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UNLIVABLE

**CONFRONTING EXTREME URBAN HEAT IN
LATIN AMERICA AND THE CARIBBEAN**



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FOREWORD

The record-breaking heat that gripped Latin America and the Caribbean in 2024 is more than a passing weather anomaly—it is a warning. In places like Belém, where heat has shaped daily life, temperatures now soar to unbearable levels, aggravated by humidity and unreliable electricity. Mexico City, once sheltered by its altitude, shattered records with six of the city’s hottest days ever recorded. In Argentina, relentless waves of extreme heat pushed temperatures past 45°C, threatening lives and livelihoods on an unprecedented scale.

Extreme urban heat is no longer a distant future concern—it’s a current crisis. Historically, cities in the region have been shielded by altitude, sea breezes, and the wisdom of centuries-old urban planning. Yet, as global temperatures rise, these defenses are rapidly eroding. Urban sprawl, aging infrastructure, and social inequalities only magnify the dangers, exposing millions to greater risk.

The stakes could not be higher. More than 80 percent of the region’s population lives in urban areas—the highest rate in the developing world. Heat endangers not just health, but also city economies, infrastructure, and the broader social fabric. It disproportionately harms the elderly, the poor, and those working in informal jobs with little shelter or recourse. With nearly half of all workers informally employed and more than 170 million people living in poverty, the urban heat crisis is also a profound equity challenge.

This report provides a sobering but necessary examination of what rising temperatures mean for cities in the Latin American and Caribbean region—and what can be done to prepare, adapt, and protect the most vulnerable. From expanding green spaces and rethinking urban design to protect those most at risk, city leaders can take practical steps to cool their cities and improve daily life for millions. The report highlights some of the most promising adaptation measures being tested or scaled across the region and the world.

Ultimately, the challenge of urban heat is also an opportunity: to reimagine cities as more livable, inclusive, and climate-resilient places. The choices made today will shape not only how cities endure rising temperatures—but how well they can thrive in the decades to come.



Maria Marcela Silva

Regional Director, Infrastructure, Latin America & Caribbean

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OVERVIEW



From Mexico City, to Santo Domingo, to Buenos Aires, a new climate reality is emerging in Latin America and the Caribbean: Not only are average temperatures rising, but very hot days are increasingly common, with many cities enduring record-breaking heat and extended heatwaves.

This trend has serious consequences for human health and well-being, for urban economies, and even for critical infrastructure such as power systems and roads, most of which were not built for such high temperatures.

Heat kills—sometimes suddenly, through heat stroke or heat-related injuries, but more often subtly, by straining the heart, lungs, kidneys and other organs and accelerating death among people who were already vulnerable. Heat-related mortality jumped by 140 percent in Latin America from 2000–2009 to 2013–2022. In 2023 alone, an estimated 48,000 over the age of 65 died prematurely from heat-related causes across the Americas.

Climate change is the main driver of this trend, but in Latin America and the Caribbean—one of the most urbanized regions of the world, with about 82 percent of residents in cities as of 2025—another key factor exacerbates heat risks: the urban heat island (UHI) effect. Built-up areas absorb and retain heat, and high-density areas with little green space can be several degrees hotter than the surrounding countryside. Inadequate housing also makes it difficult for many people to stay cool indoors.

This report examines the growing threat of heat in cities across Latin America and the Caribbean, including the outlook for the coming decades; the implications for urban infrastructure and for human health, well-being, and prosperity; and what urban leaders and national governments can do to mitigate the risks, particularly for the most vulnerable people.

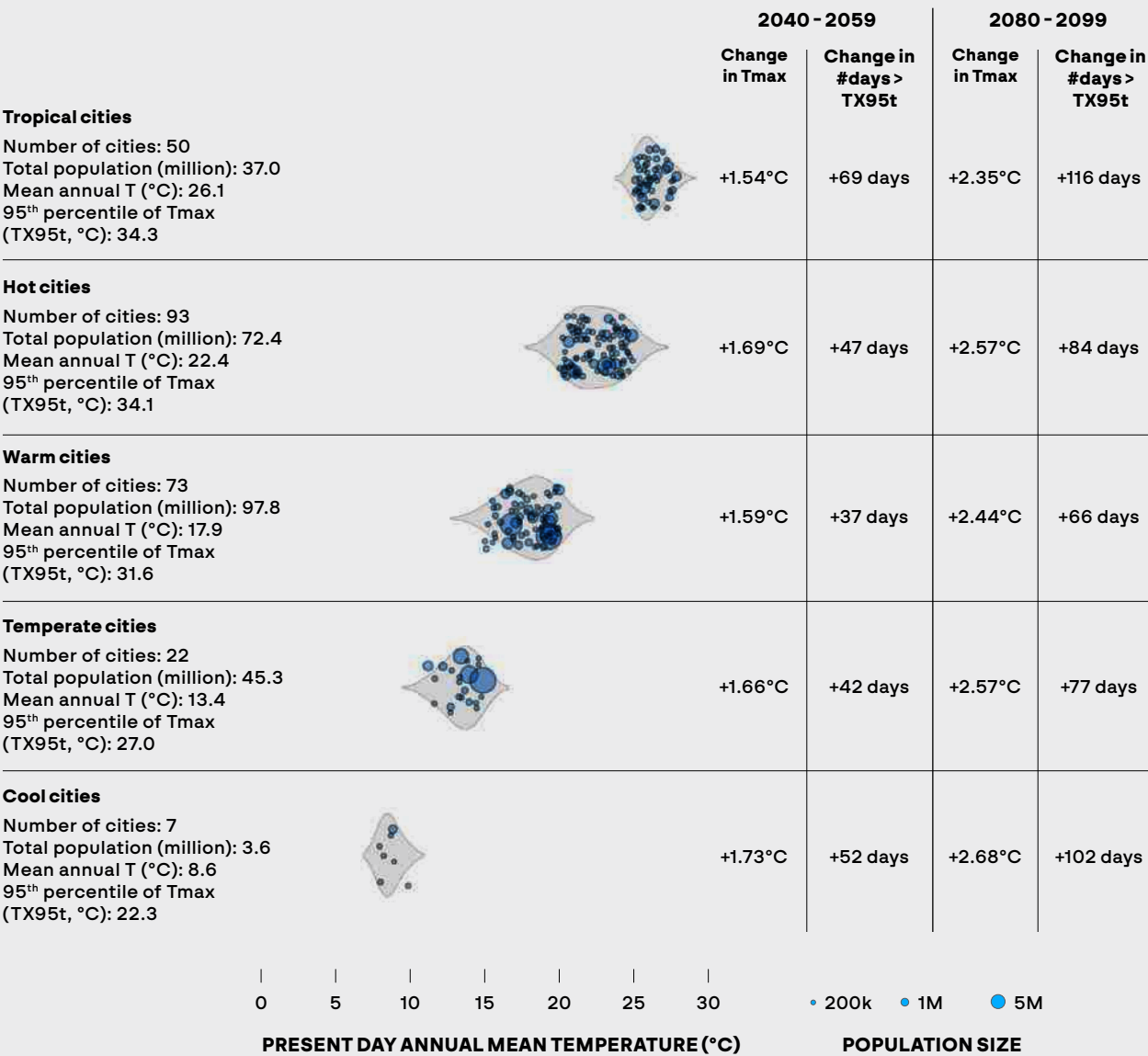
CITIES ACROSS THE REGION ARE GETTING HOTTER

Cities in Latin America and the Caribbean have milder climates, on average, than those in other regions at similar latitudes—some benefiting from high elevation, others from coastal locations. Yet temperatures are rising in cities in all climate zones. Overall, mean air temperatures over land in the region have increased by about 1.5°C since pre-industrial times.

As global temperatures rise, in a “middle-of-the-road” climate scenario (SSP2-4.5), daily maximums across Latin American and Caribbean cities are projected to increase by 1.5–1.7°C by mid-century (2040–2059), and 2.3–2.7°C by late century (2080–2099) relative to 1986–2005.

The number of hot days per year—when temperatures exceed the 95th percentile for a location in 1986–2005—is also expected to grow, with cities facing, on average, 36–69 additional hot days by mid-century, and 66–116 additional hot days by late century (Figure O-1). The largest increases are projected in tropical and cool cities, showing that no climate zone is exempt.

FIGURE O-1. PROJECTED INCREASE IN HOT DAYS (ABOVE 95TH PERCENTILE OF LOCAL DAILY MAXIMUM TEMPERATURES) FOR LATIN AMERICAN AND CARIBBEAN CITIES DAILY MAXIMUM TEMPERATURES)



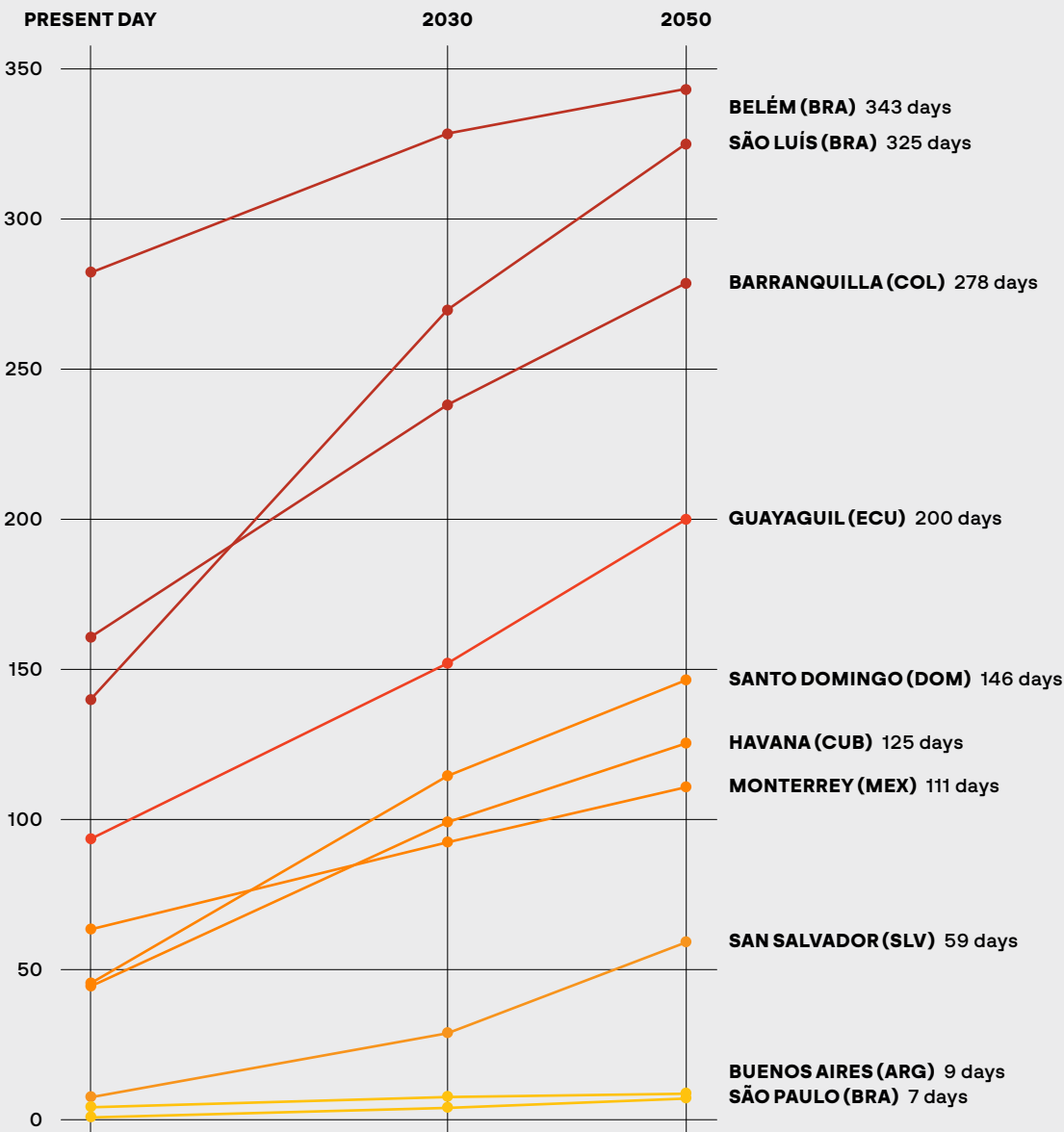
Source: World Bank staff analysis using data from ERA5-Land Reanalysis, NEX-GDDP-CMIP6, and the Urban Centre Database.

Note: Analysis includes medium-sized (>200,000 population) or larger cities available in the Urban Centre Database, that are grouped per present-day annual mean temperature category: tropical (>25°), hot (20–25°C), warm (15–20°C), temperate (10–15 °C), and cool (5–10°C). The UCD database contains no cold cities (< 5°C) with a population greater than 200,000 people. A hot day is defined as a day with a daily maximum temperature exceeding the 95th percentile of observed temperatures for that city in that period. The threshold for a “hot day” varies significantly, from 22.3°C in cool cities, to 31.6°C in warm cities, to 34.3°C in tropical cities, but health risks also arise at lower temperatures in cooler locations, because people are not acclimatized.

Further analysis accounting for the UHI effect and models the wet-bulb globe temperature (WBGT)—a measure that incorporates air temperature, humidity, wind speed, and exposure to solar radiation—highlights the risks to human health. Already today, the hottest cities in the region (e.g., in the Amazon basin and on the Caribbean) face up to six months’ worth of extreme heat: days with WBGT above 30.5°C. By mid-century, Barranquilla could exceed that threshold for three-quarters of the year, and Belém and São Luís, Brazil, for 89 and 94 percent of the year, respectively (Figure O-2).

FIGURE O-2. RISING HEAT IN LARGE CITIES: DAYS OF EXTREME HEAT (WBGT ABOVE 30.5°C) THROUGH 2050

DAYS WITH EXTREME HEAT IN THE SUN
WET-BULB GLOBE TEMPERATURE ABOVE 30.5°C



Source: World Bank staff analysis using WBGT data from CarbonPlan and city data from the Urban Centre Database.

Note: An extreme heat day is defined as a day with a maximum wet-bulb globe temperature (WBGT) greater than 30.5°C in the sun.



Photo: Johnnie Miller

In Buenos Aires, affluent neighborhoods with abundant green space border informal settlements like this one near San Isidro.

URBAN INFRASTRUCTURE EXACERBATES HEAT

The urban population of Latin America and the Caribbean increased from about 62 million in 1950 to an estimated 538 million by 2023. To accommodate this growth, cities large and small have both increased their density and sprawled out into the surrounding countryside, fundamentally changing the landscape.

Urbanization replaces farmland or natural landscapes with concrete, asphalt, brick, steel, and other materials that absorb and retain heat. Buildings disrupt and block airflow, particularly in densely built-up areas. Vehicles and mechanical systems such as air conditioning emit additional heat. In many urban areas, green areas are sparse, depriving urban dwellers of the shade provided by trees and the cooling from plants' evapotranspiration.

Due to the UHI effect, average nighttime temperatures in a city might be 2–3°C warmer than in the nearby countryside. And after very hot, sunny days studies in Paramaribo, Suriname, and Rio de Janeiro, for example, have found nighttime temperature differences as great as 7–8°C.

