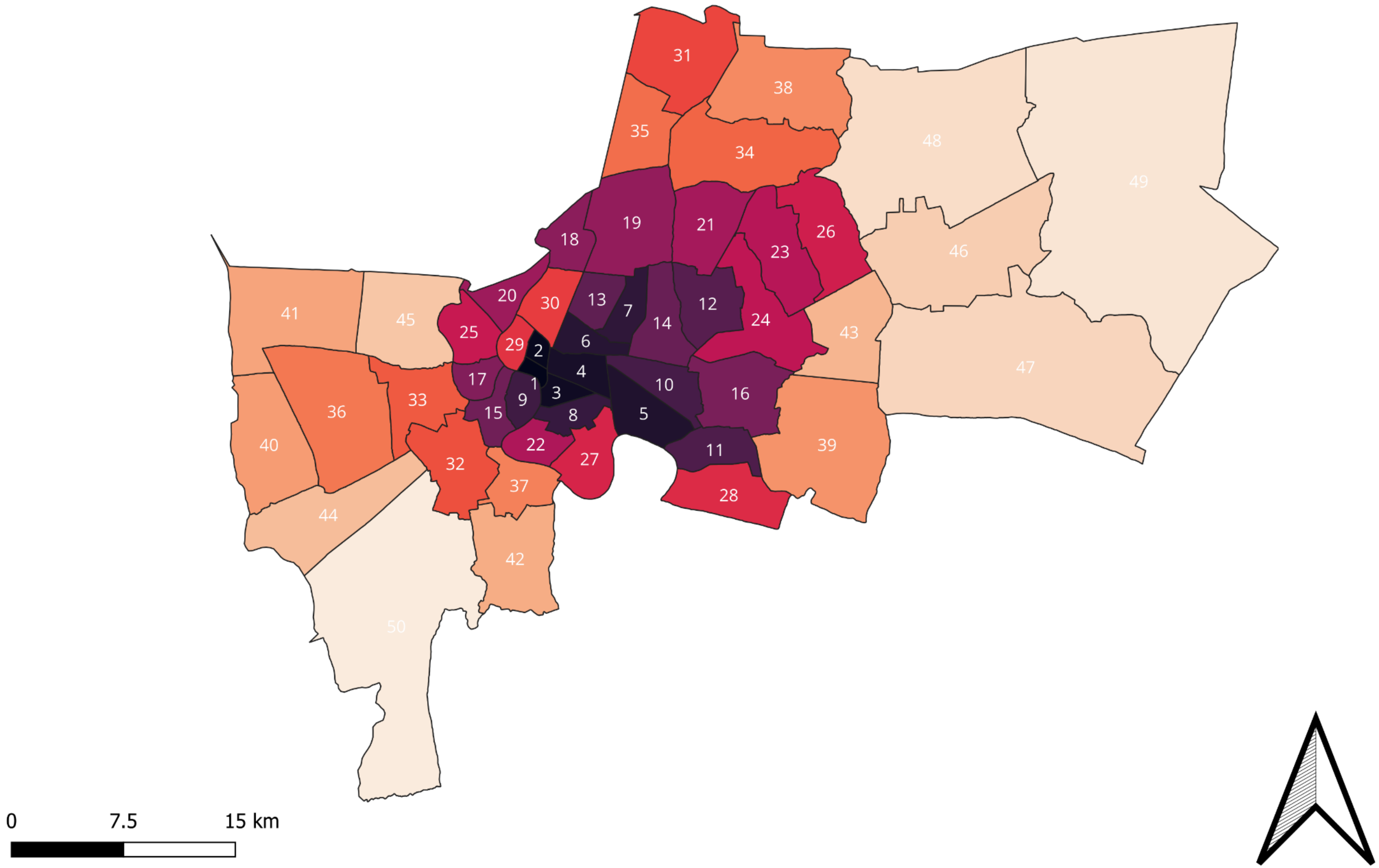


Figure 22 Heat Vulnerability Rankings Bangkok Districts (ADPC, 2025)

Spatial Distribution of Vulnerability

The spatial distribution of heat vulnerability across Bangkok reveals a clear pattern: central urban districts generally show higher vulnerability than peripheral districts. This pattern is characterized by:

1. **Core Urban Area Vulnerability**: The highest vulnerability is concentrated in the dense, central business districts and historical center of Bangkok, including Samphantawong, Pom Pram Sattru, Bang Rak, and Pathum Wan.
2. **Transitional Zone**: A belt of moderately vulnerable districts surrounds the core, including areas like Wang Thonglang, Suan Luang, and Huai Kwang.
3. **Peripheral Low Vulnerability**: Outlying districts such as Bangkhuntien, Nong Chok, and Khlong Sam Wa demonstrate significantly lower vulnerability indices, coinciding with lower population densities and greater green space.
4. **Riverside Variations**: Districts along the Chao Phraya River show varied vulnerability patterns, with some (Khlong San, Bang Rak) highly vulnerable while others show moderate vulnerability.

Component Analysis:

Heat Exposure Patterns

Heat exposure scores across Bangkok districts reveal:
• **Extreme Heat Islands**: Samphantawong (1.000), Pom Pram Sattru (0.981), and Bang Rak (0.930) experience the highest heat exposure, characterized by:

- High heat wave frequency (93.27-102.37 events)
- Maximum heat wave severity (1.85-1.91)
- Extended heat wave duration (41.77-43.8 days)
- Minimal green space coverage (0.007-0.018 ratio)
- Extremely high population and housing density

• **Moderate Heat Zones**: Districts like Chatuchak (0.391), Bang Plad (0.414), and Bang Kapi (0.366) show intermediate heat exposure with:

- Moderate heat wave frequency (34-40 events)
- Moderate heat wave severity (1.4-1.44)
- Moderate green space coverage (0.026-0.075 ratio)
- Substantial but not extreme urban density

• **Low Heat Exposure Areas**: Bangkhuntien (0.015), Nong Chok (0.000), and Khlong Sam Wa (0.052) experience minimal heat exposure due to:

- Low heat wave frequency (8-11.23 events)
- Minimal heat wave severity (0.85-0.95)
- Short heat wave duration (7.63-8.43 days)
- Extensive green space coverage (0.115-0.403 ratio)

- Low population and housing density

The data shows a strong correlation between urbanization intensity, reduced green spaces, and increased heat exposure, demonstrating the urban heat island effect in Bangkok's core districts.

Vulnerability Patterns

Sensitivity to heat stress varies considerably across Bangkok's districts:

• **High Sensitivity Districts**: Pom Pram Sattru (0.731), Ratchathewi (0.585), and Khlong San (0.606) show elevated sensitivity due to:

- High demographic vulnerability scores
- Unfavorable built environment characteristics
- Population age structure concerns (high proportion of vulnerable age groups)
- High birth rates in some cases (e.g., Ratchathewi with birth rate of 0.0986)

• **Moderate Sensitivity Districts**: Bang Su (0.462), Khlong Toey (0.458), and Bang Plad (0.445) demonstrate mid-level sensitivity with:

- Mixed demographic profiles
- Variable built environment quality
- Moderate population density impacts

• **Low Sensitivity Districts**: Bangkhuntien (0.149), Don Muang (0.272), and Nong Chok (0.228) exhibit minimal sensitivity characterized by:

- More favorable demographic structure
- Less problematic built environment configurations
- Lower population pressures

The sensitivity analysis reveals that central districts with older buildings, higher population density, and higher concentrations of vulnerable populations face greater challenges during heat events.

Behavioural Exposure Patterns

Behavioural exposure shows interesting patterns across Bangkok:

• **High Behavioural Exposure Districts**: Don Muang (0.740), Prakanong (0.802), and Huai Kwang (0.614) demonstrate strong behavioural exposure

• **Moderate Behavioural Exposure Districts**: Bang Kapi (0.486), Chatuchak (0.511), and Saphan Sung (0.477) show mid-range adaptive capacity

• **Low Behavioural Exposure Districts**: Thon Buri (0.131), Phra Nakhon (0.104), and Khlong San (0.195) exhibit limited adaptive capacity

The behavioural exposure analysis highlights the importance of social infrastructure, particularly education, in building resilience against heat-related stresses.

6.5 Key Findings and Implications

Most Vulnerable Districts

The analysis identifies three distinct tiers of vulnerability:

1. **Critical Vulnerability (HVI > 0.6)**:
    - Samphantawong (0.750)
    - Pom Pram Sattru (0.720)
    - Bang Rak (0.635)

These districts require immediate and comprehensive heat mitigation interventions due to their extreme vulnerability scores across multiple dimensions.

2. **High Vulnerability (HVI 0.5-0.6)**:
    - Pathum Wan (0.592)
    - Khlong Toey (0.560)
    - Ratchathewi (0.554)
    - Din Dang (0.536)
    - Sathorn (0.519)
    - Khlong San (0.519)
    - Wattana (0.509)

These districts need targeted interventions addressing their specific vulnerability drivers.

3. **Moderate Vulnerability (HVI 0.4-0.5)**:
    - Wang Thonglang (0.481)
    - Phaya Thai (0.473)
    - Huai Kwang (0.444)
    - Thon Buri (0.441)
    - Prakanong (0.503)

These districts would benefit from proactive planning and moderate investments in heat resilience.

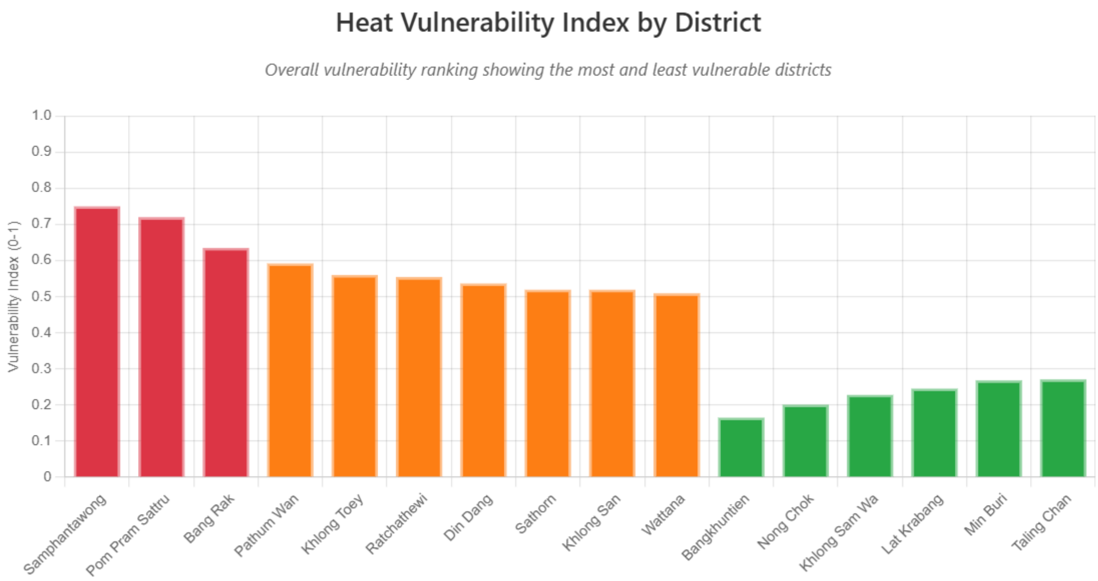


Figure 23 Heat Vulnerability Index by Districts (ADPC, 2025)

Vulnerability Drivers by District

Different vulnerability drivers dominate across Bangkok's districts:

1. **Exposure-Driven Vulnerability**:
   - **Samphantawong**: Extreme heat exposure (1.000) drives vulnerability, with minimal green space (0.007 ratio) and the highest population density (14,242 people/km²)
   - **Pom Pram Sattru**: Nearly maximum heat exposure (0.981) with minimal green infrastructure (0.018 ratio) and extreme housing density (30,192 units/km²)
   - **Bang Rak**: Extreme heat exposure (0.930) combined with very limited green space (0.018 ratio)
2. **Sensitivity-Driven Vulnerability**:
   - **Ratchathewi**: High sensitivity (0.585) driven by demographic factors including the highest birth rate (0.0986) and death rate (0.0666)
   - **Khlong San**: Very high sensitivity (0.606) combined with limited green space (0.029 ratio)
   - **Din Dang**: High sensitivity (0.545) paired with high housing density and limited green space
3. **Behavioural Exposure-Limited Vulnerability**:
   - **Thon Buri**: Extremely limited adaptive capacity (0.131) despite moderate exposure
   - **Phra Nakhon**: Very poor adaptive capacity (0.104) combined with high exposure
   - **Khlong San**: Limited adaptive capacity (0.195) exacerbating other vulnerability factors

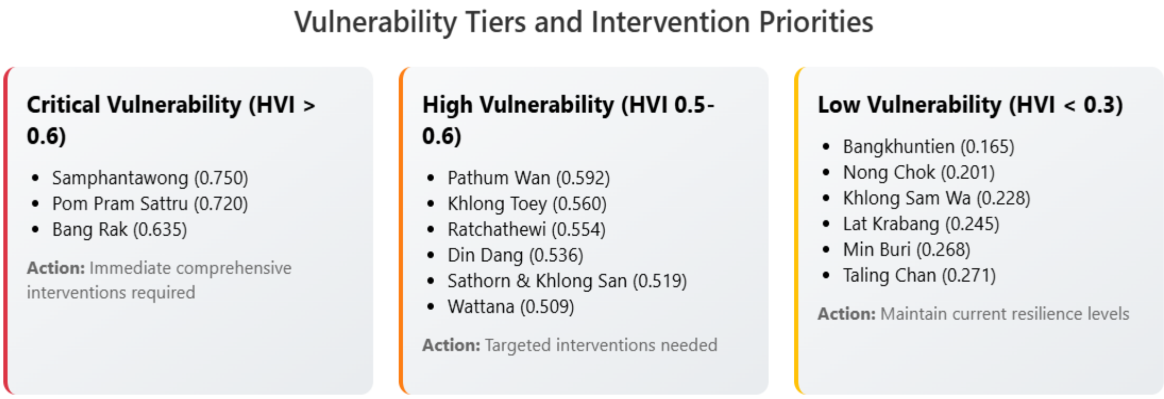


Figure 24 Vulnerability Tiers and Intervention Priorities (ADPC, 2025)

7 GEDSI Action Plan

The Gender Equality, Disability, and Social Inclusion (GEDSI) Action Plan is a core component of the "Heat Resilience: Bridging Science, Policy, and Sustainable Design" project. Its primary aim is to ensure Bangkok's urban heat resilience efforts are inclusive, equitable, and responsive to the unique needs of women, persons with disabilities, and marginalized communities. The plan reflects a shared commitment to ensuring that no one is left behind in the pursuit of climate resilience.