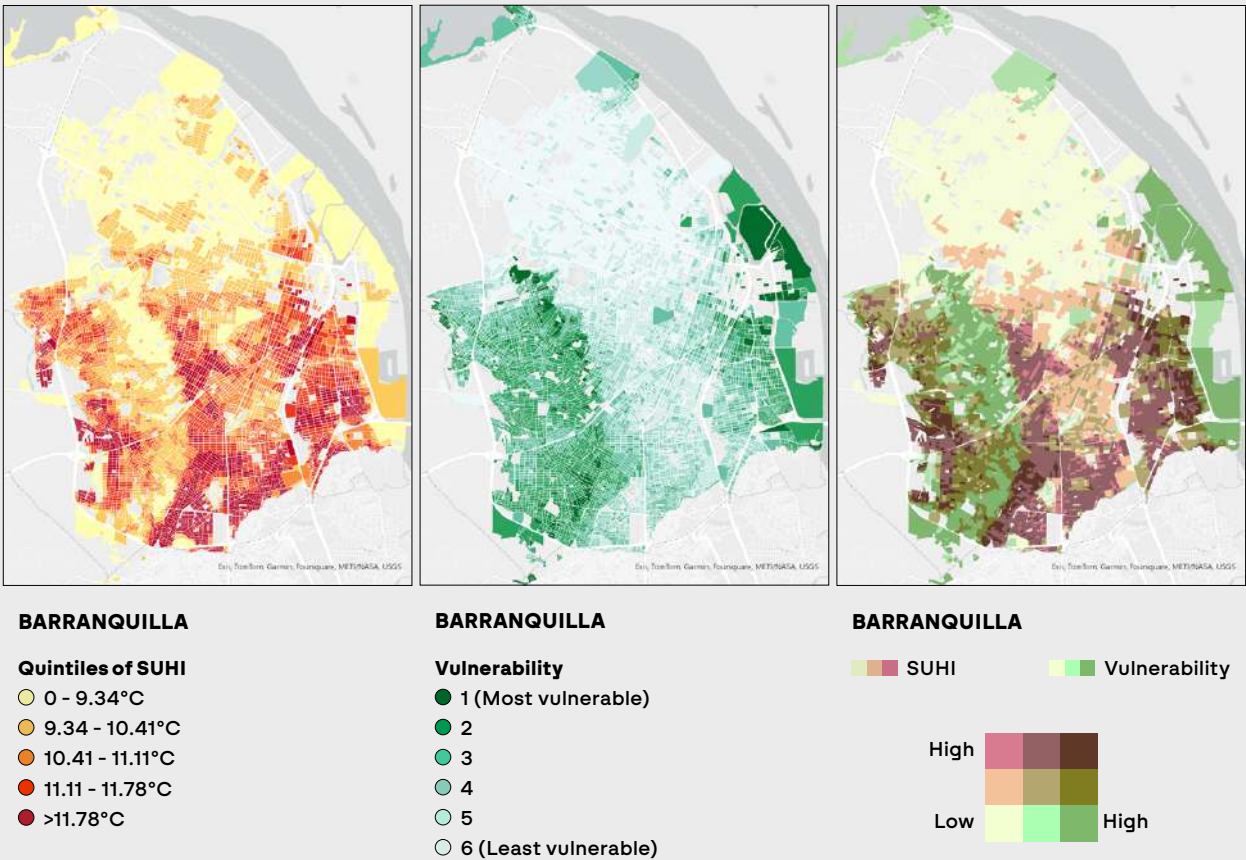
The intensity of the UHI varies across neighborhoods, depending on the shape and layout of the built environment, density and overcrowding, the building materials used, and how much vegetation remains or has been replanted. Proximity to green space, rivers, or the coast and topography can also make a difference.

Thermal inequalities have been documented in several cities. In Greater Santiago, Chile, analyses of temperature data in the summers of 2005–2017 and during heatwaves in the decade up to 2023 showed differences of up to 6.7°C between the hotter and cooler parts of the city, and significant overlap between urban heat and poverty.

New analysis for this report looking at block-level census data and high-resolution temperature data for five cities each in Colombia and Mexico shows a correlation between socioeconomic vulnerability and the intensity of the surface UHI effect in seven of the cities studied. This is linked to lack of tree cover and a large share of impervious surfaces—though in Bogotá and Medellín, for example, where the poor tend to live on hillsides, elevation has a cooling effect.

Figure O-3 shows thermal inequalities in Barranquilla, where heat and poverty overlap in the west and south of the city. The affluent neighborhoods in the north, closer to the coast, show lower heat exposure.

FIGURE O-3. SEVERITY OF UHI EFFECT BASED ON LAND SURFACE TEMPERATURE (LEFT), SOCIOECONOMIC VULNERABILITY (MIDDLE), AND OVERLAP BETWEEN THE TWO IN BARRANQUILLA, COLOMBIA



Source: World Bank analysis. Note: SUHI means surface urban heat island effect.

Thermal disparities are a critical concern in addressing urban heat because across the region, 24.5 percent of urban residents lived in poverty as of 2023, including 38.1 percent of children. Income inequality is also significant, with the Gini index scores of 14 countries with 2022–2023 data averaging 0.452. The average Gini index scores for cities in several countries—such as Brazil, Chile, Colombia, Costa Rica, Ecuador, and Panama—are similarly high.

Moreover, whether or not they live in particularly hot neighborhoods, studies show that low-income people are disproportionately exposed to urban heat due to low-quality housing and inadequate cooling, and their reliance on walking or public transit instead of driving. They may also struggle to cope with heat, as their options and resources are limited.

HOUSING, ENERGY, AND TRANSPORT SYSTEMS ARE NOT READY FOR HEAT

In many cities, population growth has significantly outpaced housing construction, resulting in large housing deficits. An estimated 93.4 million people—16.9 percent of urban residents—lived in slums, informal settlements, or inadequate housing as of 2022, and in some countries the share is much greater: 45.1 percent in Peru and 51.1 percent in Haiti.

Informal settlements concentrate poverty, social vulnerability, and often also exposure to extreme heat. Homes built without professional help, with inadequate materials, tend to be particularly prone to overheating due to poor ventilation, and roofs that provide little insulation and often absorb heat. Moreover, informal settlements are often in the urban periphery and lack essential infrastructure, basic services such as safe potable water, parks and street trees, or reliable public transit. This limits access to public services and amenities that could mitigate the effects of extreme heat, such as health care facilities and cooling centers.

Public transit systems in the region are also showing their limitations amid rising temperatures, with frequent delays and failures and extreme heat inside vehicles. In April 2024, for example, temperatures on Mexico City’s STC Metro trains reportedly reached 39°C during peak hours. Some public transit systems have air conditioning, but many others do not.

Walking is getting riskier as well amid rising heat, and it accounts for about a quarter of all trips in the region—and far more in some cities, such as Guadalajara. The lowest-income people walk far more than wealthier groups, as they often cannot afford any alternative.

Heat is also straining electricity systems. Extreme heat drives spikes in demand and affects the performance of transmission lines and transformers, sometimes resulting in catastrophic equipment failures. The region also relies heavily on hydropower, which provided 45 percent of power generated in 2022 and is highly susceptible to heat and drought. Historic droughts in Ecuador in 2022–2024, for example, caused such a sharp drop in generation that, starting in September 2024, the power had to be shut off for up to 14 hours per day in many regions, affecting essential services and costing the economy at least \$2 billion by mid-October.

EXTREME HEAT HAS SIGNIFICANT IMPACTS ON HUMAN CAPITAL

Of all the impacts of rising temperatures and heatwaves, arguably the most critical are those on human health. Extreme heat can be deadly, in both visible and more subtle, hard-to-detect ways. Exposure to high temperatures has been shown to exacerbate many conditions, including cardiovascular disease and diabetes, and to increase adverse pregnancy outcomes. It can limit people’s physical and cognitive abilities, and negatively affect mental health.

The health impacts of extreme heat impose direct costs on health care systems and even larger costs on society through disability and premature death. High temperatures also worsen air pollution, a major threat to public health in the region, and intensify its effects, and they are a key reason why the incidence of vector-borne diseases such as dengue is increasing.

A 2024 World Bank study considered these and other effects of climate change on health in 69 low- and middle-income countries, including the 11 largest in Latin America and the Caribbean. It projected that between 2026 and 2050, they would result in about 271,200–274,500 premature deaths in the region and could impose economic costs of US\$285.3–763 billion, or 0.19–0.45 percent of the 11 countries’ projected GDP over that period.

The health impacts of heat are of particular concern to cities in Latin America and the Caribbean for two key reasons: the large inequalities and socioeconomic vulnerabilities noted above, and the fact that the region is aging faster than most of the world. Already in 2022, 13.4 percent of the region’s population was over 60 years old—nearly 90 million people. By 2050, this share is projected to rise to 25 percent, or 193 million.

The body has different ways to keep internal organs at a safe, stable temperature—usually within a degree or two of 37°C—but as the severity of conditions and/or the length of exposure increase, so does the risk of lasting harm or even death. Some people are also more sensitive to heat—and less able to cope—than others. Older adults are particularly vulnerable and account for a disproportionate share of fatalities. Infants and small children are also at high risk, as are pregnant people and those with cardiovascular disease, diabetes, and other conditions.

While most research on the impacts of extreme heat focuses on older adults or workers, extreme heat also poses serious risks to children, both physically—as they generally spend more time outdoors than adults—and in their education. The impacts are already being felt at schools, with reports throughout the region of children feeling sick from the indoor heat, and some schools being forced to shift to online classes, limit their hours, or close temporarily.

Beyond physical discomfort, students and teachers routinely report having poor concentration and impaired learning under hot conditions, and research bears this out. A study in Colombia found a 1°C increase in the average daily maximum temperature in the preceding year led to a decline of at least 2 percent of a standard deviation urban students’ test scores. Research in Brazil indicates that an average student in the poorest 50 percent of Brazilian municipalities could lose up to half a year of learning overall due to rising temperatures.

MANY WORKERS ARE EXPOSED TO DANGEROUS LEVELS OF HEAT

Every day in cities across the region, tens of millions of people earn a living by performing physical labor under conditions that expose them to significant heat. As temperatures rise and heatwaves become more common, these livelihoods will become ever riskier.

The extent to which a worker is at risk of heat stress depends not only on the individual’s physiology, or on the ambient temperature, humidity, and air flow, but also on factors specific to the job and workplace, such as the level of physical exertion and the protective gear used. Across the Americas, the International Labour Organization (ILO) estimates, 70 percent of workers were exposed to excessive heat in 2020, resulting in an estimated 2.8 million injuries, including 6.7 percent of fatal occupational injuries. The analysis also found that the share of fatal injuries occurring during heatwaves had more than doubled from 2000 to 2020.

Along with physiological factors, lack of information and precarious situations, such as informal employment, can make some workers more susceptible to heat stress, as they cannot choose to protect themselves, or know how to. In the first quarter of 2024,

urban informal employment rates in the region ranged from 26.7 percent in Chile and 32.7 in Costa Rica, to 52.9 percent in the Dominican Republic, 58 percent in Ecuador, and 67.1 percent in Peru.

Workers who are vulnerable due to poverty, informality, migrant status, or other factors may also be disproportionately affected by heat-related illnesses or injuries, as they may not be able to access timely and affordable health care. But if they do not work—by choice or due to their employer’s precautions—they may not be able to rely on safety-net programs to offset any lost income. The latter is also true if they are incapacitated by heat-related injuries.

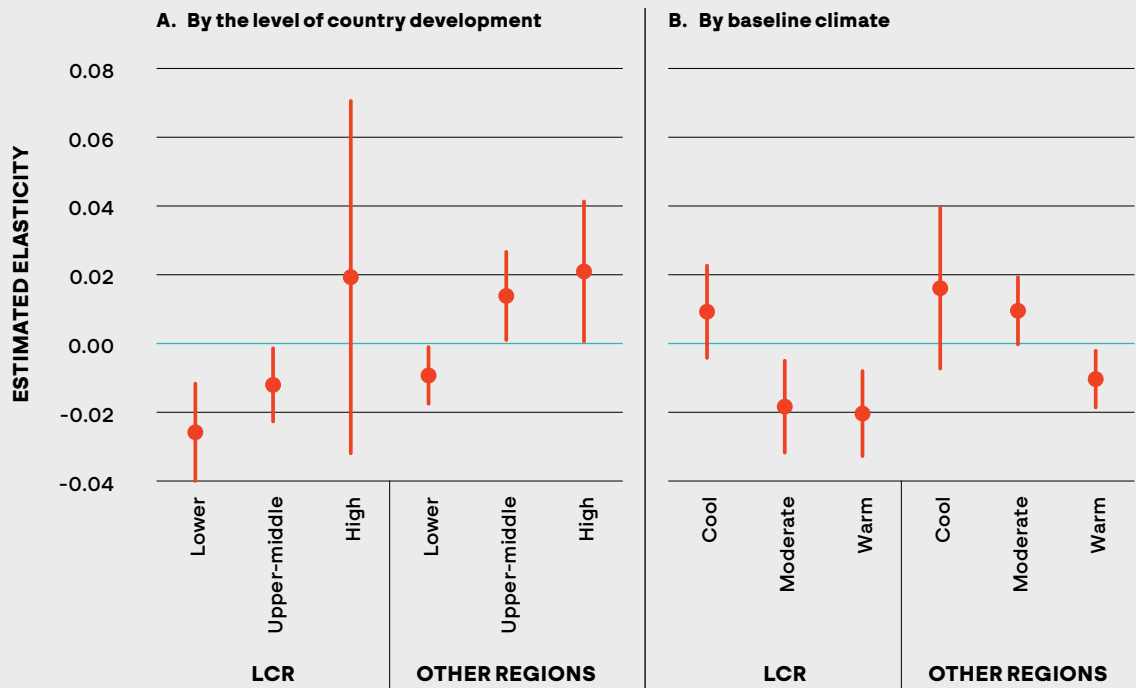
HEAT POSES GROWING THREATS TO URBAN ECONOMIES

The impacts of urban heat have significant economic implications, particularly given that cities in the region generate large shares of countries’ gross domestic product (GDP). For example, Mexico City generated 14.8 percent of Mexico’s GDP in 2023, and São Paulo, 9.2 percent of Brazil’s GDP in 2021. The shares in smaller countries are even larger: Montevideo produces about 49 percent of Uruguay’s GDP, for instance, and Quito, about 25 percent of Ecuador’s.

Urban heat can affect cities’ economic output through multiple channels, including impacts on the overall labor supply, workers’ physical and mental abilities, and the long-term supply of human capital. When infrastructure is not designed to withstand extreme temperatures, it can also fail or perform poorly, reducing total factor productivity.

New analysis for this report estimated the economic impacts of extreme heat anomalies in 2012–2020 on cities’ economic activity, using nighttime light intensity as a proxy. It revealed that urban economic activities are already being affected by extreme heat. Cities in low-income countries were the most affected by heat anomalies (2.6 percent drop in nighttime light intensity), while those located in upper-middle income countries showed a 1.2 percent drop. Cities in high-income countries did not show a decline. The analysis also revealed that the warmer a city’s baseline climate, the larger the negative impact of extreme heat (Figure O-4).

FIGURE O-4. ESTIMATED IMPACTS OF EXTREME HEAT ANOMALIES ON NIGHTTIME LIGHT INTENSITIES FOR CITIES IN LATIN AMERICA AND THE CARIBBEAN VS. OTHER REGIONS, BY THE LEVEL OF DEVELOPMENT AND BASELINE CLIMATE, APRIL 2012–DECEMBER 2020



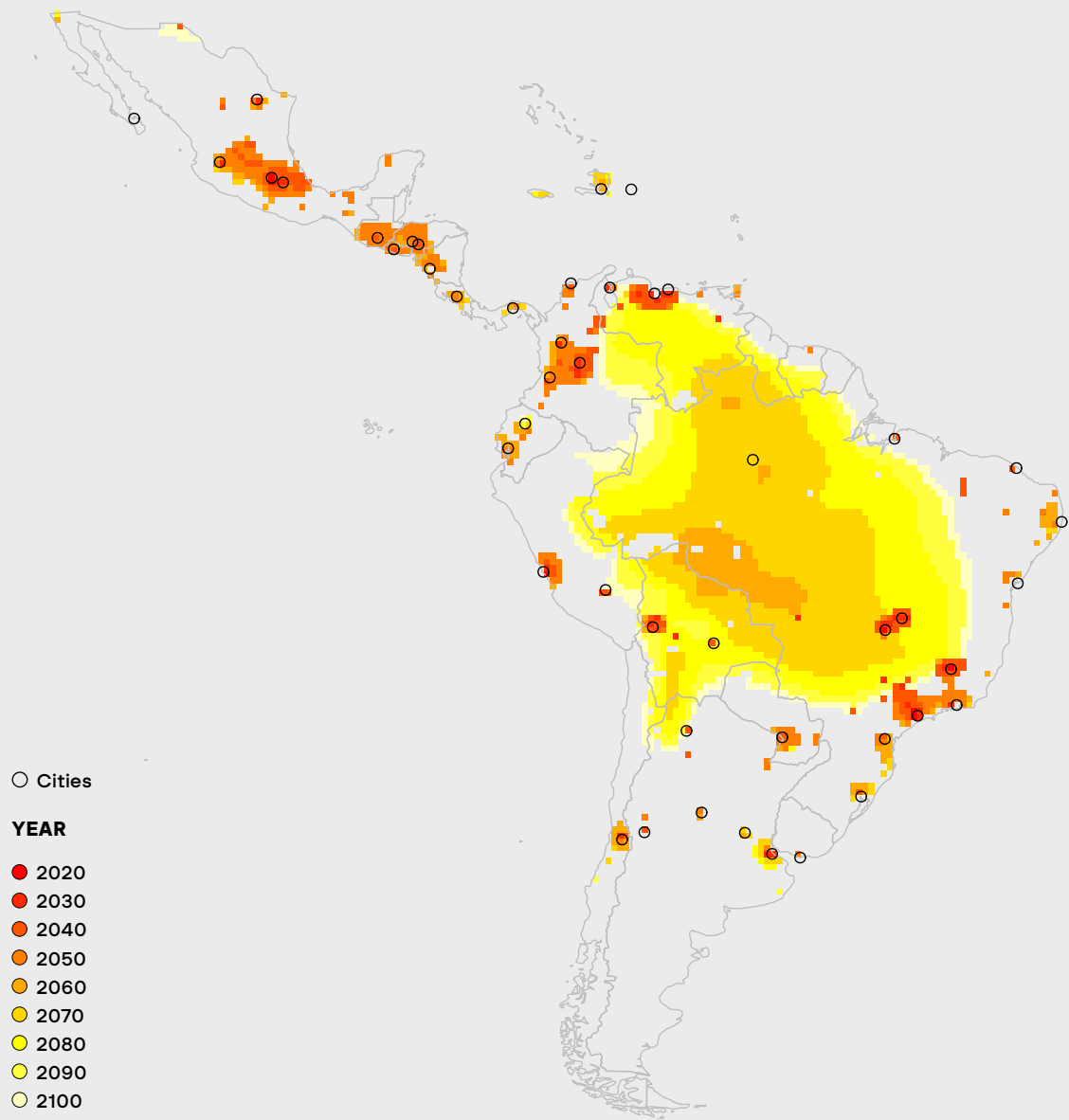
Source: World Bank calculations based on the analysis of Visible Infrared Imaging Radiometer Suite (VIIRS) nighttime lights monthly composites (<https://payneinstitute.mines.edu/eoq-2/viirs/>) and monthly weather data from Climatology Lab, TerraClimate (<https://www.climatologylab.org/terraclimate.html>).

Note: Cities are defined as urban centers following the degree of urbanization methodology of the Global Human Settlement Layer (GHSL) Urban Centre Database. Each marker shows the estimated elasticity of an extreme heat anomaly on a city's nighttime light intensity. Vertical bars indicate the bounds of the 90 percent confidence interval associated with the corresponding estimates. In both panels, lower, upper-middle, and high are based on the World Bank's country income classification for the fiscal year 2023-24, where the lower class includes low- and lower-middle-income countries. In panel b, a city's baseline climate is classified based on the terciles of the distribution of long-run mean monthly temperatures across the globe. LCR = Latin America and the Caribbean Region.

Economic modeling of the future impacts of climate change and the UHI effect in Latin America and the Caribbean shows urban heat will be costly. In a middle-of-the-road climate scenario (SSP2-4.5), by 2050, the cumulative losses in the region could reach the equivalent of 1.2 to 2.5 times each country's 2024 GDP.

Cities are already feeling the effects. The modeling suggests that major urban centers will experience much more severe economic impacts than the broader region. While most areas are not projected to see annual GDP losses exceeding 5 percent until the 2080s or later, capital cities could reach this threshold as early as the 2020s or 2030s (see Figure O-5).

FIGURE O-5. YEAR IN WHICH ANNUAL GDP LOSSES ARE PROJECTED TO EXCEED 5 PERCENT OF GDP



Source: Authors' calculation from projection of Estrada and Calderón-Bustamante (2024) for Latin American and Caribbean countries, applying the damage function that incorporates both the UHI effect and long-lasting effects of climate change in a middle-of-the-road climate scenario (SSP2-4.5).

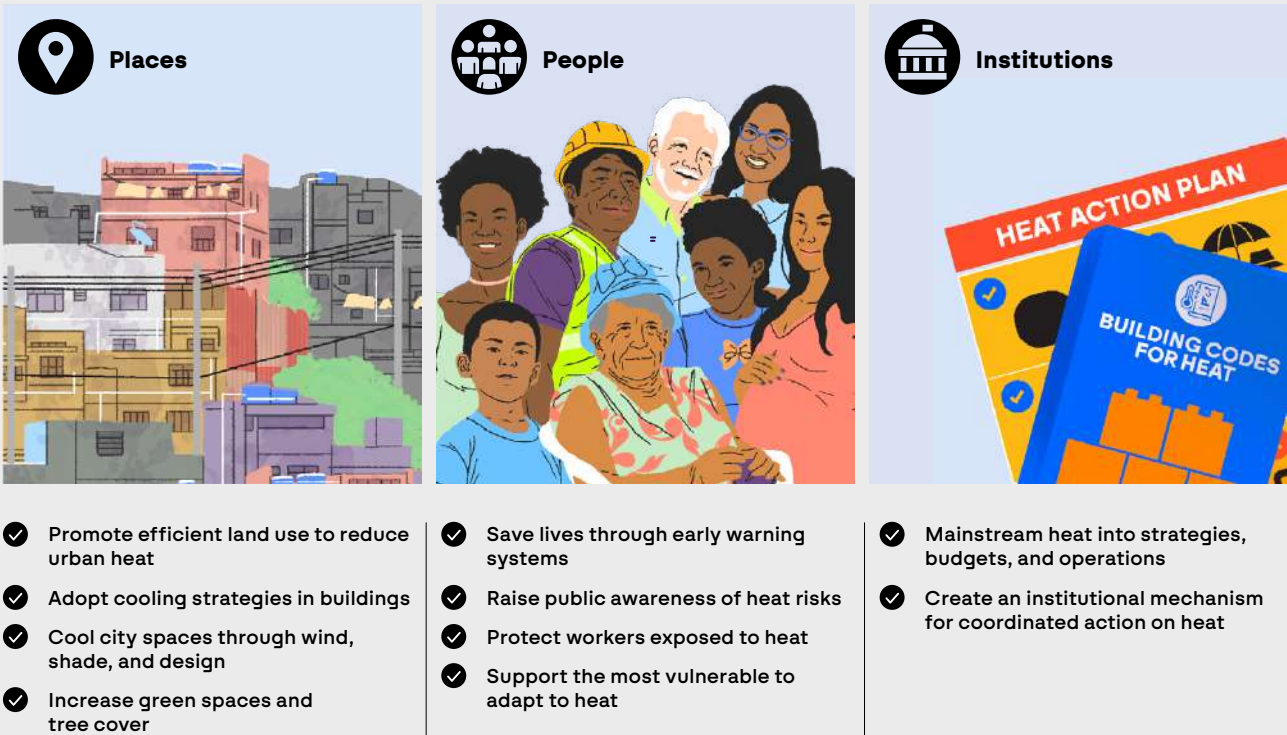
Note: Economic costs are reported as net present values calculated with 2010 as the base year, using 2024 as the baseline year for projections.

KEEPING CITIES LIVABLE:
PRIORITIES FOR ACTION

The analysis presented in this report confirms what millions of people in Latin America and the Caribbean already know firsthand: cities in the region are getting hotter—some dangerously so—and, without proactive adaptation efforts, the impacts on urban infrastructure and on human health, well-being, livelihoods, and urban economies will be significant.

Cities cannot stop climate change on their own, but by mitigating the UHI effect, they can slow overall heating. A wide range of adaptation measures can also help: from strategies to keep buildings cooler, to urban greening and design improvements, early warning systems and public health campaigns, programs to support the most vulnerable people, and comprehensive efforts to mainstream heat resilience into city strategies, operations, and budgets. The World Bank calls this a “Places, People, and Institutions” approach (Figure O-6).

FIGURE O-6. A “PLACES, PEOPLE, AND INSTITUTIONS” FRAMEWORK FOR ADDRESSING URBAN HEAT



Source: Adapted from Roberts et al. (2023).



PLACES: COOL CITIES THROUGH DESIGN, SHADE, WIND, AND NATURE

Cities in Latin America and the Caribbean have several options for reducing the heat-absorbing effects of the built environment. Many are already investing in **nature-based solutions** such as **adding green space and tree cover**. Not only does the additional vegetation provide cooling through shade and evapotranspiration, but it can also help improve air quality, makes cities more livable, and facilitate walking, cycling, and other outdoor activities.

In Mexico City, for example, the Via Verde (Green Way) project turned a major highway viaduct into a massive vertical garden, adding plantings on more than 1,000 pillars as well as green strips. In Costa Rica, “interurban biological corridors” are being used to engage communities in restoring natural landscapes, particularly along rivers in dense urban areas, and create connected ribbons of green space. Medellín’s Corredores Verdes initiative has created “green corridors” with thousands of trees and other plantings along 18 urban roads and 12 waterways. Heat mitigation is not the sole motivation for these projects, but it is still a key benefit.

Using a tool developed by the Global Program on Nature-Based Solutions for Climate Resilience (GPNBS), opportunities for NBS were analyzed across in seven cities in Latin America and the Caribbean in which 38 to 61 percent of total land area was built up. Current tree cover ranges from 16 to 49 percent. The analysis showed that green corridors in densely populated areas would provide the greatest cooling benefits, with the potential to reduce local UHI effects by 29 percent across the seven cities.

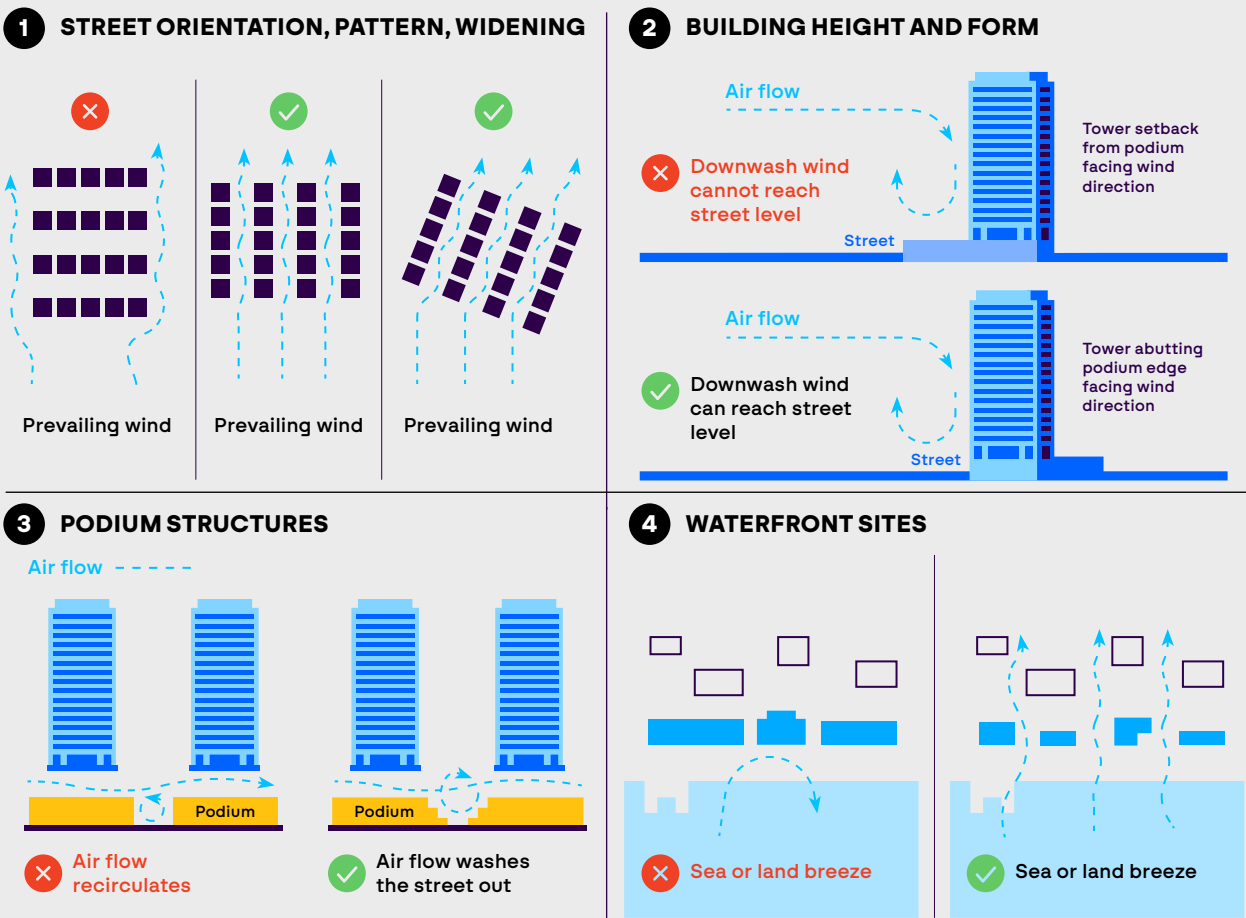
Improvements in urban design and form can be more challenging to implement, but can significantly affect the intensity of the UHI effect. Making cities more compact and connected, with mixed-use, vertical development and strategic and efficient land use, can mitigate urban heat. The compact form enables people to walk or use transit instead of driving, thus reducing congestion and heat and pollution from cars. It also frees up land that can be turned into parks, tree-lined pedestrian corridors, and other cool spaces.

For example, Bogotá’s Vital Neighborhoods (*Barrios Vitales*) project is strategically reusing space previously assigned to cars to make neighborhoods more dynamic, accessible, and pedestrian-friendly. By enhancing access to green space and integrating vegetation in the built environment, it is also making the targeted areas less likely to overheat.

Effective urban design strategies can significantly reduce urban heat, even in densely developed areas. These strategies include creating **ventilation corridors** by aligning major streets parallel to prevailing winds, arranging taller buildings farther downwind,

and ensuring that cool air can flow from nearby bodies of water (Figure O-7). Design can also maximize shade during the hottest hours by considering the angles at which the sun shines.

FIGURE O-7. STREET DESIGN FOR IMPROVED VENTILATION, COOLER TEMPERATURES, AND REDUCED AIR POLLUTION



Source: Reproduced from Roberts et al. (2023), drawing on Hong Kong SAR (2015).

The report also examines a range of design strategies for “passive cooling” of homes and other buildings, to improve thermal comfort while minimizing the need for air conditioning:



→ **Site orientation** that considers the direction of prevailing winds as well as the angles of the sun, to enhance airflow and reduce direct sun exposure during the hottest hours;



→ **Natural ventilation**, achieved through optimal site orientation, large windows, high ceilings, and vents at roof level to allow hot air to rise and flow outside;



→ **Shading** through overhangs and awnings, as well as semi-outdoor spaces such as porches and balconies;



→ **Cool roofs**, avoiding heavy materials that absorb and retain heat, and using reflective coatings (or even just painted white instead of maroon, as is common in the region); plant-covered **green roofs** are also an option, albeit costlier and more challenging to construct and maintain.

There is growing evidence that these strategies, which significantly increase the energy efficiency of buildings, make little to no difference in upfront costs and significantly reduce energy costs for the occupants. However, for policy makers, it is crucial to recognize that the large-scale uptake of passive cooling approaches is typically driven by **building codes**. Green building regulations are increasingly common in North America and Europe, but they are still uncommon in Latin America and the Caribbean. Enforcement of existing codes is also limited, and a large share of construction is informal and does not follow codes or standards.

Governments also need to invest in **adapting public transit systems** to extreme heat, to ensure that service is not disrupted, vehicles and stations are adequately cooled, and bus stops have shade. **Upgrades to road infrastructure** are needed as well to ensure it can withstand extreme heat. At the same time, it is crucial to **ensure that walking is safe and comfortable**.

Energy infrastructure investments are crucial as well, including to add solar and wind power generation capacity to reduce dependence on hydropower and to increase the heat resilience of the power grid. **Promoting energy efficiency** is also crucial, particularly as demand for cooling increases. Public outreach and minimum energy performance standards (MEPS) are both key.



PEOPLE: PROTECT HUMAN HEALTH AND WELL-BEING

A great deal is known about the causes of heat-related deaths and illnesses, who is most vulnerable, and how to avoid them—such as staying out of the sun, drinking water, and avoiding physical exertion. This means that a crucial part of the solution is to set up systems to warn the public and mobilize emergency responses as needed.

That is the purpose of heat **early warning systems** (EWS), which use weather forecasts to trigger the issuance of public health advisories and interventions such as opening public cooling centers. Global experience with heat EWS is still fairly recent, but they have proven so effective that by UN estimates, scaling up heat health warning systems in just

57 countries could save over 98,000 lives per year. A World Bank study focused on Indian cities found that heat EWS, which are relatively inexpensive to set up, had a benefit-cost ratio of 50:1.

Cities may not need dedicated EWS just for heat, however; they can also integrate heat into new or existing multi-hazard early warning systems (MHEWS) that alert people to anything from storms to wildfires. MHEWS are indispensable tools for managing complex and interconnected risks. They also enable authorities to issue coordinated alerts to ensure that communities and emergency teams are prepared for cascading or overlapping hazards.

While traditionally, warning systems have focused on specific hazards, there is a growing shift toward **impact-based warnings**. This means analyzing potential risks to human health, workers' safety, and infrastructure systems and services, for example, and communicating them to the public and to the relevant institutions.

Governments are also stepping up efforts to protect workers through **occupational health and safety regulations** and guidance for both employers and workers. The ILO has provided detailed recommendations on how to reduce heat stress on the job by limiting physical exertion during the hottest hours, ensuring that workers have time to cool off and rehydrate, and reducing temperatures at work sites. Several countries, including Brazil and Costa Rica, have adopted regulations and outreach programs that can serve as models.

Given the large impacts of extreme heat on workers' livelihoods, governments may also want to **enhance social protection** to provide targeted support to individuals and communities affected by extreme heat events. Appropriate programs may include direct cash transfers, subsidies, and insurance schemes that activate payouts when certain temperature thresholds are met.