Figure 25 GEDSI Action Plan and communication leaflet developed under the project

Rationale:

- **Disproportionate Impact:** Extreme urban heat disproportionately affects vulnerable groups, including women, children, the elderly, persons with disabilities, low-income households, and informal settlement residents. These groups face heightened risks due to limited access to cooling resources, physical and systemic barriers, pre-existing health conditions, and inadequate housing[96] [97].
- **Social Justice and Effectiveness:** Bangkok's heat problem is as much a social issue as a meteorological one. Inclusive strategies are crucial not only for social justice but also for enhancing the overall effectiveness and sustainability of heat resilience measures.

Key Objectives of the GEDSI Action Plan:

- **Ensure Inclusive Participation:** Engage women, persons with disabilities, elderly, youth, and low-income community members in project planning, decision-making, and implementation through participatory events[98].
- **Address Differential Impacts:** Identify how heat affects different populations (by gender, age, disability, income) and tailor interventions accordingly (e.g., accessible cooling centers, inclusive communication)[99] [100].
- **Promote Equity and Gender Mainstreaming:** Incorporate gender analysis and disability-inclusion checks into all project outputs, advocating for policies that protect vulnerable groups and adapting urban designs to benefit those most affected[101].
- **Link Science, Policy, and Community Knowledge:** Combine scientific data (e.g., satellite heat maps) with policy review and local community insights (e.g., where vulnerable residents live) to target interventions and ensure scientific outputs incorporate disaggregated data.

Figure 26 Gender Equality, Disability and Social Inclusion (GEDSI) – Strengthening Diversity and Inclusion
Source: Knowledge Partnership Platform (Australia-Indonesia)

7.1 Disproportionate Impacts of Urban Heat on Vulnerable Communities

Extreme urban heat is a pressing challenge that does not affect all segments of the population equally, disproportionately impacting vulnerable groups due to a combination of physiological, socioeconomic, environmental, and behavioral factors. In Bangkok, specifically, vulnerable populations including women (51% of the population), people with disabilities (4%), and elderly residents (12%), along with approximately 1.5 million informal settlement residents, face heightened risks[102] [103] [104].

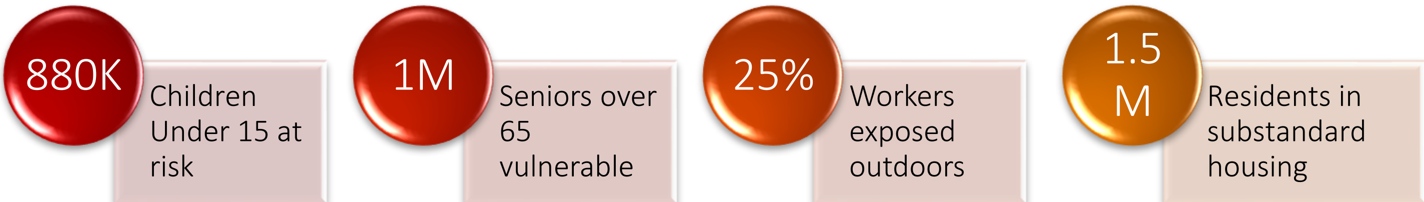


Figure 27 Bangkok Vulnerable Population (Authors)

Here's how various groups are disproportionately affected:

- **Women**[105].:
    - Women are **physiologically more susceptible to heat illness** and often experience greater exposure.
    - **Social norms** often place an extra burden on women as **caregivers** for children, elders, and other heat-vulnerable family members during heatwaves.
    - They may have **unequal access to cool spaces or energy resources**.
    - Research indicates that **women have higher heat-related illness and mortality rates** than men during heatwaves
    - Women-headed households in Asia have been observed to **lose more income** to extreme heat compared to men-headed households. Policies that do not consider these differences risk exacerbating inequality.
- **Children and the Elderly** [106]:
    - Both children (approximately 880,000 under-15) and the elderly (around 1,000,000 over 65) in Bangkok are identified as **especially heat-vulnerable**.
    - **Older adults** have **reduced heat tolerance** and frequently suffer from **chronic health issues**, making them more susceptible to severe impacts .
    - Many elderly individuals are low-income and reside in high-density neighborhoods without air conditioning. A 1°C warming scenario can lead to a steep rise in mortality risk for this group.
    - **Children's thermoregulation is still developing**, making them highly sensitive to heat stress. They may spend hot afternoons in under-cooled homes or schools.
- **People with Disabilities**[107]:
    - Individuals with disabilities face **unique barriers** during heatwaves, including **mobility constraints**, reliance on caregivers, and difficulties in accessing information in adapted formats.
    - Current adaptation plans frequently **lack tailored measures** for persons with disabilities. UNDP reports emphasize the need for accessible heat warnings (e.g., Braille, sign language) and infrastructure like ramps in cooling centers.
- **Low-Income Households and Informal Settlement Residents**[108]:
    - An estimated 1 to 1.5 million Bangkok residents live in **substandard housing** that is often crowded, poorly insulated, and lacks proper ventilation, leading to **unbearably high indoor temperatures**.
    - These households often have **limited financial capacity** for fans or air conditioning (AC) and **less access to essential services** like healthcare.
    - Examples include residents in areas like Klong Toey, Din Daeng, and parts of Bang Khen and Bang Khun Thian, who face extreme indoor heat due to insufficient cooling infrastructure and the "concrete jungle" effect.
    - Targeted interventions, such as shade trees, public fountains, and subsidized fans, can yield significant benefits for these communities.

- **Outdoor Workers[109]**:
    - In 2019, approximately 1.3 million workers in Bangkok, nearly 25% of the workforce, were engaged in outdoor jobs and experienced **significant productivity and wage losses** due to heat intensification.
    - Heat can lead to **occupational illnesses, increased risk of injury, and lower productivity** through natural defense mechanisms like slowing down or taking more breaks.
    - Special attention to work-rest schedules and hydration is crucial for both female and male outdoor workers.

Understanding these specific vulnerabilities is critical for developing and implementing effective, inclusive, and equitable heat resilience strategies that prioritize those most at risk.

7.2 GEDSI Strategies and Activities (Implementation Phases)

The GEDSI Action Plan is structured through implementation phases, ensuring inclusive strategies and actions at every stage.

Phase 1 – Inception and Planning (Months 1–3):

- **Establish a GEDSI Task Force:** Comprising project leaders, gender/disability experts, and representatives from key stakeholder groups (e.g., women's NGOs, disability organizations) to guide inclusion.
- **Conduct Gender-Social Baseline Assessment:** Collect existing data on heat impacts disaggregated by sex, age, and disability; identify data gaps.
- **Train Staff:** Train staff from BMA, line departments, NGOs, and CSOs on inclusive methods and communication (e.g., gender sensitization, disability etiquette, accessible facilitation). Ensure physically accessible workshop venues.
- **Apply GEDSI Checklists:** Review all planning outputs, ensuring draft outreach materials are reviewed by sign-language interpreters and local women's groups.

Phase 2 – Research, Analysis, and Design (Months 4–9):

- **Participatory Workshops:** Hold workshops with diverse audiences (target ≥50% women, plus youth, elderly, persons with disabilities) to discuss urban heat science and community experiences. Track participation and gather feedback on inclusivity.
- **Data Collection:** Integrate GEDSI into technical tasks, e.g., overlay demographic data when modeling heat patterns to map vulnerable groups. Collect gender- and disability-disaggregated survey data. Engage community volunteers in data logging.
- **Needs Assessment:** Conduct focus groups with key populations (women's cooperatives, elderly home care staff, disability advocates) to identify barriers and local solutions.
- **Policy Review:** Analyze existing heat and disaster policies for GEDSI gaps, summarizing findings for project design.

Phase 3 – Implementation and Piloting (Months 10–15):

- **Inclusive Design of Interventions:** Design all pilot projects (e.g., cooling centers, green spaces, heatwave communication systems) with GEDSI principles (e.g., wheelchair access, elder-friendly schedules, diverse community health volunteers).
- **Targeted Outreach:** Launch tailored communication campaigns using local media, social media, community meetings, and places of worship, with materials in multiple languages and formats (Thai, English, Vietnamese,). Partner with women's networks and disability organizations.
- **Capacity Building at Community Level:** Train local leaders (including women and disabled persons) as "Heat Ambassadors" to help neighbors prepare for heatwaves.
- **Feedback Mechanism:** Establish easy ways for beneficiaries to provide feedback (hotline, suggestion boxes, mobile surveys).

Phase 4 – Monitoring, Evaluation and Consolidation (Months 16–18):

- **Data Analysis:** Assess GEDSI indicators collected during implementation (e.g., attendance of target groups, satisfaction ratings).
- **Impact Evaluation:** Compare baseline and end-line health or productivity indicators for vulnerable groups; evaluate if marginalized participants feel safer and more prepared.
- **Policy Dialogues:** Organize multi-stakeholder validation workshops to present results, ensuring community voices inform final policy recommendations.
- **Reporting:** Document lessons learned for inclusive heat resilience. Produce policy briefs aligning findings with SDGs and Sendai priorities.

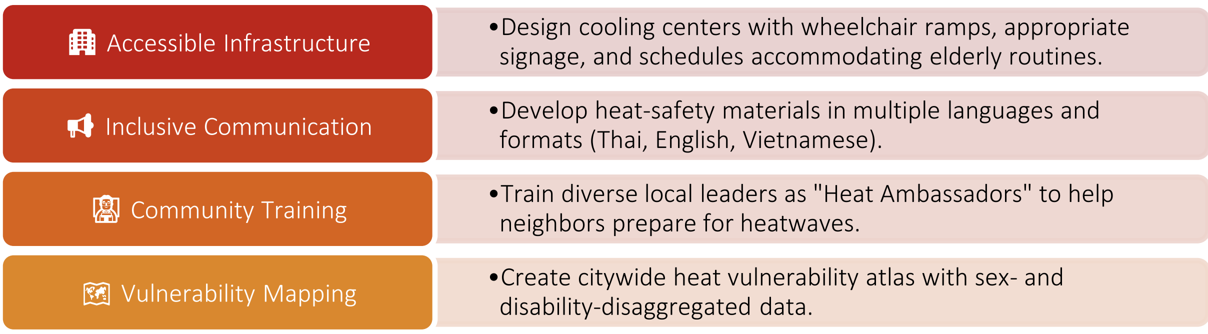


Figure 28 Key Interventions(Authors)

7.3 Monitoring, Evaluation, and Indicators for GEDSI

The plan includes SMART indicators to track GEDSI integration. Monitoring should use both quantitative and qualitative indicators, ensuring progress is transparent and adjustments can be made.

- **Participation Indicators:** Percentages of women, youth, elderly, and persons with disabilities engaged in project activities (target: at least 50% women; PWDs represented proportionally).
- **Access Indicators:** Number of project facilities/services meeting accessibility standards (e.g., wheelchair access in cooling centers).

- **Awareness Indicators:** Increases in heat risk awareness among vulnerable groups (e.g., women vs. men, disabled vs. non-disabled) through pre/post surveys; tracking use of inclusive communication tools.
- **Outcome Indicators:** Reductions in heat-related health incidents in target areas; increased use of communal cooling solutions; number of families installing home cooling after project subsidies.
- **Equity Indicators:** Monitoring equitable distribution of benefits (e.g., jobs in greening projects, grants) to women or persons with disabilities.