Many countries in the region already have strong social protection systems and have even used **adaptive social protection** (ASP) systems to quickly deliver assistance after disasters and during the Covid-19 pandemic. Yet despite advances in recent years, significant gaps remain—both in the underlying systems, and in the financing, data and information systems, and institutional arrangements needed to successfully deploy ASP. **Innovative micro-insurance instruments** provide another, potentially more feasible option for governments with limited resources. For example, in India, a micro-insurance scheme for extreme heat was implemented for 50,000 self-employed female workers, with automatic payouts during heatwaves.



INSTITUTIONS: MAINSTREAM HEAT INTO STRATEGIES, BUDGETS AND OPERATIONS

Governments across the region increasingly recognize that extreme heat is a serious threat that requires comprehensive, systemic responses. This requires mainstreaming heat resilience into city strategies, operations, and budgets—and into the national systems that support them. Heat action plans provide an overarching strategy for doing this, laying out an array of strategies tailored to local needs and identifying the resources needed and the key agencies that need to be involved. Many cities are also creating new institutional mandates on heat resilience, from committees of inquiry, to task forces, to a dedicated Chief Heat Officer.

Heat action plans have proven to significantly reduce heat-related illnesses and fatalities, protect vulnerable populations, and maintain the continuity of essential services. They provide a vehicle for coordinated action across government agencies, with time-bound goals, targets, and performance indicators, and they help make the case for funding allocations.

While heat action plans are still a fairly new concept for most cities, significant resources are available to support municipal leaders in developing them, with examples and lessons from around the world. A well-crafted plan should incorporate both near-term actions, such as the implementing EWS, which are crucial for saving lives, and long-term strategies to tackle the UHI effect, such as urban greening and infrastructure improvements.

Another feature of effective heat action plans is special attention to vulnerable populations, including children, older adults, people who lack adequate housing (such as residents of informal settlements), and others who are at particularly high risk, with targeted measures to support them.

CHAPTER

1

A NEW CLIMATE REALITY FOR CITIES



Maracaibo has always been sweltering-hot, with daily highs averaging about 34°C in 1986–2015.¹ Still, temperatures have risen so much that it is now common for the Venezuelan city to feel like 40–50°C with the heat and humidity. People know to drink water, and air conditioning is widely used—at least when the power is not out. “It’s relentless,” they say, “unbearable.”²

Mexico City sits on a high plateau and has historically enjoyed a much milder climate, with daily maximum temperatures rarely exceeding 30°C before the late 1990s.³ The hottest months have been getting hotter, however, and heatwaves in April and May 2024 brought six of the city’s 15 hottest days ever, breaking records four times to reach 34.7°C on May 25, 2024.

Record-breaking heat also struck Argentina in 2024, during a prolonged heatwave in January and February that brought 6–12 days of sweltering heat to cities from Buenos Aires, to Córdoba, to Santiago del Estero, in the north, where a quarter-million people endured a record high of 45.7°C.⁴

Latin America and the Caribbean straddle the Equator, but topography and strategic choices made first by Indigenous Peoples, then by Spanish and Portuguese colonists, have historically enabled most people in the region to live free from extreme heat. Like Mexico City, Bogotá, Quito, and especially La Paz are all at high elevations. Panama City, Santo Domingo, Kingston, Havana, Caracas, Montevideo, and Lima are on the coast and benefit from the sea breeze.

Favorable climates, in turn, contributed to population growth. Today, analysis for this report shows, the combined population of cities in warm, temperate, and cool climates in Latin America and the Caribbean is about 147 million, while only about 109 million (about 43 percent) live in hot and tropical cities (see Figure 1.9 in section 1.3). But the region has been getting hotter, and cities feel it most intensely.

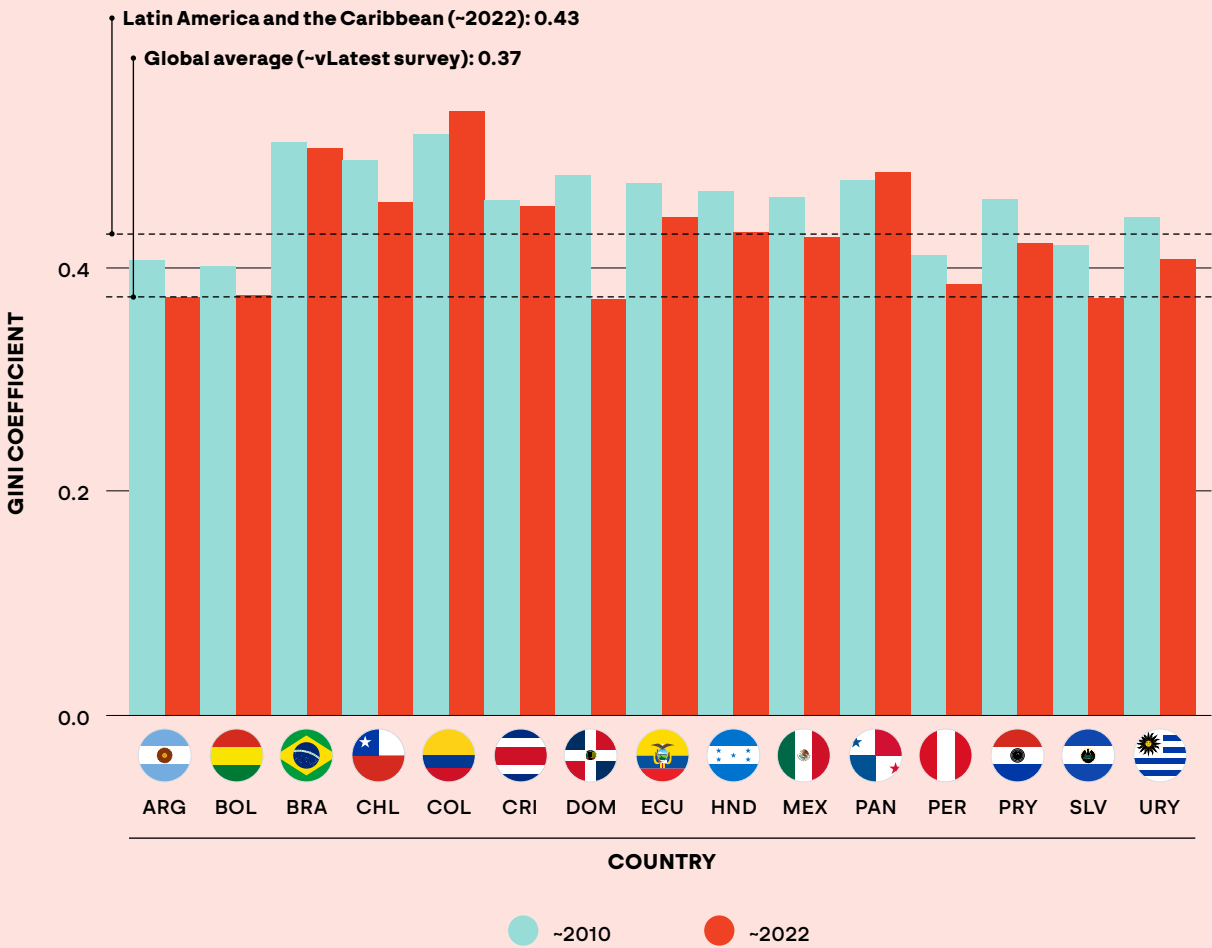
This report examines why hot days and heatwaves are becoming so frequent in urban areas across Latin America and the Caribbean; how much worse the situation is likely to get in the coming decades; the implications for urban infrastructure and for human health, well-being, and prosperity; and what urban leaders and national governments can do about it.

Understanding the threats that heat poses to cities is particularly crucial in Latin America and the Caribbean because over 80 percent of the population lives in urban areas—more than in any other region of the world except North America.⁵ Heat also disproportionately affects older people, and this region is aging faster than most of the world. As of 2022, 13.4 percent of the population—nearly 90 million people—was over 60 years old, and by 2050, the share is projected to rise to 25 percent, or 193 million.⁶

Low-income and marginalized groups are particularly affected by heat as well, as they often live in substandard housing and are likelier to have livelihoods that expose them to

heat stress.⁷ Despite progress on poverty reduction, as of 2023, about 172 million people in the region lived in poverty, and 66 million, in extreme poverty.⁸ And, while cities offer more opportunities for prosperity than rural areas, the urban poverty rate is still high: 24.5 percent in 2023, and 38.1 percent among children up to 14 years old.⁹ Almost half of workers were employed informally as of 2022, without the benefits and legal protections of formal jobs.¹⁰ Countries in the region also have very high levels of income inequality, with the Gini index scores of 15 countries with ~2022 data averaging 0.452.¹¹ As shown in Figure 1.1, urban inequality is high across the region.

FIGURE 1.1. GINI INDEX FOR URBAN POPULATIONS IN CITIES OF LATIN AMERICA AND THE CARIBBEAN, AROUND 2010 AND 2022



Source: World Bank Global Monitoring Database surveys, from Datalibweb.

Note: Country abbreviations: ARG=Argentina, BRA=Brazil, BOL=Bolivia, CHL=Chile, COL=Colombia, CRI=Costa Rica, DOM=Dominican Republic, ECU=Ecuador, HND=Honduras, MEX=Mexico, PAN=Panama, PER=Peru, PRY=Paraguay, SLV=El Salvador, URY=Uruguay. A Gini index of 0 would indicate perfect equality, while 1 would indicate that all wealth is concentrated in a single person.

The rest of this section focuses on quantifying the heat threat, based on temperature trends in recent decades and climate projections for 2040–2059 and 2080–2099. Climate change is only part of the problem, however; cities are also getting hotter because they are highly built-up, with large areas with little or no vegetation, and they keep encroaching into surrounding farmland and natural landscapes. Section 2 looks at how the urban heat island (UHI) effect manifests itself in the region, as well as how it interacts with social vulnerability to create profound thermal inequalities. Section 3 then examines how heat interacts with three key infrastructure systems: buildings, including housing; power grids, and transport systems.

Section 4 focuses on the human toll of increasing heat in Latin America and the Caribbean: on health and mortality, education, and livelihoods—especially those that involve physical labor—and discusses some of what countries in the region are doing to mitigate those impacts, and what more they could do. This section then examines the implications of rising heat for urban productivity, recognizing that cities generate an outsize share of the region’s economic output. Section 5 concludes with a discussion of how cities can save lives by better preparing for and managing heat risks; how changes to urban form, including added green space and various nature-based solutions, could help reduce heat exposure; and how key policy measures and programs can help protect the most vulnerable populations in an increasingly hot climate.

Before diving into the analysis, it is helpful to understand key terms that will be used throughout this report—and how, specifically, they are used here. Box 1.1 provides an overview.

BOX 1.1

HOW HOT IS TOO HOT? DEFINING HEAT STRESS AND HEATWAVES

To a great extent, “hot” is a relative term. A 35°C day in Panama City is hot though not unusual—but in the cool mountainous setting of La Paz, Bolivia, it would be intensely alarming. It would also be far more difficult for people to handle, as the human body adapts to the local climate, while clothing styles, daily routines and housing design also differ across climate zones.

This means the answer to “How hot is too hot?” is rarely simple. Yet for practical purposes—to know when to issue extreme-heat alerts, for instance, or when to limit arduous physical activity—it is important to understand key terms and their quantitative definitions.



HEAT STRESS:

Heat stress refers to environmental conditions that make it difficult for the human body to maintain a safe core body temperature (around 37°C), causing heat strain and, if the core temperature exceeds 40°C, heat stroke. Both conditions can be fatal, particularly for people with pre-existing health problems (see section 4.1).



HEAT METRICS:

When explaining and communicating extreme heat risks, there is a trade-off between metrics that are easy to measure and understand, and those which provide a more robust scientific basis for decision-making. The simplest and most commonly used metric is air temperature. To inform the public about how humidity adds to heat stress, meteorologists often report “feels like” (apparent temperature) metrics such as the heat index, which accounts for both heat and humidity. *This report uses the wet-bulb globe temperature (WBGT) to measure heat stress.*¹² This metric accounts for air temperature, wind speed, humidity, and radiation from the sun and nearby surfaces. It is widely used by scientists and in regulating safety in workplaces and at athletic events.



HOT DAYS:

Recognizing the key role of acclimatization, this study uses a relative definition of “hot days:” days with maximum air temperatures at or above the 95th percentile for that location during a historical baseline period. This report also presents some analysis of the extent to which a specific temperature threshold, 35°C, is surpassed in each location.



HEATWAVES:

A heatwave is a multi-day period of excessive heat. In line with the definition of hot days, this report uses a relative definition of “heatwave”: a set of at least three consecutive days when temperatures exceed the 90th percentile daily maximum during a historical reference period for a given location. The severity of heatwaves is measured with the Heat Wave Magnitude Index daily, which combines the duration and intensity relative to average temperatures at the time of year when a heatwave occurs.¹³



EXTREME HEAT:

Although people can adapt to higher temperatures, physiology research has established that there are certain levels of heat stress that even fit young adults cannot withstand for prolonged periods. For many individuals who are vulnerable due to their age, health, or other factors, the safety threshold will be lower. The same applies when people are exercising or doing physical work, as physical exertion also produces heat (see section 5.2.2). This report defines an “extreme heat” day as one when heat stress exceeds 30.5°C WBGT.

1.1 TROPICAL AND HOT CLIMATE ZONES ARE EXPANDING

Spanning both hemispheres, Latin America and the Caribbean is an extraordinarily diverse region. It extends from around 30° north at Mexico's northern border to 55° south at the southern tip of the Tierra del Fuego. It encompasses some 70 percent of the climate zone types in the Köppen-Geiger classification scheme: from tropical climates in Central America, the Caribbean islands and northeastern Brazil (ranging from tropical rainforest to savanna), to a mix of dry and temperate climates across swathes of Argentina, Uruguay, southern Brazil, and much of Chile, to cold and polar climates in the high Andes and the far south.

These climate regimes have helped shape economic activity and daily life in the region's cities. Some are hot year-round, such as Manaus in Brazil, Panama City in Panama, Caracas in Venezuela, and San Pedro Sula, Honduras. Daily temperatures in the hottest months often exceed 30°C in those cities. Elsewhere, climates are cooler. Quito and Bogotá's high elevation contributes to mild temperatures and high rates of nighttime cooling. Daily peak temperatures in the warmest months are about 20°C, on average, with substantial nighttime cooling. Most of La Plata Basin—the largest urban and industrial cluster in Latin America, including the cities of São Paulo, Buenos Aires, and Montevideo—also has temperate climates.

Figure 1.2 presents color-coded maps showing the distribution of Köppen-Geiger climate zones across Latin America and the Caribbean in 1991–2020. For a big-picture perspective of what lies ahead with climate change—without yet considering the UHI effect in cities—those maps are juxtaposed with projections of the future distribution of climate zones under a “middle-of-the-road” climate scenario (SSP2-4.5).¹⁴ By 2071–2099, the areas of tropical savanna and hot, semi-arid steppe are projected to increase most, by 2.6 and 2.1 percent, respectively. In turn, cold arid deserts, tropical rainforest, polar tundra and temperate climates with warm summers and no dry seasons will decline in geographic extent, by 1.1–1.5 percent. A significant portion of the Mexican central highlands could transition from cold to hot semi-arid climates; parts of La Plata Basin could transition from temperate to tropical climates; and semi-arid and steppe regions in the Chilean and Brazilian coasts could become deserts.

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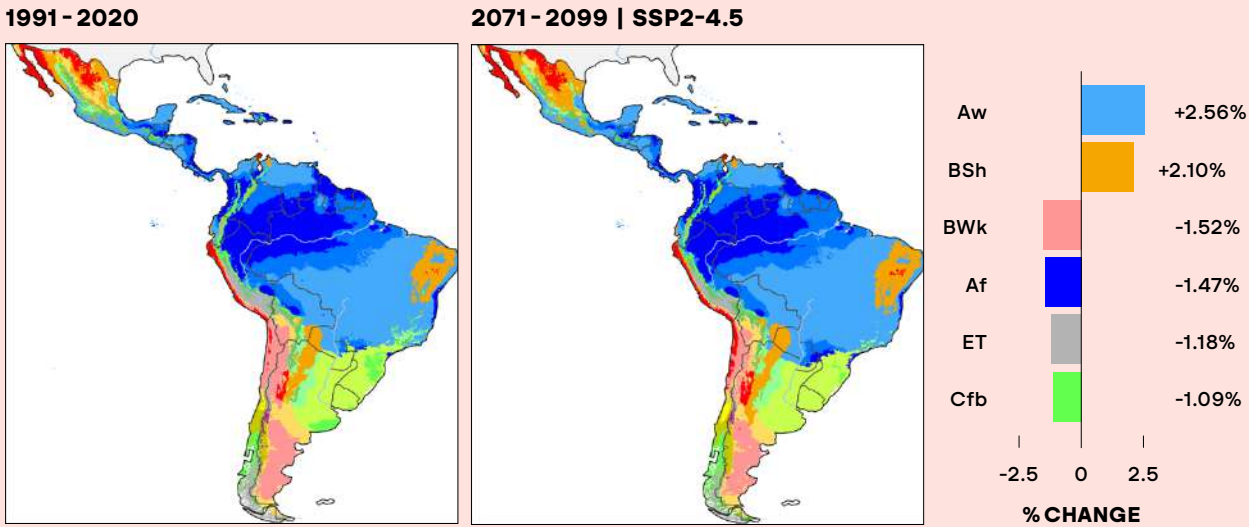
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FIGURE 1.2 PRESENT-DAY AND PROJECTED END-OF-CENTURY CLIMATE ZONES IN LATIN AMERICA AND THE CARIBBEAN



KÖPPEN - GEIGER ZONES

- Af: Tropical, rainforest
- Am: Tropical, monsoon
- Aw: Tropical, savannah
- BWh: Arid, desert, hot
- BWk: Arid, desert, cold
- BSh: Arid, steppe, hot
- BSk: Arid, steppe, cold
- Csa: Temperate, dry summer, hot summer
- Csb: Temperate, dry summer, warm summer
- Csc: Temperate, dry summer, cold summer
- Cwa: Temperate, dry winter, hot summer
- Cwb: Temperate, dry winter, warm summer
- Cwc: Temperate, dry winter, cold summer
- Cfa: Temperate, no dry season, hot summer
- Cfb: Temperate, no dry season, warm summer
- Cfc: Temperate, no dry season, cold summer
- Dsa: Cold, dry summer, hot summer
- Dsb: Cold, dry summer, warm summer
- Dsc: Cold, dry summer, cold summer
- Dsd: Cold, dry summer, very cold winter
- Dwa: Cold, dry winter, hot summer
- Dwb: Cold, dry winter, warm summer
- Dwc: Cold, dry winter, cold summer
- Dwd: Cold, dry winter, very cold winter
- Dfa: Cold, no dry season, hot summer
- Dfb: Cold, no dry season, warm summer
- Dfc: Cold, no dry season, cold summer
- Dfd: Cold, no dry season, very cold winter
- ET: Polar, tundra
- EF: Polar, frost

Source: Beck et al. (2023),¹⁵ with supplementary analysis by World Bank team.

Note: The climate zones presented above are based on the Köppen-Geiger classification scheme, which does not consider latitude, but rather categorizes areas based on annual temperature and precipitation patterns. The right panel shows the Köppen-Geiger expected percentage change in land area for classes where expected percentage change exceeds 1 percent.

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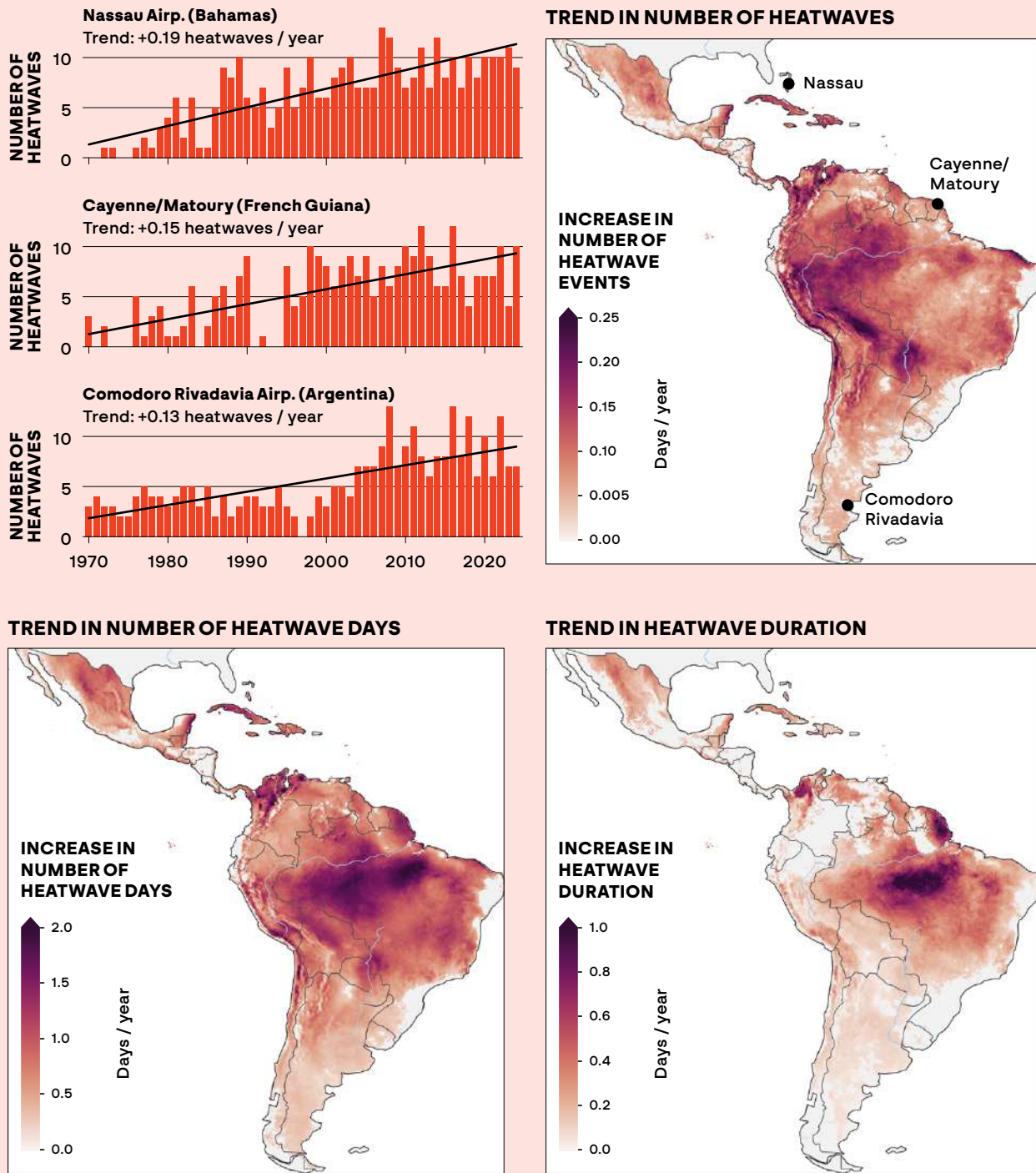
1.2 THE NUMBER AND INTENSITY OF HEATWAVES IS INCREASING

Urban climate researchers often break down local temperatures into three main components: (1) the regional background climate, which is the typical climate of the surrounding area; (2) the urban effect, which shows how the city environment alters the climate; and (3) the local effect, which includes the influence of altitude, terrain, and other unique features of a specific location. In Latin America and the Caribbean, climate change has been raising temperatures at the same time as the UHI effect has kept making it more difficult for cities to cool off.

Mean air temperatures over land in the region have increased by about 1.5°C since pre-industrial times, with specific regional effects shaped by local geography and climate systems.¹⁶ These localized impacts vary significantly, reflecting the region’s diverse ecosystems, altitudes, and proximity to oceans. In parallel, urban growth in Latin America and the Caribbean over the past half-century brought rapid landscape changes that altered local climate processes. The region was already ahead of world urbanization trends in 1960, with over 49 percent of the population living in urban areas; by 1995, it was at 73 percent, and as of 2025, an estimated, 82 percent.¹⁷

To gauge the impact of those processes on the region, data from local weather stations in selected Latin American and Caribbean cities were analyzed.¹⁸ The results show heatwaves have become more frequent and longer in duration, accounting for a greater proportion of days each year. Since the 1970s, the average number of heatwave events per year has risen by 1.1–2.0 per decade. Notably, the Amazon Basin, the northern coast of Brazil, and the islands of Cuba and Hispaniola have experienced particularly pronounced trends (Figure 1.3, upper-right panel). With each decade, the number of heatwave days has increased by between 6 to 20 days for subregions of Latin America and the Caribbean, while the longest annual heatwave has lengthened by up to six days per decade (Figure 1.3, lower-left and lower-right panels).

FIGURE 1.3. TRENDS IN HEATWAVE CHARACTERISTICS SINCE THE 1970S

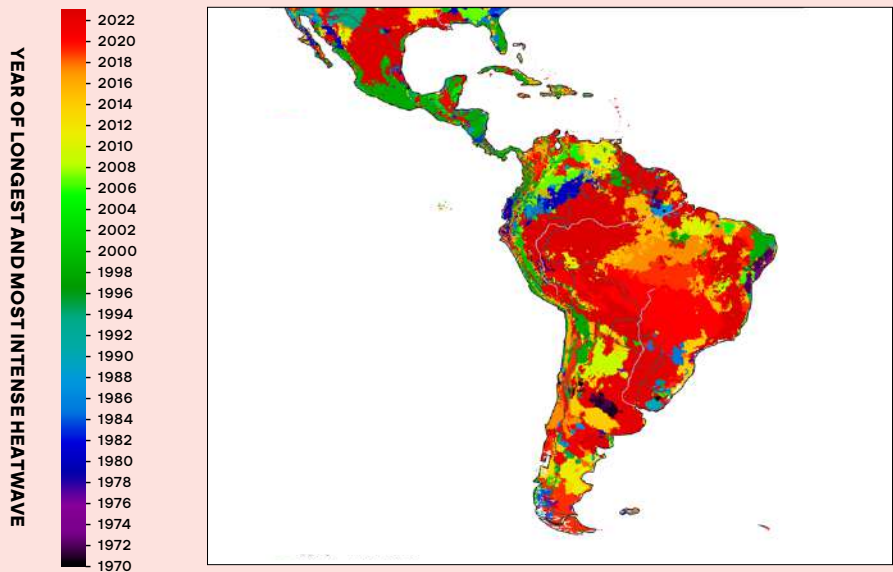
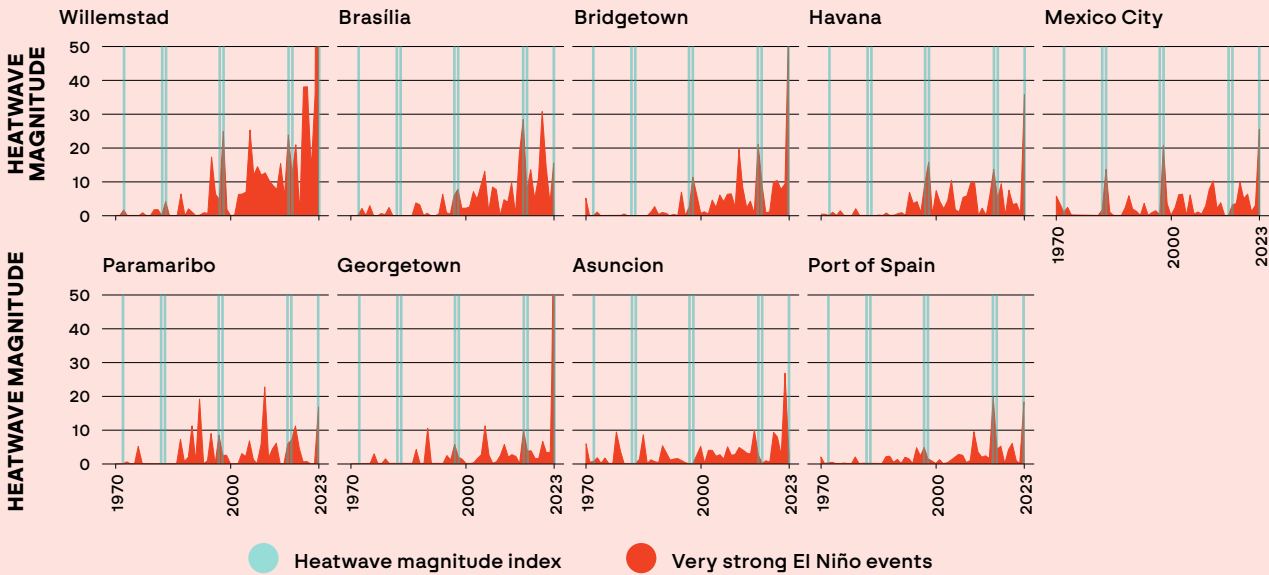


Source: World Bank staff analysis based on daily maximum temperature data from WMO observations and ERA5- Land Reanalysis (Muñoz-Sabater et al., 2021).¹⁹

Note: The upper-left panel presents the annual number of heatwaves trend for selected locations as measured by WMO weather stations. The trends in heatwave occurrence at these weather stations (located at Nassau Airport in the Bahamas, Cayenne/Matoury in French Guiana, and Comodoro Rivadavia Airport in Argentina respectively) all have statistically significant positive trends (p-value < 0.05). The map panels depict heatwave trends based on a global climate reanalysis dataset (ERA5-Land). Clockwise from the top right, the panels represent trends in the number of heatwave events per year, the total number of heatwave days per year, and the length (in days) of the longest yearly event. Areas with non-significant trends are shown in white. Heatwaves are defined as multi-day events lasting at least three consecutive days with daily maximum temperatures exceeding the 90th percentile of the 1970–2000 historical average.

For additional perspective, the region's history of heatwaves since 1970 were assessed using the Heat Wave Magnitude Index daily (HWMId).²⁰ As Figure 1.4 shows, in a diverse sampling of cities across the diverse subregions of the continent, more intense and longer heatwaves have become increasingly frequent. Often they have coincided with El Niño Southern Oscillation (ENSO), a cyclical climate phenomenon in which warming of parts of the Pacific Ocean triggers a change in ocean and atmospheric circulation patterns. Extreme weather, including intense heatwaves, occur more frequently in El Niño years. The analysis shows that much of the continent has also seen its most intense heatwaves on record (since 1970) in the past decade (Figure 1.4, right panel).

FIGURE 1.4. MAGNITUDE OF THE LARGEST ANNUAL HEATWAVE FOR SELECTED CAPITAL CITIES SINCE 1970 (TOP) AND THE YEAR OF THE LONGEST AND MOST INTENSE HEATWAVE IN EACH LOCATION (BOTTOM)

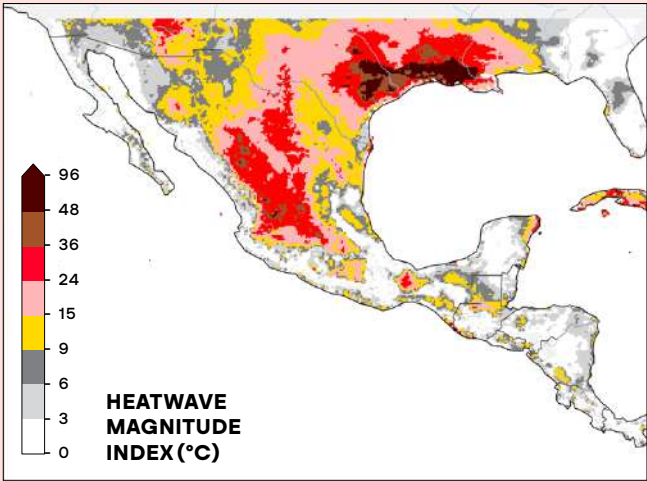


Source: World Bank staff analysis using daily maximum temperature data from ERA5-Land Reanalysis and the monthly Oceanic Niño Index (NOAA Climate Prediction Center).

Note: The Heat Wave Magnitude Index daily (HWMId)²¹ is a single metric that combines the intensity and duration of the largest heatwave in a year. A heatwave is defined as a sequence of three or more days in which the daily maximum temperature is above its 90th percentile for a 31-day running window surrounding this day during the 1970-1999 baseline period. Its unit is in degrees Celsius and presents the accumulated temperature differences above the 90th percentile for the strongest heatwave in a year. Very strong El Niño years are defined as years with a maximum monthly Oceanic Niño Index ≥ 2 (1972, 1982-1983, 1997-1998, 2015-2016, 2023).

The HWMI_d was used to map two major heatwaves affecting the region in 2023: first spanning Mexico and the southern United States, the second affecting extensive regions of South America, including much of Brazil. Figure 1.5 illustrates this, combining geographic depictions of heatwave severity with media coverage to provide insights into how these events were experienced and perceived by affected populations.

FIGURE 1.5. INTENSITY MAPS FOR TWO 2023 HEATWAVES (LEFT) AND CONTEMPORANEOUS MEDIA COVERAGE



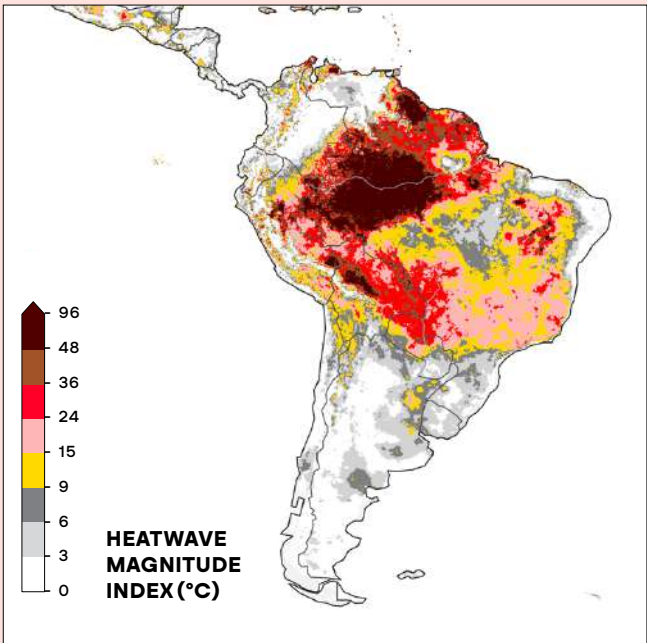
Heat wave in Mexico leaves at least 100 dead, authorities say

MEXICO CITY - At least 100 people have died over the past two weeks in Mexico due to heat-related causes as temperatures climbed close to 50 degrees Celsius in parts of the country, the health ministry said on Thursday.