Data collection methods include surveys, interview records, workshop attendance sheets, and official statistics, with gender and disability recorded wherever feasible. Reporting aligns with relevant SDG targets (e.g., SDG 5 on gender equality, SDG 11 on sustainable cities, SDG 13 on climate action) and Sendai priorities on inclusive risk reduction.

7.4 Alignment with International Frameworks

The GEDSI Action Plan explicitly supports global commitments to ensure that heat resilience efforts "leave no one behind".

- **Sustainable Development Goals (SDGs)[110] [111]:** Advances SDG 5 (gender equality), SDG 10 (reduced inequalities), SDG 11 (sustainable cities), SDG 13 (climate action), and SDG 3 (good health and well-being) by integrating gender and inclusion into heat resilience initiatives.
- **Sendai Framework for Disaster Risk Reduction (SFDRR) 2015–2030[112]:** Incorporates extreme temperature events within disaster risk reduction, promoting comprehensive risk assessment and early warning systems that empower women and marginalized groups.
- **UNFCCC[113]/Paris Agreement[114]:** Adds a social dimension to adaptation, proposing inclusive resilience as part of Thailand's path toward its Nationally Determined Contribution (NDC) targets, filling a policy gap where gender and youth considerations were minimal.
- **Convention on the Rights of Persons with Disabilities (CRPD)[115]:** Implements Thailand's commitments under CRPD Article 11 by ensuring persons with disabilities have a voice and access to heat relief measures.

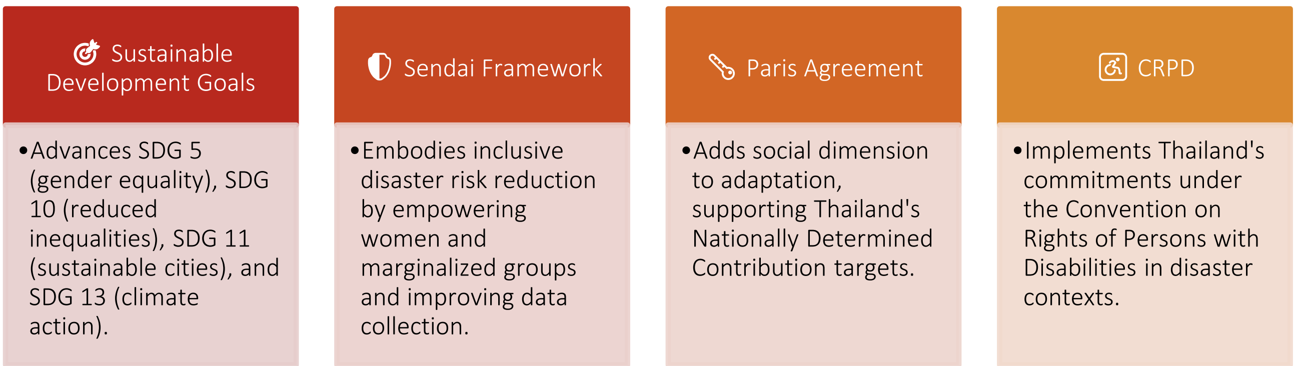


Figure 29 GEDSI Alignment with International Frameworks (Authors)

8 Policy Landscape and Stakeholder Engagement

Effective heat resilience requires collaboration among diverse actors, and the policy landscape in Southeast Asia is complex and evolving.

8.1 International Heatwave Policy Frameworks

In the last two decades, several international frameworks and guidelines have been proposed to address rising temperatures and heatwaves.

- **World Meteorological Organization (WMO):** Provides technical guidelines for heatwave definition and monitoring, including Multi-hazard Impact-based Forecast and Warning Services and standardized early warning systems [116] [117].
- **World Health Organization (WHO):** Offers operational frameworks for climate-resilient health systems, emphasizing early warning systems, health sector preparedness, vulnerability reduction, public health messaging, and urban planning considerations[118] [119].
- **Sendai Framework for Disaster Risk Reduction:** Integrates extreme temperature events within disaster risk reduction and promotes comprehensive risk assessment and early warning systems [120].
- **European Union Framework:** Demonstrates a highly developed regional approach with Heat-Health Action Plans (HHAPs)[121], Urban Adaptation Strategy[122], cross-border alert systems[123], and Copernicus Emergency Management Service coordination[124].

8.2 National Policies in Thailand

Thailand has begun to incorporate heat resilience into its urban planning and climate adaptation strategies.

- **Bangkok Master Plan on Climate Change 2013–2023:** Outlines strategies to mitigate extreme heat, including enhancing insulation, using thermal barrier roof coatings, greening roofs and walls, managing solar radiation with louvers, and increasing green spaces (public parks, street trees, urban mangroves)[125].
- **Heat Action Plans for Primary Schools:** Guidelines from the Ministry of Education allow schools to suspend in-person classes for online instruction during heat, prohibit outdoor activities, ensure adequate water supplies, and implement medical emergency protocols[126].
- **Thailand's Occupational Heat Standard (revised 2016):** Utilizes Wet Bulb Globe Temperature (WBGT) to assess heat stress for indoor and outdoor settings. Employers are encouraged to use engineering controls (e.g., cooling fans) and provide protective equipment; workers with symptoms receive medical care[127].

Table 8: Key Stakeholder Groups, Examples, and Roles in Bangkok's Heat Resilience Project (Authors)		
Stakeholder Group	Examples	Key Role/Influence
Government	BMA, Ministry of Social Development, Health Dept., etc.	Policy-making, regulation, public health coordination, funding for infrastructure
Private Sector	Construction firms (e.g. CP Group, Sansiri), Industry Assns.	Innovation, investment in buildings/infrastructure, promoting heat-resilient technologies
Civil Society & NGOs	Thai Volunteer Service, TEI, community-based NGOs	Community mobilization, advocacy, education, implementation of grassroots resilience projects
Advocacy Groups	Women's associations (APSW), Disability & Elderly networks	Represent vulnerable groups, provide targeted services/support, advise on needs
Academic/Research Institutions	Chulalongkorn Univ., Mahidol Univ.	Research on heat risks, data analysis, training and knowledge dissemination
Community Organizations	Slum resident groups, labor unions, youth clubs	Local insights, leadership in outreach, collecting data through citizen science
Media/Communications	Local news outlets, social media channels	Public awareness campaigns, disseminating heat alerts and safety information

8.3 National Policies in Vietnam

Vietnam has also started recognizing the impact of urban heat, with sustainable cooling actions explicitly emphasized in national strategies.

- **Decision No 438 on development of Vietnam resilience cities with climate change:** In March 2021, the Prime Minister approved Decision No. 438/QD-TTg, which outlines the development of climate-smart cities in Vietnam for the 2021–2030 period. This decision emphasizes the integration of climate change adaptation into urban planning, focusing on enhancing technical infrastructure, environmental services, and overall master plans to mitigate risks associated with climate change, including urban heat. It also advocates for the use of sustainable materials and technologies in construction to improve resilience against climate impacts [128].
- **National Climate Action Plan Period 2021-2030 vision to 2050, P. Minister, 2021:** The plan focuses on integrating climate change adaptation into development strategies, improving disaster risk management, and promoting sustainable practices in agriculture, water resources, infrastructure, and biodiversity conservation. It emphasizes the importance of cross-sectoral coordination, public awareness, and investment in science and technology to support adaptation efforts. The National Action Plan (NAP) outlines specific tasks and solutions for

each sector and region, aiming to reduce vulnerabilities and minimize losses from climate-related disasters and sea-level rise. A monitoring and evaluation system is established to assess progress and inform policy adjustments. The plan also highlights the need for international cooperation and mobilization of financial resources to effectively implement adaptation measures. The term concerning urban heat is focusing on **"development of climate-smart cities that integrate green infrastructure, energy-efficient buildings, and sustainable urban planning[129]"**

- **National Green Growth Strategies period 2021-2030 vision for 2050, P.M.o. Vietnam, 2021:**The urban heat was embedded in the strategy in the area of climate-smart cities development integrating green infrastructure, energy-efficient buildings, and sustainable urban planning. Key initiatives include enhancing tree coverage to reduce heat-induced problems and increase the absorption of greenhouse gas emissions in urban areas, contributing to the target of net-zero emissions by 2050. Additionally, the plan advocates for the construction of buildings and urban areas in accordance with green standards and close to nature, applying energy efficiency standards in buildings, and promoting the efficient use of energy, renewable energy solutions, and recycling waste and wastewater in line with the circular model. As part of the Green Growth strategies, Vietnam has implemented the Urban Cooling Action Plans (UCAPs) in various cities to address the urban heat island effect and extreme heat events. which include measures such as improving urban design, implementing nature-based solutions, and promoting energy-efficient cooling technologies. The project has pilots in cities like Hanoi, Can Tho, and Tam Ky serve as models for scaling up urban cooling interventions nationwide [130].

8.4 Stakeholder Mapping and Roles

Effective urban heat resilience requires collaboration among diverse actors. The project's stakeholder mapping illustrates an inclusive approach, integrating different stakeholders and their roles. The diagram below shows the stakeholder mapping for Urban Heat Resilience project in Southeast Asia, specifically focusing on Bangkok, Thailand and Vietnamese cities. This organizational structure shows how the project integrates different stakeholders and their roles in addressing urban heat challenges. The diagram effectively illustrates:

- Who benefits from the project (direct beneficiaries)

- Who implements the project (implementation partners)

- Who provides policy support and governance (policy & support)

- Who provides technical expertise (knowledge partners)

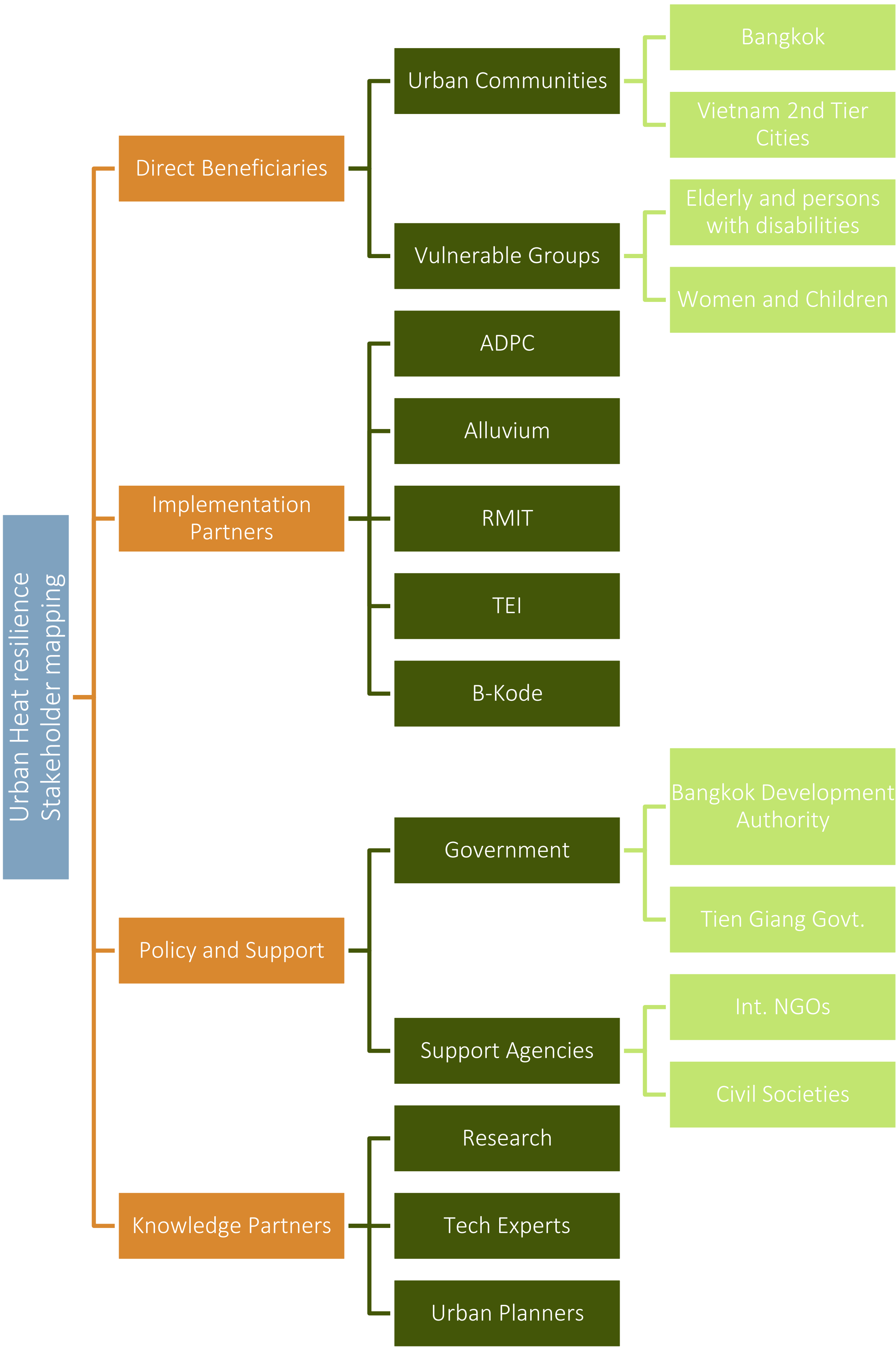


Figure 30 Urban Heat Stakeholder Mapping (Authors)

The structure emphasizes the project's inclusive approach, particularly with respect to vulnerable populations. From an urban governance perspective, this stakeholder mapping presents a compelling intersection of policy, practice, and community engagement.