A three-week-long heat wave this month strained the energy grid with record demand, forced authorities to suspend classes in some areas and left many Mexicans sweltering.

Over two-thirds of the deaths came the week of June 18-24, with the remainder the previous week, the ministry said in a report on extreme temperatures. During the same period last year just one heat-related fatality was registered.

© Reuters, June 30, 2023



‘Even Lucifer was using a fan’: Brazil bakes as mercilessly hot spring begins

Climatologist Karina Bruno Lima said the succession of record-breaking temperatures was unusual and “extremely concerning”. The heatwave follows a similar hot spell in August – shortly after the world’s hottest month on record – during the southern hemisphere winter.

Indigenous Amazonians urge Brazil to declare emergency over severe drought

Drought and heatwave has killed fish in rivers as Indigenous group Apiam says villagers have no water, food or medicine.

© The Guardian, Reuters in Manaus, Tue 10 Oct 2023 21.19 CEST

Source: World Bank staff analysis using ERA5-Land Reanalysis.²²

1.3

MORE HOT DAYS AHEAD, ESPECIALLY IN
ALREADY-HOT CITIES

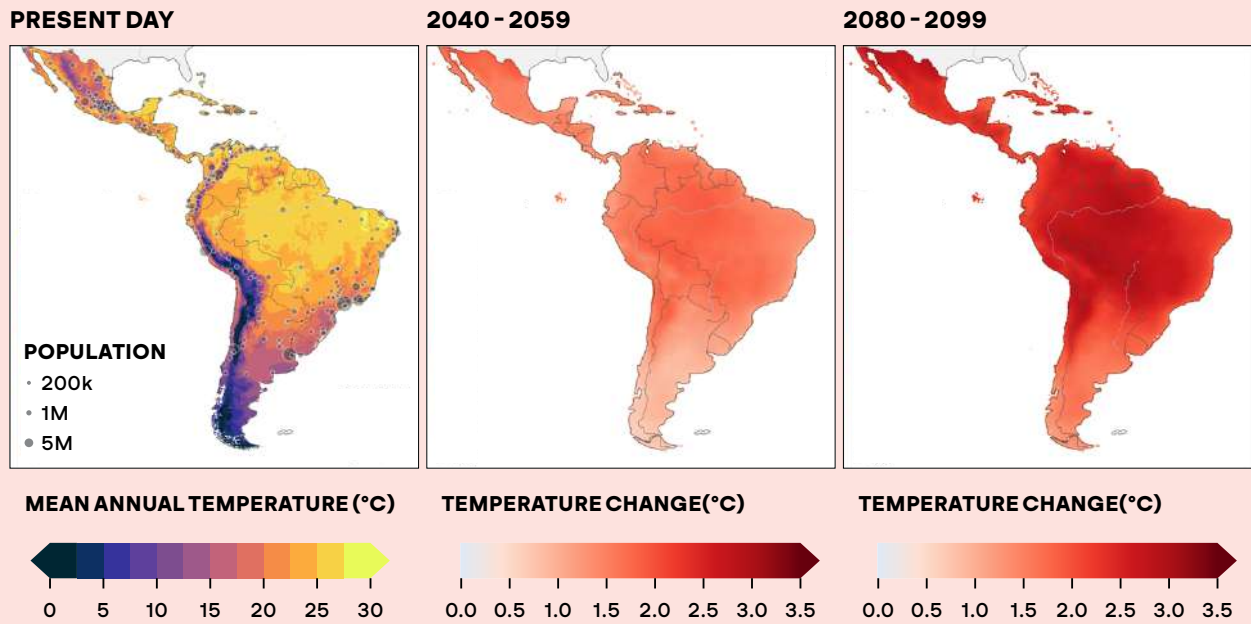
How much dangerous heat stress will residents of cities in Latin America and the Caribbean be exposed to by mid-century and beyond? This section and the next present the results of climate modeling exercises aimed at determining the extent to which different parts of the region may get hotter and be faced with increased frequency and intensity of extreme heat and heatwaves.

The first analysis extends to the end of the century and is based on global climate models that simulate the earth’s climate system. They are used to project how temperatures will evolve by 2040–2059 and by 2080–2099 under the SSP2-4.5 scenario.

A second analysis, presented in Section 1.4, then draws on an existing dataset created by a team at CarbonPlan that incorporates the urban heat island effect into climate modeling (using the scenario SSP2-4.5) for a historical reference period (1985–2014); the near term (2020–2039), and the medium term (2040–2059).²³

As global temperatures rise, Latin America and the Caribbean are also expected to get hotter, though unevenly so. As shown in Figure 1.6, by the end of this century, annual mean temperatures are projected to be higher by 1.3–3.2°C than they were, on average, in 1986–2005. These projections show the future background climate that cities in the region can expect before considering the UHI effect, which will add further to heat stress experienced within cities (see sections 1.4 and 2.1).

FIGURE 1.6. HISTORICAL MEAN ANNUAL TEMPERATURES AND PROJECTED TEMPERATURE INCREASE BY MID-CENTURY AND LATE CENTURY



Source: World Bank staff analysis using data from ERA5-Land Reanalysis,²⁴ NEX-GDDP-CMIP6,²⁵ and the Urban Centre Database.²⁶

Note: The present-day mean annual temperature is sourced from ERA5-Land reanalysis and represents the years 1986–2005. Grey dots in the left map indicate medium-sized or larger cities (population > 200,000). Future climate projections are based on NASA's global daily downscaled climate projections (NEX-GDDP-CMIP6). The analysis is based on the "middle of the road" SSP2-4.5 climate scenario, which assumes a moderate trajectory for global greenhouse gas emissions consistent with a continuation of current socio-economic trends. Both future time horizons depict the projected mean annual temperature change vis-à-vis the multi-model mean NEX-GDDP-CMIP6 baseline temperature (1986–2005).

With overall warming, cities in the region are also expected to see a considerable increase in the number of hot days per year. As noted in Box 1.1, to a great extent, heat is relative: people's bodies are adapted to the climate in which they live, so temperatures that may be comfortable in Maracaibo could feel stifling in Bogotá. The analysis therefore grouped cities by their mean annual temperatures, focusing on cities with more than 200,000 residents as of 2015. Table 1 provides an overview of the climate categories, with examples.

TABLE 1. CITY CLIMATE CATEGORIES (BASED ON MEAN ANNUAL TEMPERATURES IN 1986–2005), WITH EXAMPLES

	CATEGORY	MEAN ANNUAL TEMPERATURE	EXAMPLE CITIES	% OF POPULATION*
	Cool	5–10°C	La Paz and El Alto, Bolivia; Cuzco, Peru	0.7%
	Temperate	10–15°C	Santiago, Chile; Bogotá, Colombia; Quito, Ecuador; Mexico City	17.7%
	Warm	15–20°C	Buenos Aires and Córdoba, Argentina; Belo Horizonte, Curitiba, and São Paulo, Brazil; Cali and Medellín, Colombia; Guatemala City; Guadalajara, Mexico; Lima, Peru;	38.2%
	Hot	20–25°C	Rio de Janeiro, Brazil; San José, Costa Rica; Santo Domingo, Dominican Republic; Guayaquil, Ecuador; San Salvador, El Salvador; San Pedro Sula and Tegucigalpa, Honduras; Monterrey, Mexico; Asunción, Paraguay; Caracas, Venezuela	28.2%
	Tropical	>25°C	Belém, Manaus, and Recife, Brazil; Barranquilla, Colombia; Havana, Cuba; Port-au-Prince, Haiti; Kingston, Jamaica; Managua, Nicaragua; Panama City; Maracaibo, Venezuela	14.4%

* Note: The share of population is for the 245 cities analyzed, which had a combined population of about 256 million in 2015. The total urban population of Latin America and the Caribbean in 2015 was about 505 million.²⁷ Due to data limitations, Montevideo, Uruguay, which qualifies as a “warm” city, was omitted from the analysis. Source: World Bank staff analysis using data from ERA5–Land Reanalysis,²⁸ NEX–GDDP–CMIP6,²⁹ and the Urban Centre Database.³⁰ Analysis includes only medium-sized (>200,000 population) or larger cities. Mean temperatures are derived from ERA5–Land Reanalysis for the historical reference period 1986–2005.

Daily maximum temperatures across Latin American and Caribbean cities are projected to increase by about 1.5–1.7°C by mid-century (2040–2059), and about 2.4–2.7°C by late century (2080–2099) relative to the 1986–2005 baseline period (Figure 1.7). While some areas are expected to heat more than others, there is no clear pattern: the greatest projected increases in daily maximum temperatures are in hot, temperate, and cool cities.

The second level of analysis was to estimate how many days per year would exceed the 95th percentile of observed temperatures in each city in any given time of year. This corresponds to the definition of “hot days” noted in Box 1.1. The analysis shows that by mid-century, cities in the region are projected to experience 36–69 more hot days than they did in 1986–2005, rising to 66–116 more hot days by late century (Figure 1.7). The largest increases are projected to occur in tropical, hot, and cool cities.

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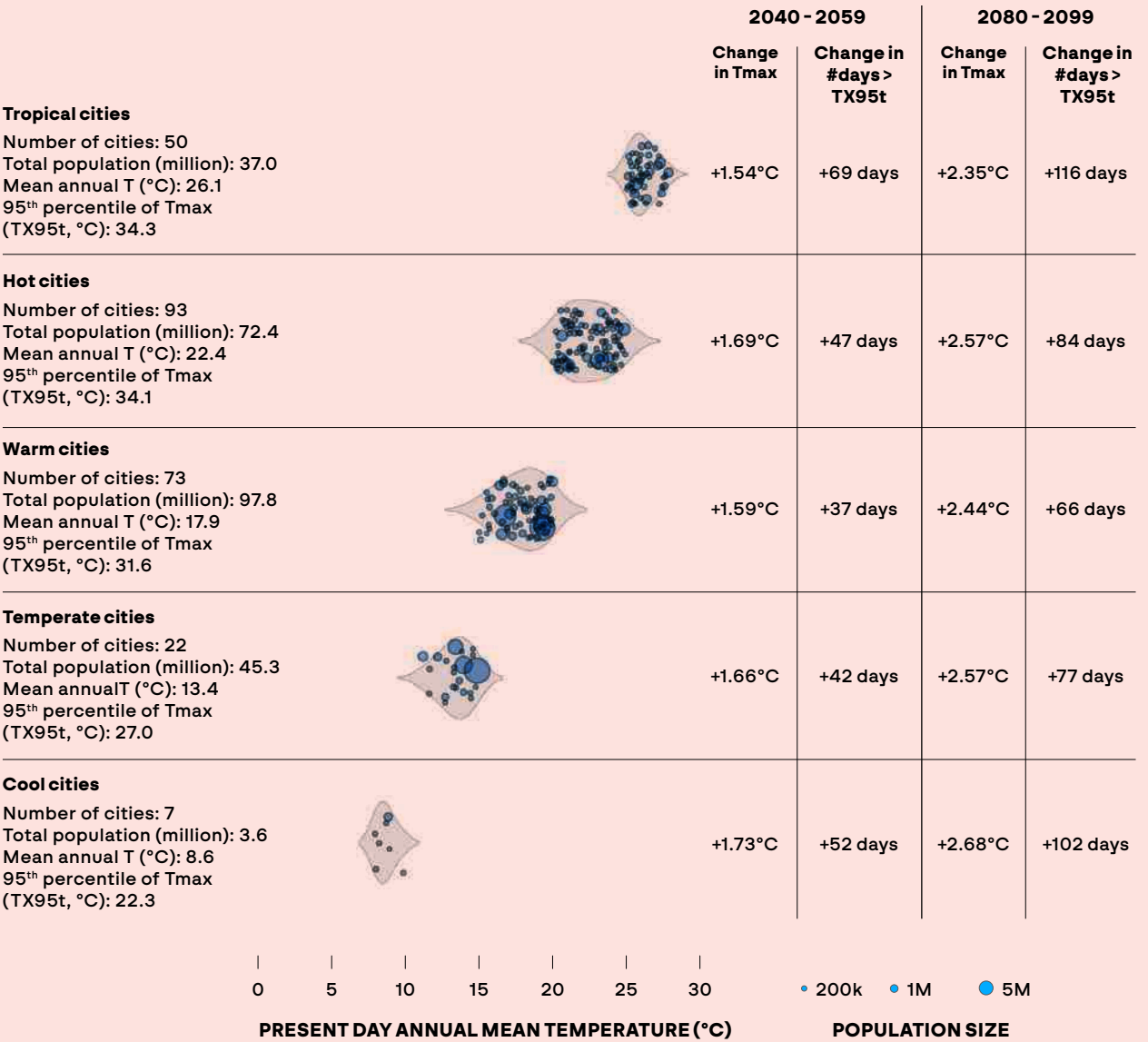
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FIGURE 1.7. PROJECTED INCREASE IN HOT DAYS (ABOVE 95TH PERCENTILE OF LOCAL DAILY MAXIMUM TEMPERATURES) FOR LATIN AMERICAN AND CARIBBEAN CITIES DAILY MAXIMUM TEMPERATURES



Source: World Bank staff analysis using data from ERA5-Land Reanalysis,³¹ NEX-GDDP-CMIP6,³² and the Urban Centre Database.³³

Note: Analysis includes medium-sized (>200,000 population) or larger cities, which are grouped based on present-day annual mean temperature category: tropical (>25°), hot (20–25°C), warm (15–20°C), temperate (10–15 °C), and cool (5–10°C). The UCD database contains no cold cities (< 5°C) with a population greater than 200,000 people. A hot day is defined as a day with a daily maximum temperature exceeding the 95th percentile of observed temperatures for that city during the historical reference period 1986–2005.

The threshold for a “hot day” varies significantly, however: from 22.3°C in cool cities, to 31.6°C in warm cities, to 34.3°C in tropical cities. Still, as discussed further in section 4.1, heat-related illness and mortality increase at lower temperatures in cooler places more than in warmer ones, because people are not acclimatized. For example, a study found that heat-related mortality in Mérida, Mexico, began to rise gradually at temperatures above 25.8°C, and the mortality risk at the 95th percentile temperature for the city, 30.4°C, was 10.5 percent higher.³⁴

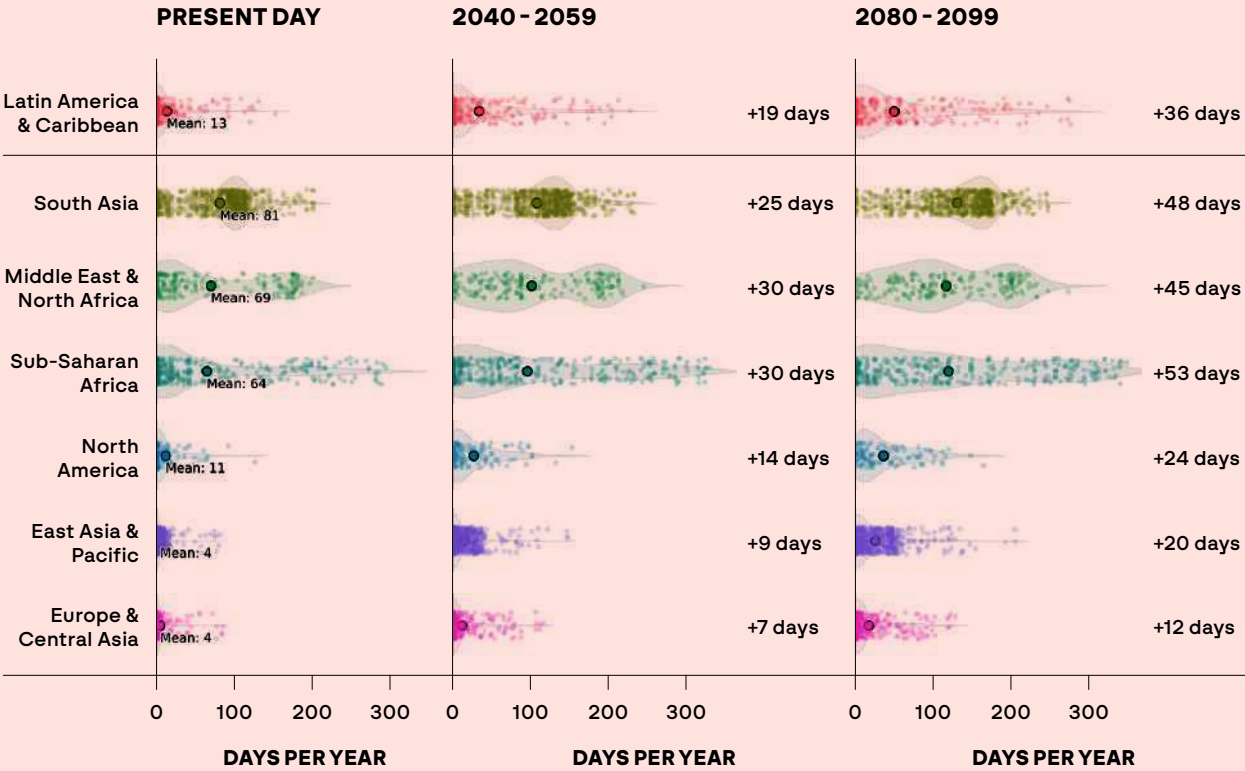
That said, higher temperatures also increase the risk of exceeding thresholds for what even fully acclimatized, healthy people can safely withstand. While recognizing that air temperature is only one of several factors in determining the risk of heat stress (see Box 1.1), to provide a simple, easily comparable metric, the analysis also considered how many days with maximum temperatures above 35°C can be expected in cities in different climate zones.

In 1985–2005, days above 35°C were rare in cool and temperate cities, and the climate projections show that remaining the case by late century. However, cities in those categories (especially in temperate climates) have already documented some days above 35°C, and they are likely to see more in the future.

In warm cities, however, which saw an average of six days above 35°C in the baseline period, the number is projected to rise to 15 by 2080–2099. In hot cities, which averaged 19 days above 35°C in 1985–2005, the number is projected to triple, to 60—equivalent to two additional full months of sweltering heat. Tropical cities, which averaged 25 days above 35°C in the baseline period, are projected to average 118 by late century, or nearly four additional months of temperatures at which it may be unsafe to play sports or do physical labor outside.

Overall, on average, Latin American and Caribbean cities are projected to see the number of days above 35°C nearly quadruple, from 13 to 49 per year. Among world regions, only East Asia and the Pacific and Europe and Central Asia are projected to see a larger relative increase in annual days above 35°C, up sixfold and fourfold, respectively (Figure 1.8). Cities in South Asia, the Middle East, and sub-Saharan Africa will continue to have hotter climates, with some projected to experience more than 300 such days per year by the end of the century. However, the hottest cities in the Caribbean, Central America, and the Amazonian basin are projected to see more than 200 days above 35°C per year by 2100, comparable to the number experienced by hot cities in South Asia and the Middle East today.

FIGURE 1.8. EXPECTED NUMBER OF DAYS PER YEAR ABOVE 35°C IN CITIES BY WORLD REGION, 1986–2005 AND IN THE FUTURE



Source: World Bank staff analysis using data from NEX-GDDP-CMIP6³⁵ and the Urban Centre Database.³⁶

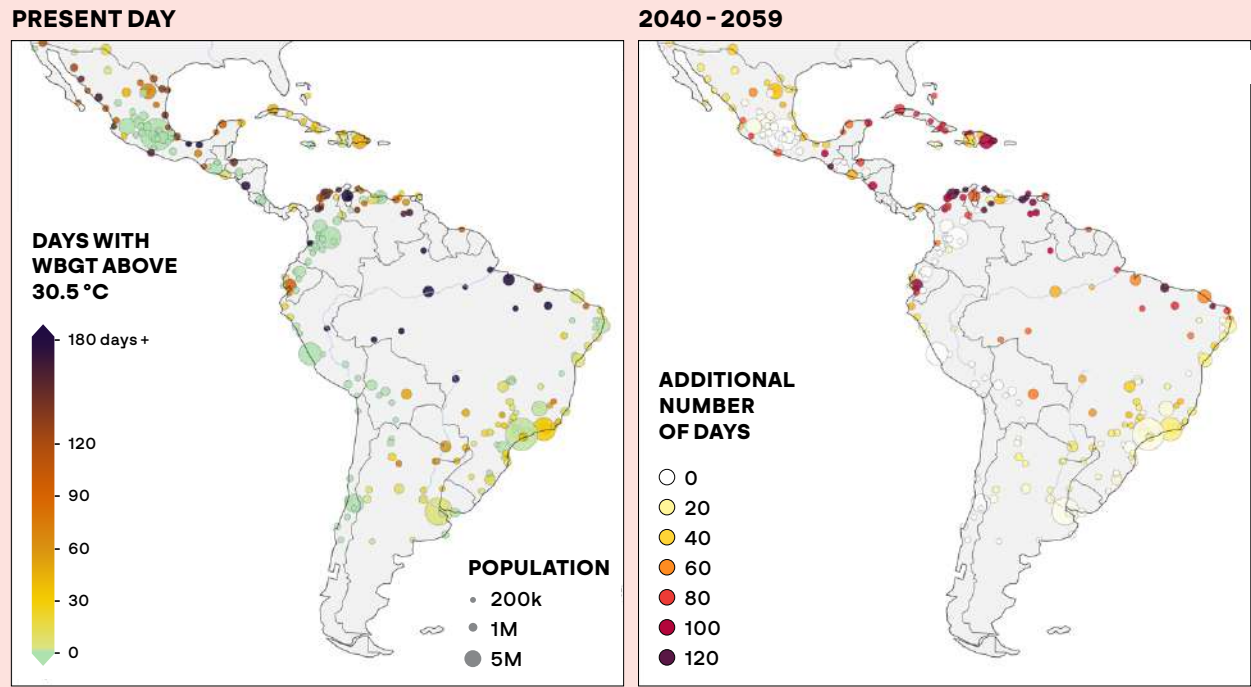
Note: Each dot represents a medium-size or larger city (minimum population: 200,000). For each region's cities, the mean number of hot days per year in the present and the expected additional hot days per year by future periods is highlighted. The calculations use a "middle-of-the-road" climate and socioeconomic scenario (SSP2-4.5). A hot day here is defined as a day with a daily maximum temperature greater than 35°C.

1.4 THE URBAN HEAT ISLAND EFFECT WILL MAGNIFY EXTREME HEAT RISKS

For a closer look at heat stress risks in cities in Latin America and the Caribbean, a separate analysis was conducted using data from CarbonPlan, which accounted for the UHI effect and also modeled the wet-bulb globe temperature (WBGT), thus covering the impacts of humidity, wind speed, and exposure to solar radiation.³⁷ The data were used to quantify how many days of extreme heat—with WBGT above 30.5°C—cities across the region face today, as well as the outlook to mid-century.

As shown in Figure 1.9, already today, some cities in the Amazon basin and coastal cities in the Caribbean face over six months' worth of extreme heat days. By mid-century, many cities will face up to three additional months of potentially life-threatening heat.

FIGURE 1.9. CITIES ACROSS THE REGION WILL FACE MORE EXTREME HEAT DAYS (WBGT ABOVE 30.5°C) BY MID-CENTURY



Source: World Bank staff analysis using WBGT data from CarbonPlan ³⁸ and city data from the Urban Centre Database.³⁹

Note: Analysis includes medium-sized (>200,000 population) or larger cities. The size of the circles corresponds to the population size of each city. An extreme heat day is defined as a day with a maximum wet-bulb globe temperature (WBGT) greater than 30.5°C in the sun.

Figure 1.10 shows how this warming trend will hit close to home for urban populations. Cities such as Belém and São Luís in Brazil could face extreme heat almost year-round by 2050—up from an already oppressive 250–300 days today. Cities such as Guayaquil, Ecuador, and Santo Domingo are projected to shift toward climates that resemble today’s hottest zones, forcing millions to adapt to a new reality of extreme urban heat. Others, such as Havana, Cuba, and Monterrey, Mexico, will see extreme heat days double within the same time frame. Even cities known for milder climates, such as Buenos Aires and São Paulo, are not spared, with extreme heat becoming a more regular occurrence.

FIGURE 1.10. RISING HEAT IN LARGE CITIES: DAYS OF EXTREME HEAT (WBGT ABOVE 30.5°C) THROUGH 2050

DAYS WITH EXTREME HEAT IN THE SUN
WET-BULB GLOBE TEMPERATURE ABOVE 30.5°C



Source: World Bank staff analysis using WBGT data from CarbonPlan⁴⁰ and city data from the Urban Centre Database.⁴¹

Note: An extreme heat day is defined as a day with a maximum wet-bulb globe temperature (WBGT) greater than 30.5°C in the sun.

These projections have serious implications for the future of cities in Latin America and the Caribbean. The next two sections examine how urban form and inadequate urban infrastructure exacerbate vulnerability to heat stress, as well as key strategies to address the problems (with additional analysis in Section 5). Section 4 then considers some of what is at stake, focusing on the human and economic impacts of rising temperatures in cities across the region.

CHAPTER

2

URBAN GROWTH AND THE UNEQUAL IMPACTS OF HEAT



The urban population of Latin America and the Caribbean increased from about 62 million in 1950 to an estimated 571 million by 2025, raising urbanization levels from 41 percent, to more than 82 percent and making this one of the most urbanized regions of the world.⁴² São Paulo, Rio de Janeiro, Mexico City, Buenos Aires, Bogotá, and Lima have all grown into megacities with more than 10 million residents. Cities large and small have sprawled out into the surrounding countryside, fundamentally changing the landscape.⁴³

This section examines how urban form and land use choices intensify the heat endured by people in Latin America and the Caribbean—often with disproportionate impacts on poor and vulnerable groups. It begins by examining why cities in Latin America and the Caribbean are hotter than their surroundings, and how temperatures have risen as cities have grown. Section 2.2 looks at how different factors can exacerbate heat within individual neighborhoods, using Mexico City as an example. Section 2.3 examines links between heat exposure and socioeconomic vulnerability, with a detailed new analysis of 10 cities in Colombia and Mexico.

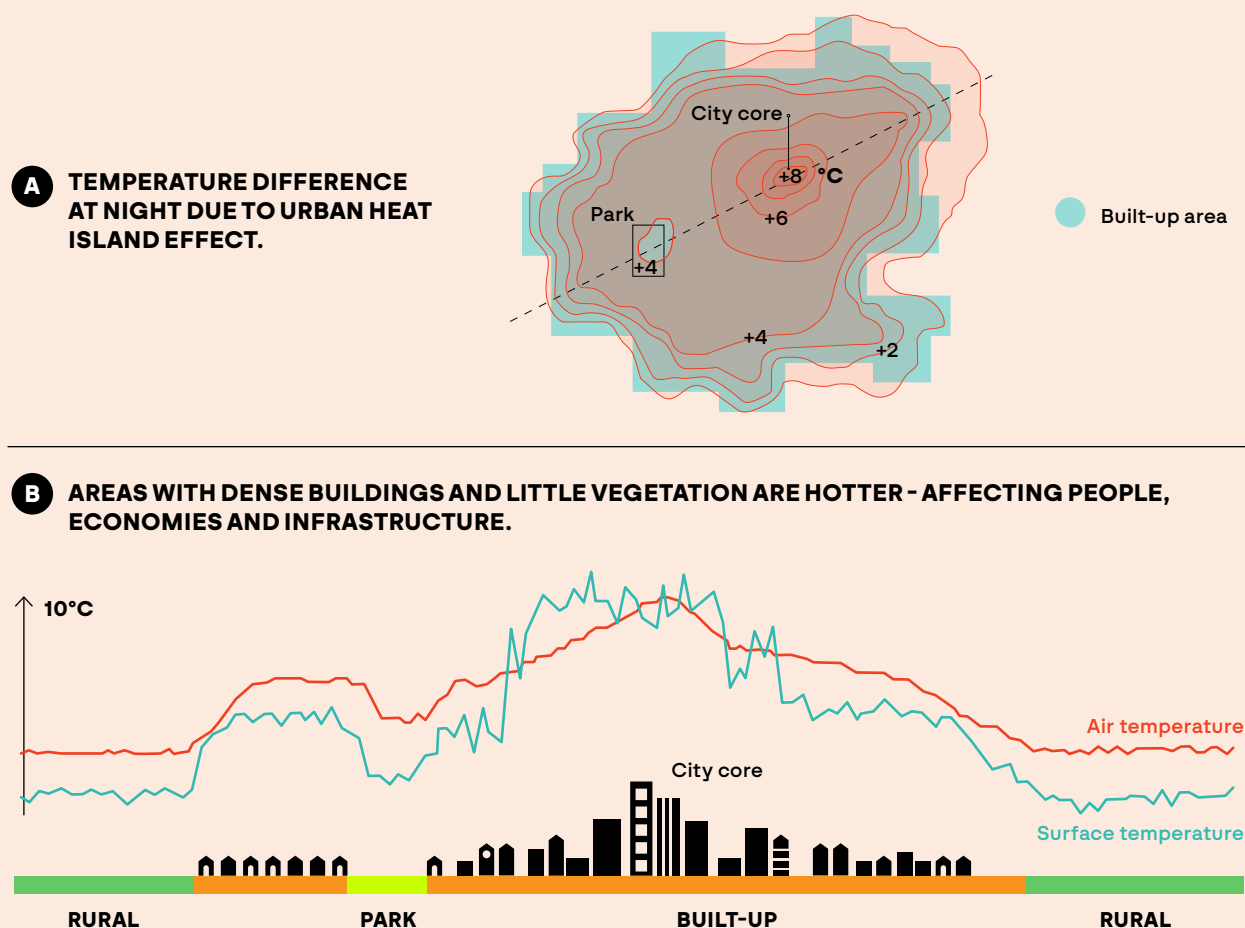
2.1 URBAN FORM AND EXPANSION ALTER LOCAL CLIMATES

Temperature and exposure to heat can vary significantly within a single urban area. Geography is a key factor—whether a neighborhood is in the hills or in a low-lying area, for example, or next to the coast vs. inland. Another is the built environment.

Urbanization replaces vegetated areas—farmland or natural landscapes—with a built environment made of concrete, asphalt, brick, steel, and other materials that absorb and retain heat. Buildings disrupt and block airflow, particularly in densely built-up areas. Vehicles and mechanical systems such as air conditioning emit additional heat. And, because all this takes up a great deal of space, vegetated areas may be sparse, depriving urban dwellers of the shade provided by trees and the cooling from plants' evapotranspiration.

When surface and air temperatures are measured across a region, cities look like islands of heat, often with a particularly hot core (Figure 2.1) or splotches of heat corresponding to heavily built-up areas of the city. Though temperatures are highest during the day, the effect is most pronounced at night, as all the heat stored up in human-made materials dissipates much more slowly than in natural landscapes.

FIGURE 2.1. EFFECT OF BUILDING DENSITY AND LAND COVER ON TEMPERATURES FOR A CITY CROSS-SECTION



Source: Adapted from Oke et al. (2017).⁴⁴

Cities tend to be warmer than surrounding rural areas in general due to the urban heat island (UHI) effect, but the temperature difference is generally strongest in hot, clear weather with low wind speeds, when there is significant sunshine and heat for the built environment to absorb. Looking at year-round averages can therefore understate the UHI effect. A given city might experience nighttime temperatures that are 2–3°C hotter than the nearby countryside, on average, across a given year. But under peak weather conditions, studies in Paramaribo, Suriname,⁴⁵ and Rio de Janeiro, Brazil,⁴⁶ for example, have found nighttime air temperatures as much as 7°C and 8°C hotter than in the nearby countryside.

The physical form of urban neighborhoods—comprising streets, blocks, buildings, and natural features—plays a critical role in shaping the thermal environment. Urban sprawl plays a significant role as well: as cities extend outward, replacing farmland with housing developments or industrial areas, for instance, the local climate changes. Around the world and in Latin America and the Caribbean in particular, rapid urban growth has profoundly modified local climates, especially during periods of intense urbanization.⁴⁷

The effect was carefully documented in Mexico City between 1961 and 1985, when the city's population grew rapidly, the urban footprint expanded, and both density and average building height increased. Ernesto Jáuregui, a pioneer in the study of Latin American urban climates, took a consistent set of measurements at meteorological stations in and around the city and documented how nighttime temperatures (daily lows) changed.⁴⁸ In suburban stations, minimum daily temperatures increased by an average of 0.15°C per year, compared with 0.08°C per year at rural stations. This equates to a rise of 1.5°C—about as much as global mean temperatures have risen since the pre-industrial era—every decade.