First, in the Direct Beneficiaries category, the mapping distinguishes between spatial communities—specifically, Bangkok and various Vietnamese urban settlements—and demographic vulnerabilities, which include the elderly, individuals with disabilities, women, and children. This bifurcation highlights a nuanced understanding of how urban heat vulnerability manifests both geographically and socially, which is a critical consideration in contemporary urban climate resilience discourse.

The Implementation Partners segment is especially intriguing, combining regional expertise (represented by the Asian Disaster Preparedness Center), international technical knowledge (sourced from Alluvium), academic rigor (provided by RMIT), and local environmental wisdom (from TEI). This multilateral implementation structure reflects best practices in transboundary urban climate initiatives, where effective integration of diverse institutional capabilities is often essential for success.

Within the Policy & Support domain, the framework acknowledges the vital interplay between formal governance structures—such as the Bangkok Metropolitan Authority and Tien Giang Government—and civil society actors, including international NGOs and civil society organizations. This relationship is particularly relevant in the Southeast Asian context, where urban governance frequently operates through both formal and informal channels.

The Knowledge Partners component demonstrates an appreciation for the multidisciplinary nature of urban heat resilience by incorporating research institutions, technical experts, and urban planning professionals. This tripartite knowledge structure aligns with the contemporary understanding that urban climate challenges require integrated technical and planning solutions.

Key Stakeholder Groups and their roles in Bangkok:

- **Direct Beneficiaries:** Urban Communities (Bangkok, Vietnam 2nd Tier Cities) and Vulnerable Groups (elderly, persons with disabilities, women, children). These are the populations most affected by heat stress.
- **Implementation Partners:** ADPC, Alluvium, RMIT, TEI, B-Kode. These organizations bring regional expertise, international technical knowledge, academic rigor, and local environmental wisdom.
- **Policy & Support:** Government agencies (National Thai Government, Bangkok Metropolitan Administration (BMA) with its various departments, Bangkok District Offices, Tien Giang Government) and Support Agencies (International NGOs, Civil Society Organizations). They are responsible for policy-making, regulation, public health coordination, funding, and community mobilization.

- **Private Sector:** Domestic and International developers, construction companies. They have technical capacity and can implement built-environment solutions, potentially funding community cooling programs through CSR initiatives.
- **Knowledge Partners:** Academic and Research Institutions (e.g., Chulalongkorn University, Mahidol University), Technical Experts, Urban Planners. They provide expertise in climate modeling, public health, social surveys, and data analysis.
- **Community or Grassroots Organizations:** Slum resident groups, elderly associations, labor unions. They represent direct target populations and provide local knowledge.
- **Media and Communication Platforms:** Local news outlets, social media channels. They help disseminate heat warnings and educational messages.
- **International Agencies/Donors:** Asian Development Bank, UN agencies, Mekong THOUGHT network. They bring best practices and mandates to promote SDGs and Sendai goals.

Coordination mechanisms, such as regular consultations and community workshops led by civil society groups, ensure all stakeholder voices are heard and inform project design.

Vietnam Workshop Insights:

Focus group discussions with provincial policymakers (Tien Giang – My Tho), academic researchers (Ho Chi Minh University of Natural Resources and Environment), and urban planners confirmed that extreme heat is a growing phenomenon, affecting even smaller cities like My Tho. Participants noted significant temperature differences between city centers and suburban areas, with inner-city zones experiencing higher heat due to urbanization, reduced green spaces, concrete surfaces, and increased AC use/traffic. The impacts of extreme heat are far-reaching, affecting daily life and well-being. Vulnerable groups, such as the urban poor in makeshift housing and middle-class individuals frequently moving between air-conditioned and non-air-conditioned environments, face greater health vulnerabilities. My Tho participants qualitatively recognized heat impacts on travelers, highlighting a need for better understanding of heat comfort for outdoor workers, informal merchants, and vulnerable communities.A key challenge identified was the limited current local policies and lack of leadership awareness regarding urban heat as a priority issue.Discussions emphasized the need for short-term and long-term infrastructure planning, the active promotion of nature-based solutions (expanding green spaces, increasing tree coverage, restoring urban wetlands), and rethinking urban park design to be greener and climate-responsive4546. The importance of engaging local communities in planning and implementation was also highlighted to ensure context-specific and effective solutions.

Figure 31 Stakeholder meetings through the project

Figure 32 Filed Visits in Bangkok

9 Nature-Based Solutions (NBS) for Urban Heat Mitigation

Nature-based Solutions (NBS) are a powerful, place-based mitigation strategy for urban heat, leveraging natural processes to create cooler, more livable urban environments.

Figure 33 NbS conceptual framework (IUCN 2020)

9.1 NBS Definition and Core Elements

NBS is an umbrella term for "actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits"[131]. In the urban context, the focus is often on restoring significantly altered modified ecosystems.

Key elements of NBS in the context of urban heat mitigation include:

- **Purpose:** Addressing societal challenges like human health (reducing morbidity and mortality from extreme heat, framed as a slow-onset disaster) and contributing to climate change adaptation.
- **Approach:** Identifying effective and adaptive solutions that consider constraints and opportunities unique to vulnerable urban communities, focusing on sound evidence and practical advice.
- **Dual Outcomes:** Maximizing benefits for human well-being, with biodiversity benefits as a secondary but valued outcome.

9.2 Types of NBS for Urban Heat

The section identifies various NBS asset types relevant to managing urban heat in dense city environments, focusing on those that can be retrofitted into existing landscapes. These include[132]:

- **Gardens:** Vegetation planted in soil-based media, passively or actively irrigated.
- **Green Roofs:** Building roofs partially or completely covered in vegetation over a waterproof membrane. Can be extensive (shallow substrate) or intensive (deeper substrate, garden-like).
- **Green Walls:** Vertical vegetated systems on building facades.
- **Green Corridors:** Linear vegetated spaces.
- **Parks:** Larger green spaces.
- **Raingardens & Swales:** Vegetated depressions designed to absorb stormwater.
- **Street Trees:** Trees planted along streets, providing shade and evapotranspiration.
- **Urban Agriculture:** Cultivated areas within the city for food production.
- **Urban Forests:** Large areas of trees within the urban landscape.
- **Ponds and Lakes:** Open water bodies that permanently retain water.
- **Waterways:** Channels conveying flows, natural or modified.
- **Wetlands:** Heavily vegetated shallow water bodies for stormwater treatment, natural or constructed.

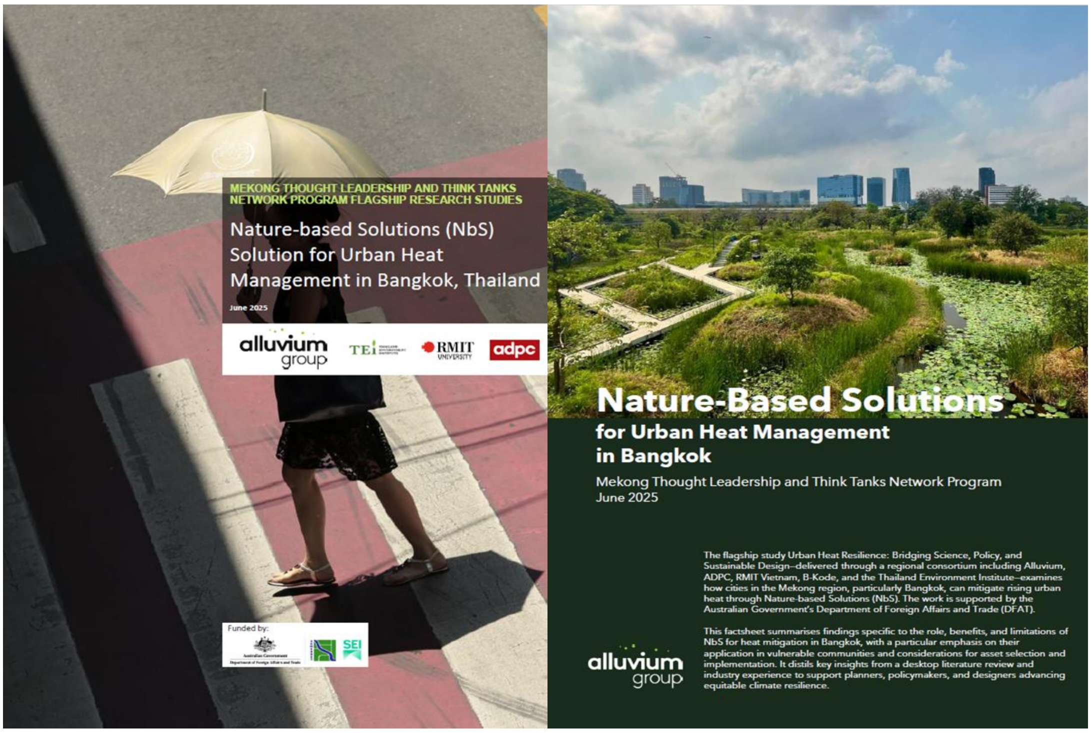


Figure 34 NbS for Urban Heat Management in Bangkok report and factsheet developed under the project

9.3 Nature-Inspired Solutions

Beyond traditional NBS, some nature-inspired solutions are :

- **Uchimizu (Sprinkling Water):** The Japanese practice of sprinkling water on urban surfaces for evaporative cooling. Model testing shows it can reduce surface temperatures by up to 15°C and air temperatures by around 2°C, offering immediate cooling comparable to replacing 30% of pavement with vegetation. It is practical for space-constrained areas.
- **Wind Design:** Designing urban forms to support air movement and cooling, such as aligning streets with prevailing winds, widening breezeways, and stepping building heights. This enhances passive cooling and can improve the effectiveness of nearby vegetated or water-based NBS.

9.4 Impact of NBS on Heatwaves (B-Kode Results)

The NBS scenario simulated a widespread increase in pervious, green, and irrigated surfaces across Bangkok, particularly targeting highly impervious districts. NBS interventions lead to:

- **Marked Reduction in Impervious Surface Area:** Central and western districts see the most significant shifts, with impervious coverage decreasing by up to 25%. This converts built-up areas into green and blue spaces, increasing evapotranspiration and reducing heat retention.
- **Clear Cooling Benefit & Frequency Reduction:** A reduction in the number of heatwave days by up to **24 days in hotspots**. The spatial pattern aligns with areas where NBS interventions were concentrated, indicating strong local cooling.
- **Shorter, Less Persistent Heatwave Events:** Average durations drop by over **30 days in some districts**, particularly in the urban core and southwest. This is likely due to enhanced evapotranspiration and reduced heat storage.
- **Slight but Important Reductions in Heatwave Severity:** Particularly in densely built areas, thermal extremes are dampened, with some areas seeing cooling effects of up to **0.4°C during extreme events**.

The benefits of NBS are spatially consistent with areas of greatest intervention, suggesting strong local effects and spillover benefits. These findings reinforce that NBS are not just environmental amenities but essential components of climate adaptation infrastructure.

9.5 Limitations of NBS Benefits

Despite their potential, the effectiveness of NBS can be limited by several factors.

- **Typology-specific Limitations:** Different NBS types have varying cooling performances. Trees generally offer more cooling than grass due to shading and evapotranspiration. Irrigated grass outperforms unirrigated grass but is more resource-intensive. Cooling rates for tree canopy tend to plateau beyond 20-40% coverage, indicating diminishing returns[133] [134].

- **Design and Implementation Constraints:** Effective cooling depends on careful placement and design. Green roofs on tall or inaccessible buildings offer limited street-level benefits, and north-south streets are lower priority for street tree planting due to reduced solar exposure. Cooling performance is highly dependent on tree species, spacing, canopy form, and appropriate siting (e.g., median strips), requiring tailoring to local context. Inadequate maintenance and irrigation can rapidly diminish cooling capacity [135].
- **Spatial and Temporal Scale Limitations:** Larger interventions (e.g., irrigated parks, extensive tree networks) provide neighborhood-scale cooling, while smaller elements cool only their immediate microclimate. Cooling effects from water bodies and small parks typically extend limited distances (e.g., 50-150 meters downwind). Irrigation outside peak heat periods or after soil moisture saturation yields diminishing returns [136] [137].
- **Water Requirements:** Street trees and irrigated green infrastructure have variable and often poorly documented water requirements. Efficient water management is essential, especially during droughts, when plant stress can negate cooling benefits[138] [139].
- **Human Behaviour and Exposure Factors:** The actual benefit from cooler microclimates depends on how, when, and whether individuals engage with NBS spaces. If people don't visit cooler areas or buildings remain sealed, cooler air may not translate to improved thermal comfort. Temporal mismatches between peak heat and typical occupancy patterns can also limit exposure.
- **Research and Evidence Base Gaps:** There are significant knowledge gaps regarding NBS performance under extreme climate conditions in tropical climates, comparative cost-effectiveness, and location-specific implementation guidelines, making site-specific evidence difficult to build.

These limitations underscore that NBS are not a guaranteed solution, and their effectiveness requires an integrated approach considering context, location, and beneficiaries.

9.6 NBS Guidance and Selection

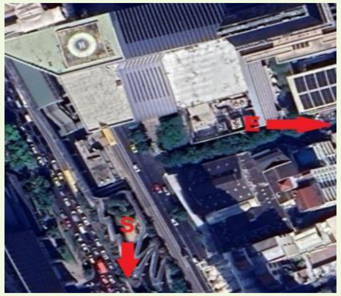
The study provides guidance on NBS selection for vulnerable communities in Bangkok, considering thermal effectiveness, spatial feasibility, and cost/maintenance. It's a preliminary guide, emphasizing the need for validation through local social research and consultation.

Overall Suitability for Vulnerable Communities (examples):

- **Very Suitable (✓✓✓):**
    - **Street Trees:** High thermal benefit through shade and evapotranspiration, adaptable to linear spaces (e.g., roads, canals), and can be integrated into existing dense areas.

    - **Green Corridors:** Provide linear cooling and enhance walkability, leveraging street trees and complementing with other solutions.
    - **Uchimizu:** Rapid, low-tech evaporative cooling, ideal for hard, paved informal areas, low cost and community-managed, practical in space-constrained areas.
- **Somewhat Suitable (✓✓):**
    - **Gardens & Urban Agriculture:** Strong evapotranspiration and shading effects, flexible layout for food or shared space, can be implemented in small parcels of land, with moderate cost and low maintenance if community-led.
    - **Parks:** High impact when irrigated with mature canopies, but often space-constrained in dense communities; benefits possible if irrigation is secured and designed with high canopy cover.
- **Low Suitability (✓) or Unlikely to be Suitable (*):**
    - **Green Roofs & Green Walls:** Limited street-level impact, high capital requirements, expensive and difficult to retrofit in existing dense areas, more relevant for formal housing typologies than informal communities.
    - **Urban Forests:** Requires large space, unsuitable for high-density areas, high cost and space requirements.
    - **Ponds, Lakes, & Wetlands:** Often space-constrained in dense communities, moderate to high capital cost and water management complexity, more promising in peri-urban or degraded water zones with more space.
    - **Wind Design:** Enhances passive cooling, but requires modification of existing urban form which can be high cost for retrofitting.

Table 9 Guidelines for targeted street-scale tree arrangement [140], adapted to the Northern Hemisphere, examples from Bangkok)

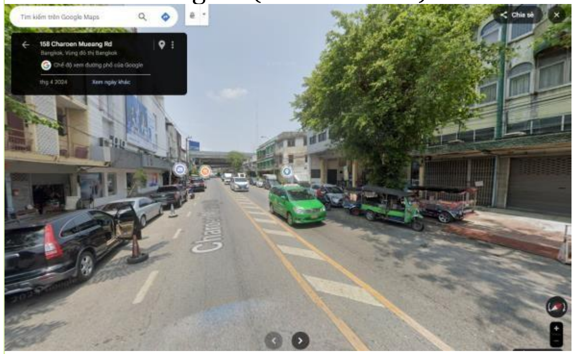
Guideline	Example
STREET WIDTH *What* Target wide, open streets with a low "Building Height to Street Width ratio" *Why* Wide open streets are exposed to greater amounts of solar radiation leading to higher daytime heat stress. Tree canopies absorb and reflect solar radiation, reducing the amount of radiation that reaches pedestrians and urban surfaces below.	Rama IV road  
STREET ORIENTATION *What* Target east-west oriented streets *Why* East-west oriented streets are exposed to more solar radiation during the day compared to north-south oriented streets where some building shading occurs in the morning and afternoon.	Khwaeng Wang Burapha Phirom, Khet Phra Nakhon  
STREET SIDES *What* Target the southern side of east-west streets (in the Northern Hemisphere). Target the western side of north-south streets *Why* In the Northern Hemisphere the north facing walls are exposed to greater solar radiation throughout the day, leading to heat stress. The west facing walls are exposed to greater solar radiation at the peak daytime heating period (maximum air temperature)	166 Naradhiwas Rajanagarindra Rd  
Guideline	**Example**

TREE GROUPING

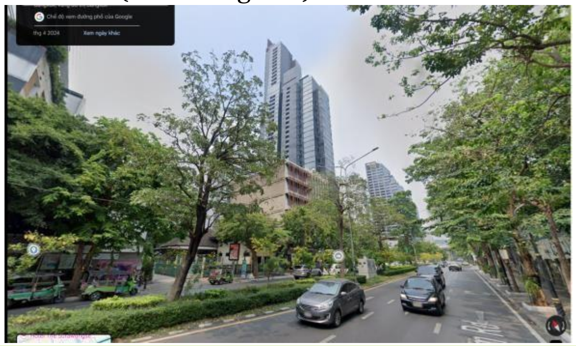
What
Trees should be clustered together in groups where possible, with overlapping canopies to maximise shading.

Why
Isolated trees can be exposed to high heat and radiation loads in urban areas, increasing tree water stress. Clustering trees delivers greater reductions in air temperature and mean radiant temperature below the canopy than isolated trees

Charoen Mueang Rd (Isolated trees)



Si Lom Rd (Clustering tree)

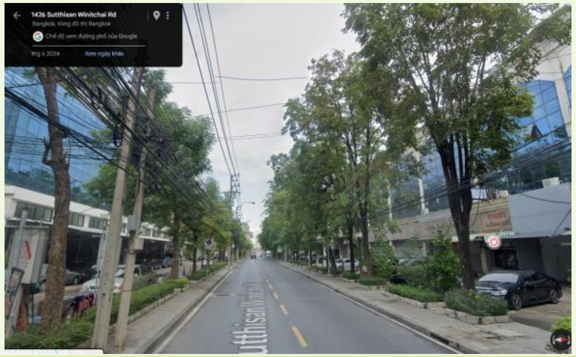


TREE SPACING

What
Groups of clustered trees should be interspersed with open spaces

Why
Groups of trees provide shading during the day, while the open spaces between allows for surface cooling and ventilation (wind) at night.

Sutthisan Winitchai Rd



9.6.1. Street Tree Guidance

Street trees are highly relevant for urban heat mitigation in dense, high-exposure urban environments due to their capacity to deliver shade, reduce ambient temperatures through evapotranspiration, and offer co-benefits. Their success depends on careful design, placement, and species selection.

9.7 Guidelines for Targeted Street-Scale Tree Arrangement (adapted for Bangkok):

- **Street Width:** Target wide, open streets with a low "Building Height to Street Width ratio" as they are exposed to greater solar radiation and experience higher daytime heat stress.
- **Street Orientation:** Prioritize streets oriented East-West as they receive more solar radiation on sidewalks and building facades for longer periods.
- **Building Type:** Focus on areas with low to mid-rise buildings as tree canopies can effectively shade these buildings and the street below. Tall buildings may benefit less from street-level canopy cover but could utilize green roofs/walls.
- **Tree Grouping:** Cluster trees with overlapping canopies to maximize shading. Isolated trees can experience high heat stress.
- **Tree Spacing:** Intersperse clustered tree groups with open spaces to allow for surface cooling and ventilation (wind) at night.

Tree Species Selection: Specific tree species should be chosen to align with the form, height, and canopy characteristics required for effective shading and integration within narrow or complex urban streetscapes. The preferred and alternate species suggested are indicative and need to consider local soil/watering conditions, streetscape design, and community interests.

9.8 Barriers and Opportunities for NBS Implementation in Vulnerable Communities

Implementing NBS in vulnerable communities requires understanding specific spatial, social, and institutional conditions.

Barriers to Implementation:

- **Tenure Security:** Informal settlements often lack legal land tenure, limiting government investment in green infrastructure that could legitimize informal developments.
- **Space Constraints:** High-density, unplanned urban layouts limit ground-based solutions (parks, water bodies). Roof-based or vertical solutions may be viable but face expensive retrofitting challenges (structural capacity, waterproofing, cost).
- **Public Investment Priorities:** Government housing estates often receive minimal environmental investment, making NBS with high capital/operating expenses unfeasible.

- **Environmental Constraints:** Canal-side or reclaimed areas may face flooding, sinking, and salinity, limiting vegetation-based NBS unless costly soil engineering or tolerant species are used.
- **Competing Uses:** In high-density areas, land use may favor immediate practical uses (parking, vending) over green infrastructure, making it difficult to secure land for NBS.
- **Overhead Cables:** Extensive overhead power and telecommunications cables prevalent in urban areas interfere with the placement and growth of large trees, limiting canopy size and impact.
- **Lack of Solid Waste Management:** Poor waste collection creates pollution risks for water-based NBS and can clog drainage, undermining cooling benefits.

Opportunities for Implementation:

- **Service Reliability:** NBS that reduce heat without increasing electricity load offer reliable and cost-effective alternatives for residents with limited financial capacity.
- **Community Stewardship:** Strong community ties in low-income areas offer potential for co-designed, community-led NBS that are locally maintained, increasing sustainability.
- **Government-Subsidised Housing Estates:** Strategic greening of common spaces (e.g., shared courtyards) in these estates could improve livability and reduce heat without high cost.
- **Private Sector Participation:** Businesses may be motivated to fund NBS in worker housing as part of Corporate Social Responsibility (CSR) initiatives.
- **Low Water Quality:** Funding to address water pollution issues in Bangkok's extensive canal system could create opportunities for constructed wetlands, which also support urban heat mitigation.

10 Urban Heat Adaptation Strategies

10.1 Overview of Adaptation Approaches

Urban heat, primarily exacerbated by the Urban Heat effect, presents significant challenges to cities like Bangkok. This phenomenon leads to increased temperatures in urban areas due to factors such as extensive concrete and asphalt surfaces, reduced vegetation cover, and climate change. Effective adaptation strategies to combat urban heat must adopt a multi-disciplinary approach encompassing nature-based solutions, technology, and urban design

Key Features:

- Multi-disciplinary: Combines ecological, technological, and community strategies.

- Integrated Policies: Incorporation into city planning and development frameworks.

- Community Engagement: Involvement of local populations in the design and maintenance of solutions.

Figure 35 Multi Disciplinary Approach Overview

10.2 Nature-Based Solutions

Nature-based solutions (NbS) leverage natural processes to mitigate urban heat. In cities like Bangkok, where dense infrastructure predominates, NbS offer a path to cooler urban environments while enhancing biodiversity and air quality.

Examples of NbS:

- Urban Green Spaces: Parks and gardens not only provide cooling but can also serve as community spaces. Studies show that urban greenery can lower surface temperatures by up to 10°C, enhancing the thermal comfort of nearby residents.

- Tree Canopy Coverage: Increasing tree cover can reduce ambient temperatures through shade and evapotranspiration, which cools the surrounding air

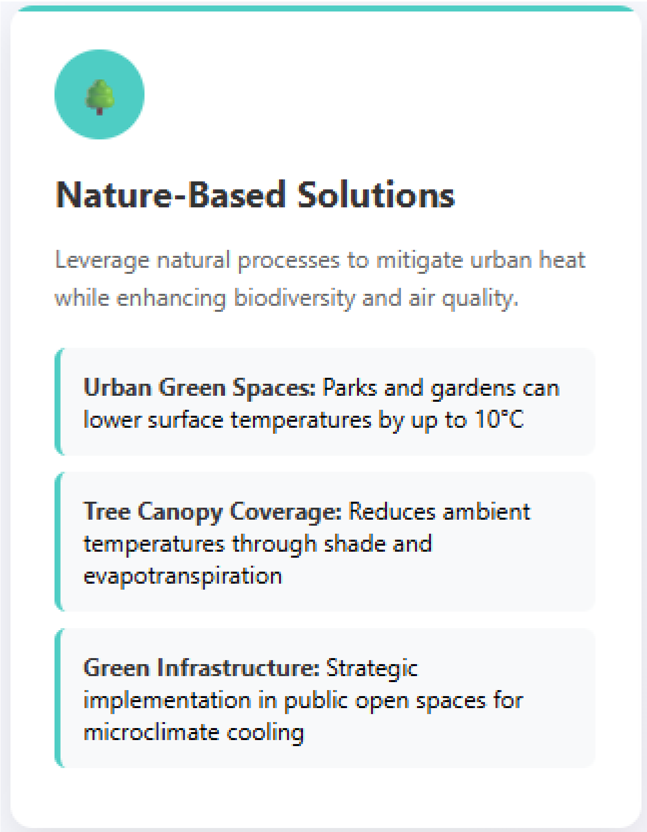


Figure 36 Nature Based Solutions

Factors Influencing the Use of Nature-Based Solutions

The adoption of nature-based solutions depends on various factors:

- Social Awareness and Cultural Values: Public recognition of the benefits of NbS can drive initiatives; community-led projects often succeed where governmental programs struggle

- Funding and Resources: Access to financial incentives is crucial. For instance, local governments can enhance participation in tree planting initiatives by providing subsidies for maintenance.

"Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes"[141]presents a structured approach to addressing urban heat through the strategic implementation of Urban Green Infrastructure (UGI). The framework emphasizes a five-step process to prioritize the use of public open spaces for microclimate cooling, specifically designed to be adaptable across different urban contexts.

Overview of the Framework:

1. Identify Priority Urban Neighbourhoods: This step involves identifying neighborhoods with high populations vulnerable to extreme heat.
2. Heat Exposure Assessment: It recognizes that urban heat is not uniformly distributed and distinguishes so-called 'hot-spots' with little vegetation or water.
3. Assess Vulnerability: This is crucial in understanding which demographic groups are particularly susceptible to heat, including socio-economically disadvantaged populations, the elderly, and those with pre-existing health conditions.

4. Behavioral Exposure: This component involves identifying areas with high public activity, which could exacerbate exposure to heat.
5. Selection of Appropriate UGI: The framework guides the selection of UGI types (like trees, green roofs, and green walls) based on the previously identified factors affecting heat exposure and vulnerability.

Key Factors Influencing NBS for Urban Heat:

- Heat Exposure: High daytime surface temperatures significantly influence the need for green infrastructure. Areas that are recognized as 'hot-spots' require urgent attention.
- Vulnerability: Sections of society more susceptible to heat stress, including low-income families, the elderly, and young children, must be prioritized in mitigation strategies.
- Behavioral Exposure: Identification of zones of high human activity—such as public transport hubs, schools, and recreational spaces—is crucial as these areas may experience heavier foot traffic, increasing the urgency for cooling interventions

Extreme heat's effects are not experienced uniformly; specific populations face greater risks due to a variety of physiological, socioeconomic, and environmental factors. Vulnerable groups such as low-income communities, the elderly, and individuals with pre-existing health conditions may be disproportionately affected due to limited access to resources, inadequate housing, or lack of social support systems.

Simultaneously, behavioural exposure plays a significant role in the impact of extreme heat. Individuals' daily activities, such as outdoor work, commuting patterns, and the use of public spaces, greatly influence their heat exposure.

Comprehensive data collection on several variables is pivotal for authorities to accurately assess heat vulnerabilities within different communities, particularly in Bangkok, where extreme heat poses significant challenges. Our analysis will focus on Bangkok while also aiming to involve Vietnam as a stakeholder to foster regional collaboration and knowledge exchange.

Key factors to evaluate include:

- Population Demographics: Understanding the makeup of the community, including age, income, and health status.
- Exposure to High Heat: Identifying which areas experience higher daytime surface temperatures and prolonged heat events.
- Urban Heat Intensity: Mapping areas with less vegetation and more heat-retaining surfaces to pinpoint 'hot spots'.
- Physiology and Health: Evaluating the health conditions prevalent in the population, such as respiratory diseases or heat-related illnesses.
- Adaptive Capacity: Assessing how well different communities can adjust to extreme heat, considering factors like access to cooling centers and public transportation.

- Exposure to Heat at Work: Analyzing how workplace environments contribute to heat exposure, particularly in outdoor jobs.
- Availability of Cooling Facilities: Identifying resources such as air-conditioned public buildings, cooling centers, and access to water bodies.
- Access to Green Areas: Evaluating the availability and accessibility of parks and green spaces that can provide relief from heat.
- Building Codes and Materials: Reviewing regulations and materials that impact heat retention and comfort in living and working environments.

Considerations:

- Policy Frameworks: Local policies promoting urban greening initiatives significantly influence their implementation.

- Climate Adaptation Policies: Integration with climate action plans ensures that NbS is consistently prioritized within the urban planning spectrum.

10.3Technological Solutions

Technological advancements can bolster efforts to mitigate urban heat. In Bangkok and similar cities, incorporating technology can improve energy efficiency and enhance urban livability.

Key Technologies:

- Cool Roofs: Reflective coatings can reduce heat absorption by up to 80%, leading to significant energy savings in air conditioning. For example, the implementation of cool roofs in densely populated areas has demonstrated reductions in building heat gain.

- Smart Urban Monitoring: Using sensor technologies for real-time monitoring of temperature and air quality enables cities to respond promptly to heat events

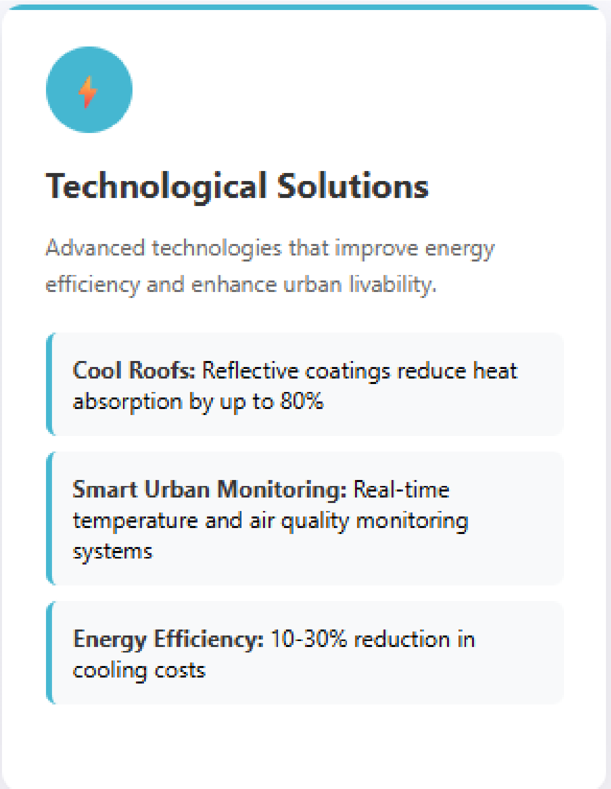


Figure 37 Technological Solutions

Implementation Impact:

- Energy Cost Reduction: Cool roofs contribute to energy savings of approximately 10-30% on cooling costs.

- Public Health Benefits: By mitigating extreme heat, these technologies reduce health risks associated with heat-related illnesses

10.4 Urban Planning and Design Strategies

Urban planning plays a crucial role in addressing urban heat. Sustainable planning can prioritize the development of heat-resilient infrastructure.

Strategies:

- Mixed-Use Development: Promoting mixed-use areas can facilitate walking and reduce car reliance, thus lowering heat emissions

- Zoning Regulations: Incorporating stipulations for green spaces in new developments can enhance urban greenery.

- Heat Vulnerability Mapping: Understanding and mapping heat hotspots helps prioritize interventions in areas most affected by the UHI effect

Figure 38 Urban Planning and Design Strategies

10.5Community-Based Adaptation Initiatives

Community involvement is vital for the success of adaptation strategies. Engaging local populations fosters ownership and sustained impact.

Initiatives:

- Community Gardening and Greening Projects: Initiatives where residents actively participate in tree planting and urban garden establishment not only lower temperatures but also create community ties

- Awareness Campaigns: Educational efforts aimed at informing residents about the benefits of heat adaptation strategies enhance community buy-in

Figure 39 Community Based Initiatives

- Partnerships with NGOs: Collaborations with non-profit organizations can enhance outreach and resource mobilization for local projects

Results:

- Empowerment of Local Communities: Such initiatives empower residents to take proactive roles in urban governance, leading to more sustainable and resilient cities.

Addressing urban heat in Southeast Asian cities like Bangkok requires a comprehensive approach that integrates nature-based solutions, technological innovations, and community engagement into urban planning efforts. By fostering collaborative environments and implementing adaptive measures, these cities can significantly enhance resilience to extreme heat, thus improving the overall quality of urban life.

Figure 40 Five Step framework for Green Infrastructure Priority

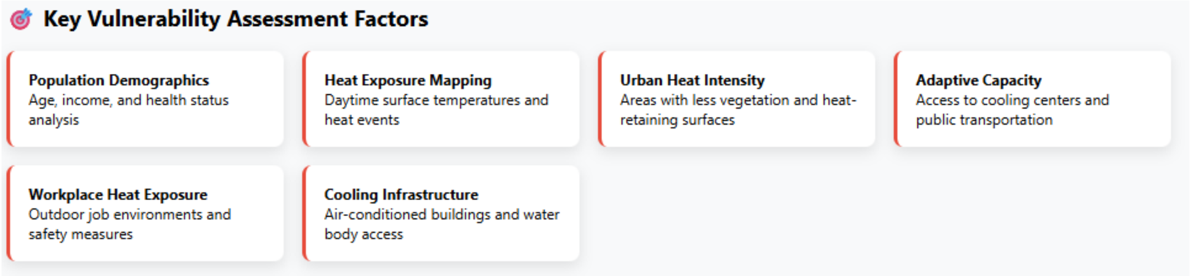


Figure 41 Key Vulnerability Assessment Factors

Figure 42 Measurable Impacts and Benefits

11 Recommendations

The escalating challenge of urban heat, exacerbated by climate change and the urban heat island (UHI) effect, poses significant threats to cities, particularly in Southeast Asia. Bangkok, as a rapidly urbanizing metropolitan area, exemplifies this urgent issue, facing rising baseline temperatures and intensified heatwave conditions that disproportionately affect vulnerable communities. Addressing this complex problem requires a multi-faceted approach that bridges scientific understanding, informed policy-making, sustainable design, and inclusive community engagement.

This document synthesizes key recommendations and conclusions derived from recent studies and action plans, focusing on Nature-Based Solutions (NbS), inclusive strategies, policy integration, and continuous monitoring to build a more heat-resilient, equitable, and livable urban environment.

The Role of Nature-Based Solutions in Urban Heat Mitigation

Nature-Based Solutions (NbS) emerge as a **powerful and place-based mitigation strategy** to combat urban heat. These solutions leverage natural processes to cool urban areas while simultaneously enhancing biodiversity and air quality. The core objective of NbS is to deliver sustainable human and ecological benefits by harnessing the multi-functionality of nature.

Proven Cooling Benefits: Studies confirm that NbS, such as urban greening, green roofs, permeable surfaces, urban waterbodies, and managed irrigation, effectively reduce elevated land surface and air temperatures, especially in densely built environments.

- **Significant Temperature Reductions**: Trees and vegetation can cool cities by up to 5°C through shading and evapotranspiration[142]. Irrigated grass can reduce air temperatures by approximately 0.5°C and surface temperatures by up to 20°C, with high irrigation leading to air temperature reductions of up to 2.5°C[143].
- **Heatwave Dampening**: In Bangkok, an ambitious NbS scenario (B-Kode analysis), envisioning widespread increases in pervious, green, and irrigated surfaces, particularly in highly impervious districts, leads to marked improvements in heatwave characteristics. This includes:
    - **Reduced Heatwave Frequency**: Up to 24 fewer heatwave days in urban hotspots.
    - **Shorter Duration**: Average heatwave duration dropping by over 30 days in some districts.
    - **Lower Severity**: Meaningful reductions in heatwave severity, up to 0.4°C, particularly in densely built areas where thermal extremes are most acute.
- **Spatial Consistency**: The benefits of NbS are spatially consistent with the areas of greatest intervention, suggesting strong local effects and spillover benefits.

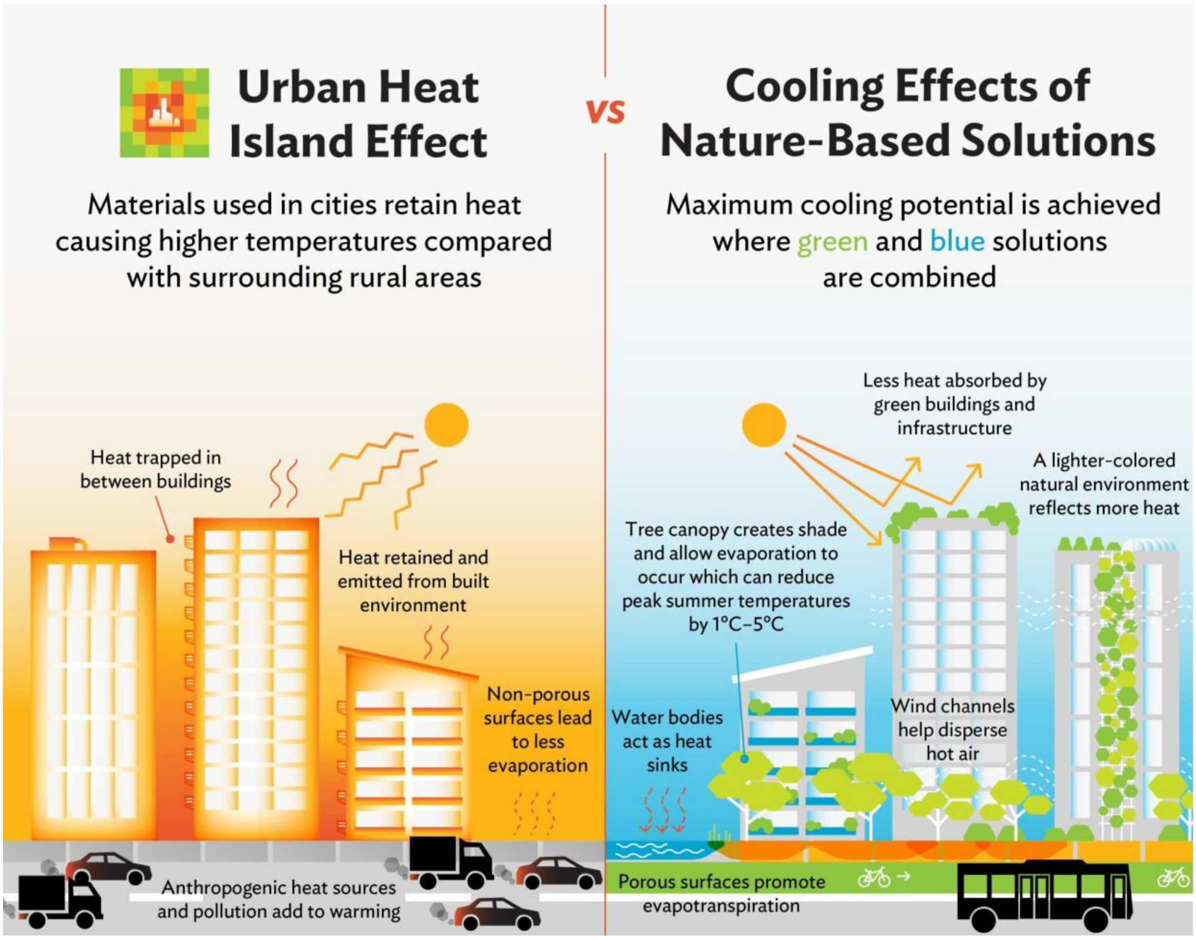


Figure 43 Cooling Effects of Nature Based Solutions[144]

Types of Nature-Based Solutions and Implementation Guidance: A range of NbS typologies can be applied, including gardens, green corridors, green roofs, green walls, parks, ponds, lakes, raingardens, sports grounds, street trees, swales, urban agriculture, urban forests, waterways, and wetlands.

- **Street Trees**: Recognized as one of the most relevant NbS for urban heat mitigation due to their proven localized cooling through shade and evapotranspiration, fitting well into streetscapes, and being cost-effective with early investment.
  - **Strategic Arrangement**: Guidelines recommend targeting wide, open streets with low "Building Height to Street Width ratios" and east-west oriented streets due to higher solar radiation exposure. Planting on the southern side of east-west streets and the western side of north-south streets in the Northern Hemisphere maximizes shade.
  - **Clustering and Spacing**: Trees should be clustered for overlapping canopies to maximize shading and interspersed with open spaces for night ventilation and surface cooling.
- **Nature-Inspired Solutions**: Beyond traditional NbS, nature-inspired approaches like Uchimizu (sprinkling water on urban surfaces for evaporative cooling) can reduce surface temperatures by up to 15°C and air temperatures by around 2°C, offering a viable alternative where greening is unfeasible or still establishing[145]. **Wind design**, which focuses on aligning

streets and building frontages with prevailing winds, can enhance passive cooling and improve the effectiveness of nearby vegetated or water-based NbS.

Limitations of Nature-Based Solutions: Despite their significant potential, NbS alone **cannot entirely offset the projected warming**. Future heatwave conditions in many districts are still expected to exceed today's levels, highlighting the need for a multi-layered adaptation strategy.

- **Context-Specific Effectiveness**: The effectiveness of NbS is contingent on factors like spatial configuration, maintenance capacity, and human behavioral patterns. For instance, green roofs on tall or inaccessible buildings offer limited street-level benefits, and inadequate maintenance can rapidly diminish cooling capacity.
- **Localized Impact**: Even large elements like parks or waterbodies tend to have localized cooling effects, typically extending up to 50-150 meters downwind. Broader impact requires scaled or distributed application[146].
- **Resource Intensity**: Irrigated green infrastructure requires efficient water management, especially during droughts, as plant stress can negate cooling benefits.
- **Implementation Barriers in Vulnerable Communities**: Challenges include land tenure insecurity, space constraints in high-density informal settlements, low public investment priorities, environmental constraints (e.g., flooding, salinity), competing land uses, extensive overhead power cables that interfere with tree growth, and poor solid waste management affecting water-based NbS.

Inclusive and Equitable Urban Heat Resilience (GEDSI)

Urban heat is not merely a meteorological problem; it is a **profound social issue** that deepens existing inequities and disproportionately impacts vulnerable populations. These groups include women, children, the elderly, persons with disabilities, low-income households, and informal settlement residents.

- **Differential Impacts**: Women, for example, face a "double burden" of higher physiological risk and caregiving responsibilities during heatwaves, often experiencing higher illness and mortality rates. People with disabilities face heightened risks due to physical and communication barriers.
- **Vulnerability Drivers**: The most vulnerable districts in Bangkok, such as Samphantawong, Pom Pram Sattru, and Bang Rak, are characterized by extreme heat exposure, minimal green space, and high population and housing densities. Informal settlements like Klong Toey also experience extreme indoor heat due to poor insulation.

Figure 44 GEDSI[147]

To ensure that no one is left behind in climate resilience efforts, a **Gender Equality, Disability, and Social Inclusion (GEDSI) Action Plan** is crucial.

- **Key Objectives**:
  - **Inclusive Participation**: Actively engage women, persons with disabilities, the elderly, youth, and low-income community members in all stages of project planning, decision-making, and implementation through participatory workshops and surveys.
  - **Address Differential Impacts**: Identify how heat affects diverse populations and tailor interventions accordingly. This includes ensuring cooling centers are physically accessible and communications (like heat warnings) use inclusive formats such as simple language, sign language, or pictograms.
  - **Promote Equity**: Incorporate gender analysis and disability-inclusion checks into all project outputs, advocating for policies that protect vulnerable groups and adapting urban designs to benefit those who spend more time near home, such as women and children.
  - **Link Knowledge**: Combine scientific data (e.g., satellite-derived heat maps) with local knowledge about where vulnerable residents live to target interventions effectively.

Recommendations for GEDSI Integration:

- **Policy Integration**: Integrate GEDSI guidelines into Bangkok's Heat Action Plan and future National Adaptation Plans, mandating accessibility standards for cooling centers and public spaces, and updating emergency alert protocols to include sign-language broadcasts and voice announcements for the visually impaired.

- **Data and Research**: Support the creation of a citywide, sex- and disability-disaggregated "heat vulnerability atlas" to map temperature, socioeconomic status, and health outcomes, enabling evidence-based and equitable interventions. All activities should generate gender-disaggregated and disability-inclusive data.
- **Capacity Building**: Allocate funding for training city officials, architects, and planners on inclusive design and promote diverse staffing in agencies dealing with heat and disaster. Encourage employment programs (grants or quotas) for women and persons with disabilities in green jobs, such as urban forestry.
- **Community Empowerment**: Continue supporting local organizations representing vulnerable groups, such as women's cooperatives, to implement communal shade or water stations. Institutionalize mechanisms, like advisory councils, for these groups to provide input on climate policy. Train local leaders, including women and disabled persons, as "Heat Ambassadors" to help neighbors prepare for heatwaves.

Policy and Urban Planning Recommendations

Effective urban heat management necessitates robust policy frameworks and integrated urban planning strategies that go beyond just environmental considerations.

- **Strategic Planning**: Policy-making should involve multi-disciplinary approaches combining ecological, technological, and community strategies, and should be incorporated into city planning and development frameworks.
- **Mainstreaming Heat Resilience**: Thailand's National Adaptation Plan already acknowledges the need for modeling heat stress scenarios and formulating guidelines for urban heat in large cities. Vietnam's National Strategy on Climate Change for 2050 emphasizes sustainable cooling, sun-proof buildings, energy-efficient solutions, and leveraging natural elements. However, local policies in Vietnam often lack leadership awareness and commitment to urban heat as a priority issue.
- **Urban Design Strategies**:
    - **Mixed-Use Development**: Promote mixed-use areas to facilitate walking and reduce car reliance, thereby lowering heat emissions.
    - **Zoning Regulations**: Incorporate stipulations for green spaces in new developments to enhance urban greenery.
    - **Heat Vulnerability Mapping**: Utilize tools like the Heat Vulnerability Index (HVI) to identify and prioritize interventions in areas most affected by the UHI effect. The analysis in Bangkok identified critically vulnerable districts like Samphantawong, Pom Pram Sattru, and Bang Rak, requiring immediate comprehensive interventions.
    - **Consideration of Traditional Practices**: Explore traditional solutions like Uchimizu, which could offer temporary cooling where greening is impractical.

- **Technological Solutions**: Incorporate technological advancements such as:
    - **Cool Roofs**: Reflective coatings can reduce heat absorption by up to 80%, leading to significant energy savings.
    - **Smart Urban Monitoring**: Use sensor technologies for real-time monitoring of temperature and air quality to enable prompt responses to heat events.

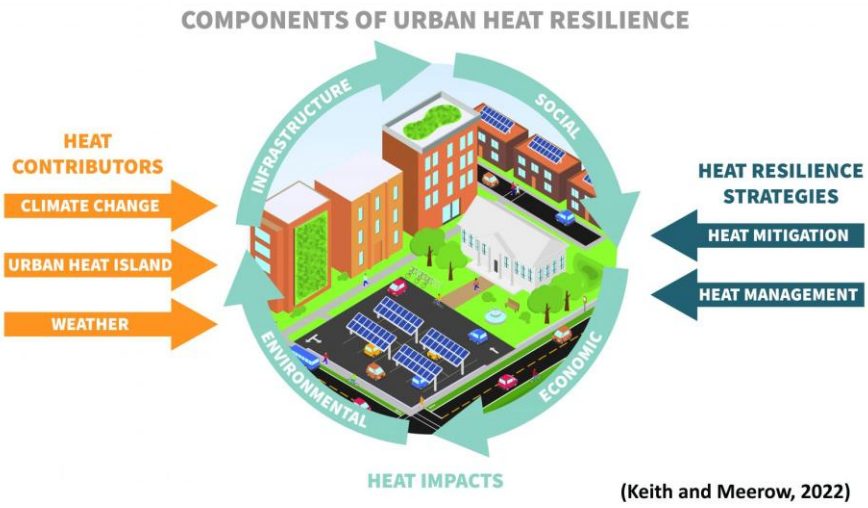


Figure 45 Components of Urban Heat Resilience [148]

Cross Border Collaborations

Cross-border collaboration is a crucial component of the "Urban Heat Resilience: Bridging Science, Policy, and Sustainable Design" project, specifically aiming to share learnings from Bangkok with second-tier cities across the Mekong region to build a stronger regional response to urban heat. The project is designed to bridge the gap between scientific understanding, policy frameworks, and practical implementation of urban heat resilience strategies, focusing on nature-based solutions and their potential to support vulnerable communities.

Several mechanisms are outlined for facilitating this knowledge exchange:

- **Awareness and Communication Campaigns**
    - The project intends to develop mechanisms to disseminate knowledge gained from Bangkok to selected second-tier cities in Vietnam and establish resources to facilitate the application of these insights in diverse urban contexts.
    - **Targeted outreach and communication campaigns** will be launched, utilizing local media, social media influencers, community meetings, and places of worship to spread heat-safety information.
    - Materials will be developed in **multiple languages and formats**, including Thai, English, Vietnamese, to ensure inclusivity and reach diverse populations, including those with low literacy or non-Thai speakers.

    - **Public health messaging** is a key aspect of international heatwave policy frameworks, and training media on inclusive messaging should be part of the strategy.
- **Workshops and Participatory Engagement**
    - **Participatory workshops and surveys** are mandated to ensure representation from diverse groups, including women, the elderly, youth, and persons with disabilities, enabling the co-design of solutions.
    - Workshops will encourage sharing of experiences on how heat affects different households, such as a mother's account of cooking in heat versus a disabled person's challenges accessing clinics.
    - **Focus groups** involving provincial policymakers, academic researchers, and international experts in Vietnam have already been a mechanism to discuss the current situation and challenges of urban heat in Vietnamese cities, including My Tho.
    - Engaging local communities in the planning and implementation process is emphasized to ensure that solutions are context-specific and effective. Civil society groups are expected to lead community workshops.
- **Training and Capacity Building**
    - The project aims to **enhance local capacity through training and education**.
    - This includes **capacity building in urban heat resilience planning and implementation**, providing training on the use of heat modeling techniques and interpretation of results.
    - **Training staff** from government agencies (like Bangkok Metropolitan Administration - BMA), line departments, NGOs, and Civil Society Organizations (CSOs) on inclusive methods and communication, such as gender sensitization, disability etiquette, and accessible facilitation, is a planned activity.
    - **Training local leaders**, including women and persons with disabilities, as "Heat Ambassadors" will empower them to help neighbors prepare for heatwaves and organize heat-awareness sessions in community centers, markets, and schools.
    - Funding should be allocated for **training city officials, architects, and planners on inclusive design**.

Beyond these specific mechanisms, the project emphasizes a broader approach to knowledge exchange and collaboration:

- **Policy Recommendations and Dialogue**
    - The project aims to provide **evidence-based policy recommendations** for urban heat management.
    - These recommendations will be part of a flagship report, journal articles, and other communication products designed to guide the use of Nature-based Solutions (NbS) in Bangkok and the broader Mekong region.

    - **Multi-stakeholder validation workshops** will be organized to present results and ensure community voices inform final policy recommendations. Policy briefs will align findings with Sustainable Development Goals (SDGs) and Sendai priorities to be shared with national agencies.
    - This includes advocating for policies that protect vulnerable groups, adapting building designs, and ensuring labor regulations protect informal outdoor workers from heat exposure.
- **Data and Research Sharing**
    - The project utilizes **advanced heat modeling techniques** to assess urban heat risks and plans to create detailed heat risk maps for Bangkok.
    - All activities will generate **gender-disaggregated and disability-inclusive data**. This data, combined with local knowledge, will be used to map heat vulnerabilities and inform interventions.
    - The results of urban heat modeling and Nature-based Solutions (NbS) scenario analysis, which quantify the cooling benefits and reductions in heatwave frequency, duration, and severity, will be key deliverables. These technical and academic outputs are crucial for reaching a wide audience, including policymakers and researchers.
- **Peer-to-Peer Learning and Partnerships**
    - A core objective is to **facilitate peer-to-peer knowledge exchange**.
    - This involves **partnerships and knowledge exchange** between scientific institutions, policymakers, urban planners, and community representatives to address urban heat challenges and encourage **cross-border collaboration between Thailand and Vietnam**.
    - The project's implementation structure brings together regional expertise (Asian Disaster Preparedness Center - ADPC), international technical knowledge (Alluvium), academic rigor (RMIT), and local environmental wisdom (Thailand Environment Institute - TEI). This multi-lateral collaboration in itself fosters knowledge exchange and is intended to promote scalable solutions for urban heat challenges across the Mekong region.
    - International agencies and donors can also contribute by bringing best practices from other regions and reinforcing the integration of Gender Equality, Disability, and Social Inclusion (GEDSI) principles.

Monitoring, Evaluation, and Way Forward

To ensure the long-term effectiveness and equity of urban heat resilience initiatives, continuous monitoring, evaluation, and adaptive management are critical.

- **Comprehensive Indicators**: Establish SMART (Specific, Measurable, Achievable, Relevant, Time-bound) indicators to track GEDSI integration and overall project success. These include:

    - **Participation Indicators**: Percentage of women, youth, elderly, and persons with disabilities engaged in workshops, surveys, and committees (targeting at least 50% women; proportional representation for PWDs).
    - **Access Indicators**: Number of project facilities/services meeting accessibility standards (e.g., wheelchair ramps in cooling centers).
    - **Awareness Indicators**: Measured increase in heat risk awareness among various demographic groups through pre/post surveys.
    - **Outcome Indicators**: Reductions in heat-related health incidents or increased use of communal cooling solutions in target areas.
    - **Equity Indicators**: Monitoring equitable distribution of benefits like jobs in greening projects or grants.
- **Data Collection Methods**: Utilize diverse data collection methods including surveys, interview records, workshop attendance sheets, and official statistics, ensuring gender- and disability-sensitive data wherever feasible.
- **Policy Alignment**: Align reporting with Sustainable Development Goals (SDGs 5, 10, 11, 13) and Sendai Framework priorities, categorizing findings under relevant goals without losing sight of local context.
- **Continuous Improvement**: Establish easy feedback mechanisms for beneficiaries (hotlines, suggestion boxes, mobile surveys) to ensure interventions are working and can be adjusted as needed. Lessons learned should be documented and used to replicate successful strategies in other Thai cities and beyond.

Conclusion

Urban heat is a complex challenge at the intersection of climate, gender, and social dynamics. While Nature-Based Solutions offer a substantial and measurable buffer against climate-driven urban heat, their effectiveness is not guaranteed and they cannot fully offset projected warming. Therefore, they must be implemented as **integral components of a broader, multi-layered adaptation strategy**. This strategy must incorporate behavioral changes, technological interventions, comprehensive urban planning, and, crucially, a robust **Gender Equality, Disability, and Social Inclusion (GEDSI) framework**.

By centering the needs and knowledge of women, people with disabilities, and marginalized communities, urban heat resilience measures become not only fairer but also significantly more effective and sustainable. This includes embedding heat resilience in urban design and policy, deploying inclusive heat alert systems, and establishing accessible cooling centers and hydration points. Moving forward, **political will and long-term investment** are essential to support the technical design and equitable implementation of these integrated solutions. Ultimately, a multi-layered and inclusive approach is critical to enabling Bangkok and other cities in the Mekong region to cope with, and adapt to, the escalating impacts of urban heat, fostering a more heat-resilient, equitable, and livable future for all residents.

Appendices

A. Questionnaire
Questions for the government bodies (Bangkok)

1. **Urban Heat Mapping:**
   - Are there existing Urban Heat maps for Bangkok? If yes, which areas are identified as the hottest?
   - Are there ambient temperature or Wet Bulb Globe Temperature (WBGT) *(measure of temperature, humidity, wind speed, sun angle and cloud cover solar radiation maps*) available for Bangkok?
   - What alternative heat indicators are being used in Bangkok?
   - What is the criteria of heat waves in Bangkok? Is there any Early Warning System available?
   - What is the communication system of Heat Alerts if any?
2. **Population Demographics and Vulnerability:**
   - What is the total population of Bangkok and which areas have the highest population density?
   - Are there maps or data showing population distribution by age, income levels, e, and access to green spaces?
   - What is the estimated size and location of vulnerable populations such as the unhoused and refugees?
3. **Labor Conditions and Occupational Heat Exposure:**
   - Which local industries are not cooled or under-cooled (both indoor and outdoor)?
   - Is there data on the percentage or total number of people per occupation/industry that are heat-exposed?
   - Is there demographic data (gender, age, income, ethnicity) on heat-exposed workers?
4. **Zoning and Regulations:**
   - Are there zoning regulations or incentives for green spaces and water features?
   - What building regulations exist for heat mitigation (e.g., reflective roofing, green roofs, AC installation)?
   - How are current zoning laws impacting heat adaptation efforts and inequitable heat burdens?
5. **Climate Factors and Heat Wave History:**
   - Is there a documented history of heat waves in Bangkok? If yes, what were their durations, attributed mortality, and weather statistics?
   - What are the average summer heat metrics (heat index, WBGT, apparent temperature) in Bangkok?
   - How long does the heat season typically last, and which weeks of the year constitute the heat season?
6. **Weather Monitoring:**
   - Where are the weather stations located in Bangkok?

Bangkok Heat Vulnerability Assessment Questionnaire

A. Demography and Household Information

1. **Respondent Name: (Optional)**
2. **Location/street:**
3. **GPS coordinates:**
4. **Respondent's household data:**

Age group	Gender	Employment status	Any existing Medical Condition	Educational level
Children under 5				
5-14				
15-64				
65 and above				

Employment status options: Student, Employed, Self Employed, Unemployed, Retired, Housewife, Dependent, Other

Educational level options: Primary, Secondary, Vocational or Professional education, College or university, Other

5. **For employed household members:**

- Is your job primarily outdoors? [ ] Yes [ ] No
- If yes, average daily outdoor exposure time: ____ hours

6. **Are any household members pregnant?**

[ ] Yes
[ ] No

B. Exposure (High Priority)

7. **What months do you consider the hottest annually?**

8. **Do you feel it has become hotter in the last 5-10 years?**

[ ] Yes
[ ] No
If yes, please elaborate:

9. **On average, how many hours per day do you spend outdoors during the hottest months?**

10. **How would you rate the intensity of heat in your area during summer?**

[ ] Very high

[ ] High
[ ] Moderate
[ ] Low

11. Do you experience high temperatures at night that make it difficult to sleep?
[ ] Yes, frequently
[ ] Sometimes
[ ] Rarely
[ ] No

C. Sensitivity (High Priority)

12. Does anyone in the household have pre-existing health conditions that make them more sensitive to heat? (e.g., cardiovascular disease, respiratory issues, diabetes)
[ ] Yes
[ ] No
If yes, please specify:

13. Has anyone in the family been hospitalized in the last few years due to heat-related illness?
[ ] Yes
[ ] No
If yes, please provide details (age, gender, month of admission):

D. Adaptive Capacity

D1. Private Adaptive Capacity (High Priority)

14. House ownership:
[ ] Own
[ ] Rented

15. Type of House:
[ ] Community Housing
[ ] Informal house
[ ] Traditional Thai house
[ ] Modern concrete building
[ ] Mixed/semi-modern

16. Main material of the exterior walls:
[ ] Concrete
[ ] Wood
[ ] Brick
[ ] Other (specify)

17. Main material of the roof:
[ ] Concrete
[ ] Asbestos
[ ] Metal sheets
[ ] Plastic sheets
[ ] Other (specify)

18. Is the ceiling exposed to direct sunlight?
[ ] Yes
[ ] No

19. Exterior wall paint of the household:
[ ] Light colors (white/blue)
[ ] Dark colors (black/brown)

20. Do you have access to the following cooling methods at home?
- Fans: [ ] Yes [ ] No
- Coolers: [ ] Yes [ ] No
- AC: [ ] Yes [ ] No

21. If you have AC, how often do you use it during hot months?
[ ] Daily [ ] Several times a week [ ] Rarely [ ] Never

22. Average monthly household income:

23. Average Monthly Electricity Bill
- **Do you get any subsidy on Electricity?**

24. Average monthly income loss due to heat (taking days off due to heat):

25. Is there an increase in the electricity bill during the summers?
[ ] Yes

[ ] No
If yes, approximate percentage increase compared to cooler seasons:

26. Are there any green cover/trees around the house?
[ ] Yes
[ ] No

D2. Public Adaptive Capacity (High Priority)

27. Are there public cooling centers available in your area?
[ ] Yes
[ ] No
[ ] Don't know
If yes, how far is the nearest one? ____ km

28. Are there public parks or water bodies near your home?
[ ] Yes
[ ] No
If yes, approximate distance: ____ km

29. Are there shaded public areas (e.g., covered walkways, tree-lined streets) in your neighborhood?
[ ] Yes
[ ] No

D3. Occupational/Educational Adaptive Capacity (Medium Priority)

30. For each working/studying household member, please provide:
- Average distance to workplace/school: ____ km
- Most common mode of transportation:
- Is air conditioning available at your workplace/school? [ ] Yes [ ] No
- What cooling options are available at your workplace/school?

31. Is there flexibility to adjust work/school hours to avoid peak heat?
[ ] Yes
[ ] No

E. Infrastructure and Urban Planning (High Priority)

32. Do you face any power outages during peak heat hours?
[ ] Yes
[ ] No
If yes, frequency in peak summer months:

33. How would you rate the reliability of electricity supply during summer?
[ ] Very reliable
[ ] Somewhat reliable
[ ] Unreliable
[ ] Very unreliable

34. If using public transport, is it air-conditioned?
[ ] Yes, always
[ ] Sometimes
[ ] Rarely
[ ] Never

F. Heat Impact and Coping Strategies

35. What are the key impacts of heat during summer on:
- Households:
- Women:
- Children:
- Senior citizens:

36. How does your family stay hydrated during hot weather?

37. Name the food/beverage articles avoided at home in summer:

38. Name the food/beverage articles preferred at home in summer:

39. Have you taken days off due to summer/excess heat?
[ ] Yes
[ ] No
If yes, number of days taken off in the last year:

G. Heat-Health Awareness & Impact

40. Are you aware of the following problems related to heat stress? (Check all that apply)

[ ] Sweating
[ ] Excessive thirst
[ ] Dizziness
[ ] Heat rash
[ ] Heat cramp
[ ] Heat stroke
[ ] Dehydration
[ ] Fatigue
[ ] Nausea
[ ] Headache
[ ] Other (specify)

41. Do you receive any information about measures during heatwaves?

[ ] Yes
[ ] No
If yes, how is this information shared with you?

42. Is there a public health center in your area?

[ ] Yes
[ ] No
If yes, how far is it? ____ km

H. Heat Stress Adaptation & Mitigation Measures

43. Are there any community-level initiatives in your area/neighborhood during summers to mitigate heat stress? (Check all that apply)

[ ] Drinking water stations
[ ] Treatment camps
[ ] Awareness campaigns
[ ] Others (specify)

44. What measures do you suggest for building heat stress resilience in Bangkok?

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