Since Jáuregui's landmark study, several other long-term observational studies have documented urban temperature increases of similar magnitude. For example, from 2000 to 2019, temperatures in the Teresina–Timon conurbation area in northeastern Brazil rose by 0.70°C per decade, with particularly intense hotspots in socially vulnerable areas.⁴⁹

From 1982 to 2011, daily minimum temperatures within Querétaro, Mexico, rose by 0.75°C per decade.⁵⁰ And a comparison of the Brazilian cities of Porto Alegre, Curitiba, Brasília, Cuiabá, Porto Velho, and Manaus in 1985 and 2020 found they had all gotten hotter, especially those at lower latitudes, and there was a strong correlation between how much the share of impervious surfaces had grown and the relative amount of warming and heat stress.⁵¹

Recent research across 359 major Latin American cities offers further insight into the drivers of this warming.⁵² The study found that cities with stronger economic conditions tended to warm faster—partly because better-off cities had already lost more green space by 2001 due to earlier waves of development and land conversion. While some of these cities have since seen modest increases in greening, especially in arid and more economically developed areas, this has only partially offset the warming trend. These findings indicate that green space, while a powerful tool for heat mitigation (see section 5.1), is often shaped by a city's historical development trajectory and socioeconomic landscape.

Whether the clearing of farmland and forest for urban infrastructure and buildings is driven by public investment, the private sector, or impoverished people in fast-growing cities creating informal settlements in the absence of affordable housing (section 3.1), the results are the same: hotter temperatures in human settlements.

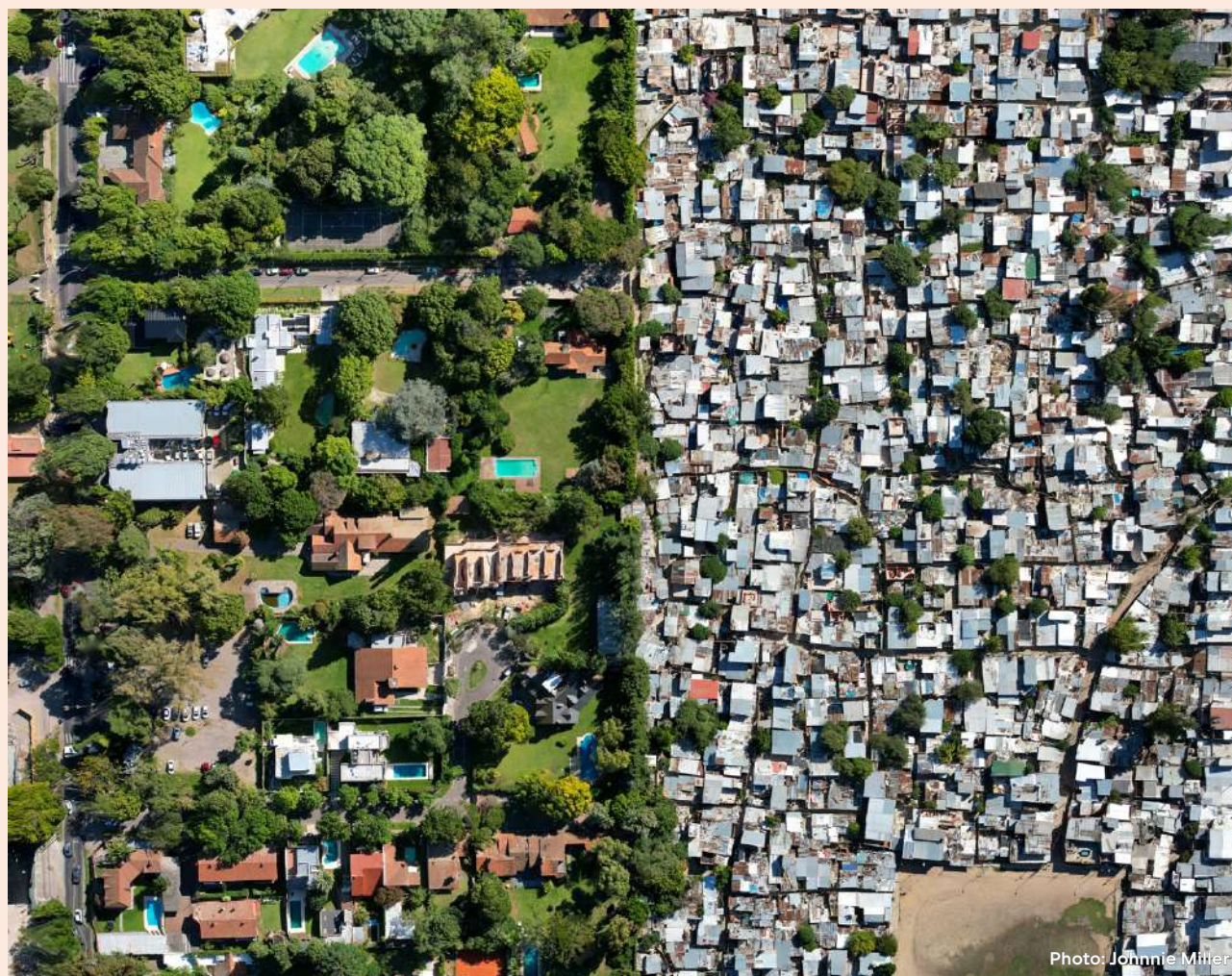


Photo: Johnnie Miller

2.2 LAND-USE LEADS TO TEMPERATURE DIFFERENCES WITHIN CITIES

The intensity of the UHI effect depends on density, building materials, and how much green-spaces and vegetation has been kept, among other factors.⁵³ In any city, these conditions can vary significantly across neighborhoods and even within a few blocks, resulting in measurable temperature differences. While being heavily built-up and treeless is likely to make an area warmer, higher elevation, the prevailing wind, and proximity to green space, rivers or lakes, or the coast can make it cooler.

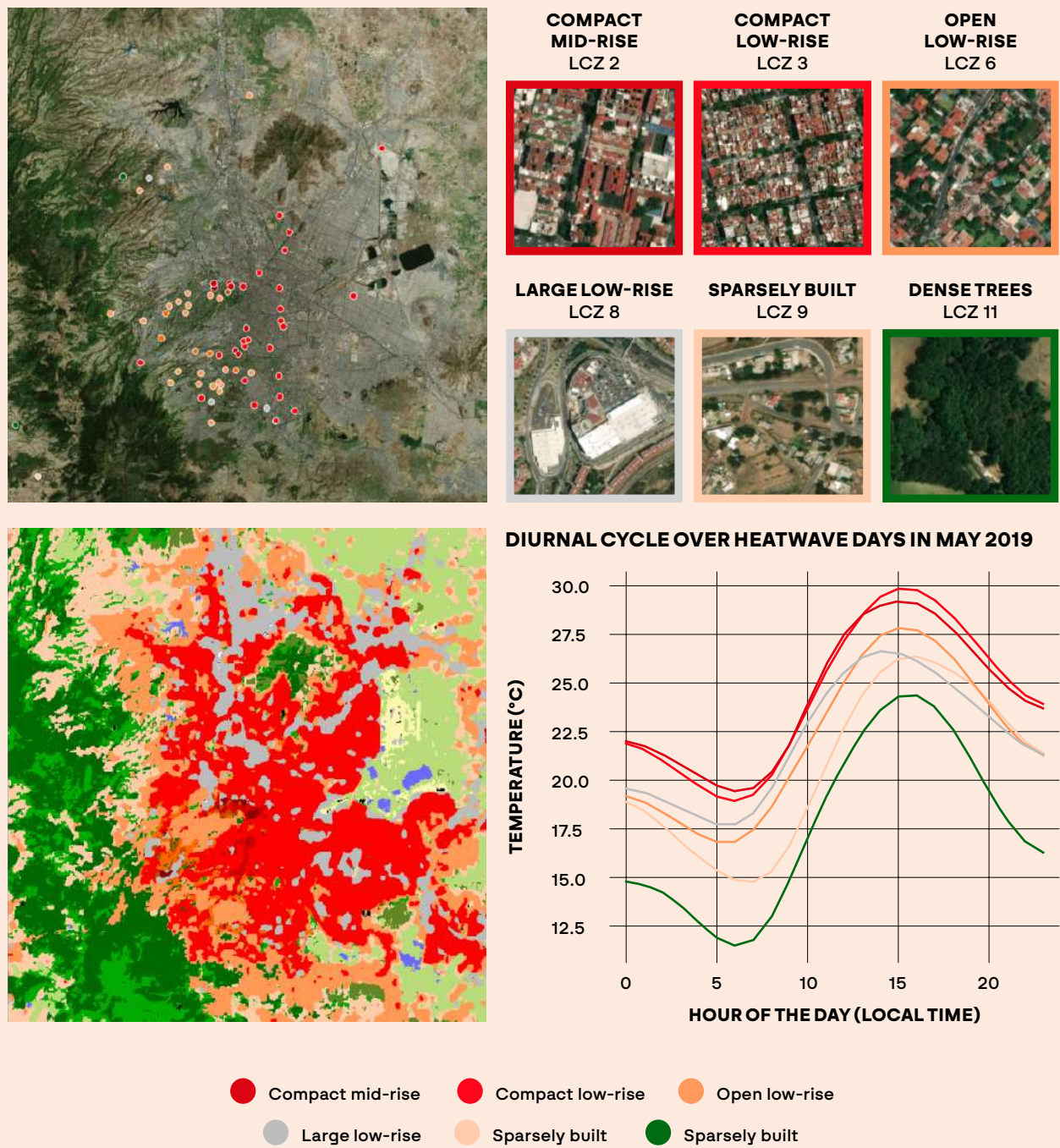
To illustrate how the physical characteristics of neighborhoods affect temperature, data from more than 100 citizen science weather stations in Mexico City (owned by individuals who volunteer to install a device, usually outside their home) during the April–May 2019 heatwave were analyzed. During that period, the city had 18 straight days with maximum temperatures exceeding its 90th percentile temperature for 1970–2000. Areas with dense tree cover experienced cooler peak afternoon temperatures and cooled more rapidly at night. In contrast, densely built-up mid-rise and low-rise neighborhoods were up to 5°C hotter during the day and retained heat at night (Figure 2.2).

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FIGURE 2.2. DAYTIME TEMPERATURES IN DIFFERENT PARTS OF MEXICO CITY DURING THE MAY 2019 HEATWAVE



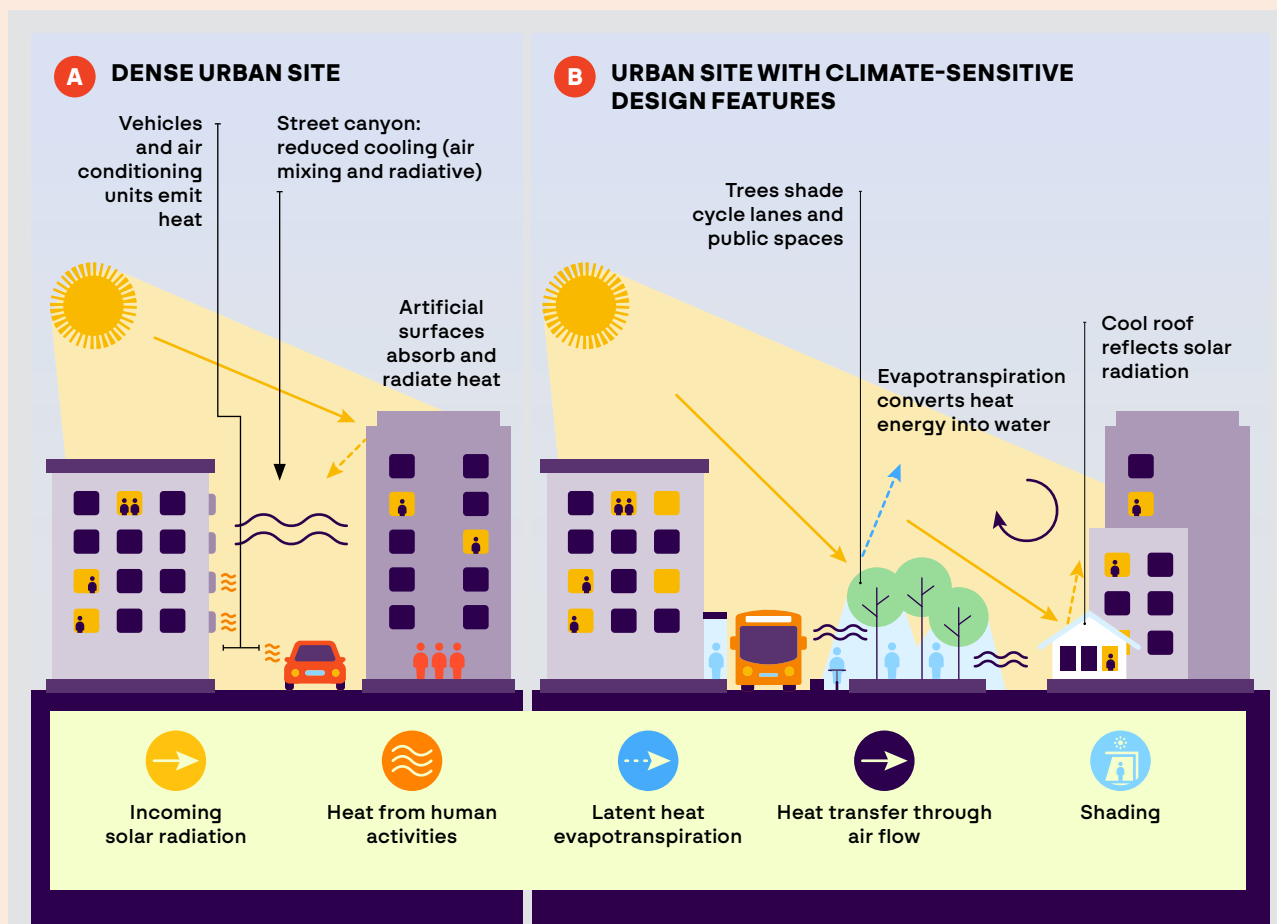
Source: World Bank analysis based on hourly Netatmo data provided by Ruhr-University Bochum and the global local climate zone (LCZ) map by Demuzere et al. (2022).⁵⁴

Note: Clockwise from top left: Map of citizen science weather stations in Mexico City that supplied data covering the April–May 2019 heatwave; visual representation of LCZs and their morphology in Mexico City; 24-hour temperature profile showing median hourly temperatures on 8–13 May 2019, land cover of Mexico City according to the Local Climate Zone (LCZ) scheme. Each line in the temperature profile presents the mean over many available Netatmo stations: 7 for LCZ2, 26 for LCZ3, 23 for LCZ6, 3 for LCZ8, 2 for LCZ9, and 11 for LCZ11. The temperature data was corrected for elevation differences to a reference height using the environmental lapse rate of -6.5 K/km.

Nighttime cooling is particularly critical for human health, as natural temperature cycles over the day and night help regulate sleep and recovery. However, as shown in Figure 2.2, highly built-up neighborhoods in Mexico City retained significantly more heat at night, with temperatures remaining up to 8°C higher than in areas with extensive tree cover. This disparity is driven by heat-retentive surfaces, reduced evaporative cooling, street canyons that limit upward heat release, and reduced airflow.

The analysis highlights important lessons for urban design and heat mitigation strategies, which are discussed at greater length in section 5.1. The physical form of urban areas—including street layouts, building density, the presence of natural features, and the choice of building materials—plays a crucial role in localized warming and in causing or avoiding heat stress. Good airflow, shade from both built structures and trees, a reduction in the share of space covered by heat-absorbing materials such as asphalt and concrete, and particularly green space—from landscaped parks or natural forests—can significantly reduce urban heat. As cities in Latin America and the Caribbean continue to grow, integrating climate-sensitive urban planning that prioritizes these features is essential for reducing urban temperatures and protecting residents' health and well-being (Figure 2.3).

FIGURE 2.3. INFLUENCE OF CLIMATE-SENSITIVE DESIGN FEATURES ON THE URBAN SURFACE ENERGY BALANCE



2.3 IN SOME CITIES, VULNERABLE POPULATIONS LIVE IN HOTTER NEIGHBORHOODS

If some parts of cities are much hotter than others, it is important to know who lives in those hotter areas—and how vulnerable they are. Section 4.1 looks at heat vulnerability from a physiological perspective, highlighting the urgent need to protect infants, small children, pregnant women, and older adults, for instance. This section focuses on poverty and vulnerability within cities, which can increase people's exposure to climate hazards and significantly constrain their adaptive capacity.⁵⁵

A study of 25 cities around the world, including Buenos Aires, Mexico City, and São Paulo, found that in 72 percent of cases, poorer neighborhoods faced more heat than wealthier ones.⁵⁶ Thermal disparities varied significantly, but some cities, including Buenos Aires and Mexico City, had a “noticeably pro-wealthy UHI intensity distribution.” The global evidence is not conclusive, however. For instance, an analysis for the World Bank of 18 cities in South Asia and Sub-Saharan Africa found that informal settlements were not necessarily more exposed to floods or excessive heat than other parts of those cities.⁵⁷

UHI effects in some urban areas of Latin America and the Caribbean have been studied at length, including in terms of disparities between rich and poor. An analysis of Barranquilla, Colombia, for instance, found that the average surface temperature in poorer neighborhoods was more than 5°C higher than in wealthier areas.⁵⁸ The main factor was found to be distance from the cooling effects of the coast; the poor live farther inland.

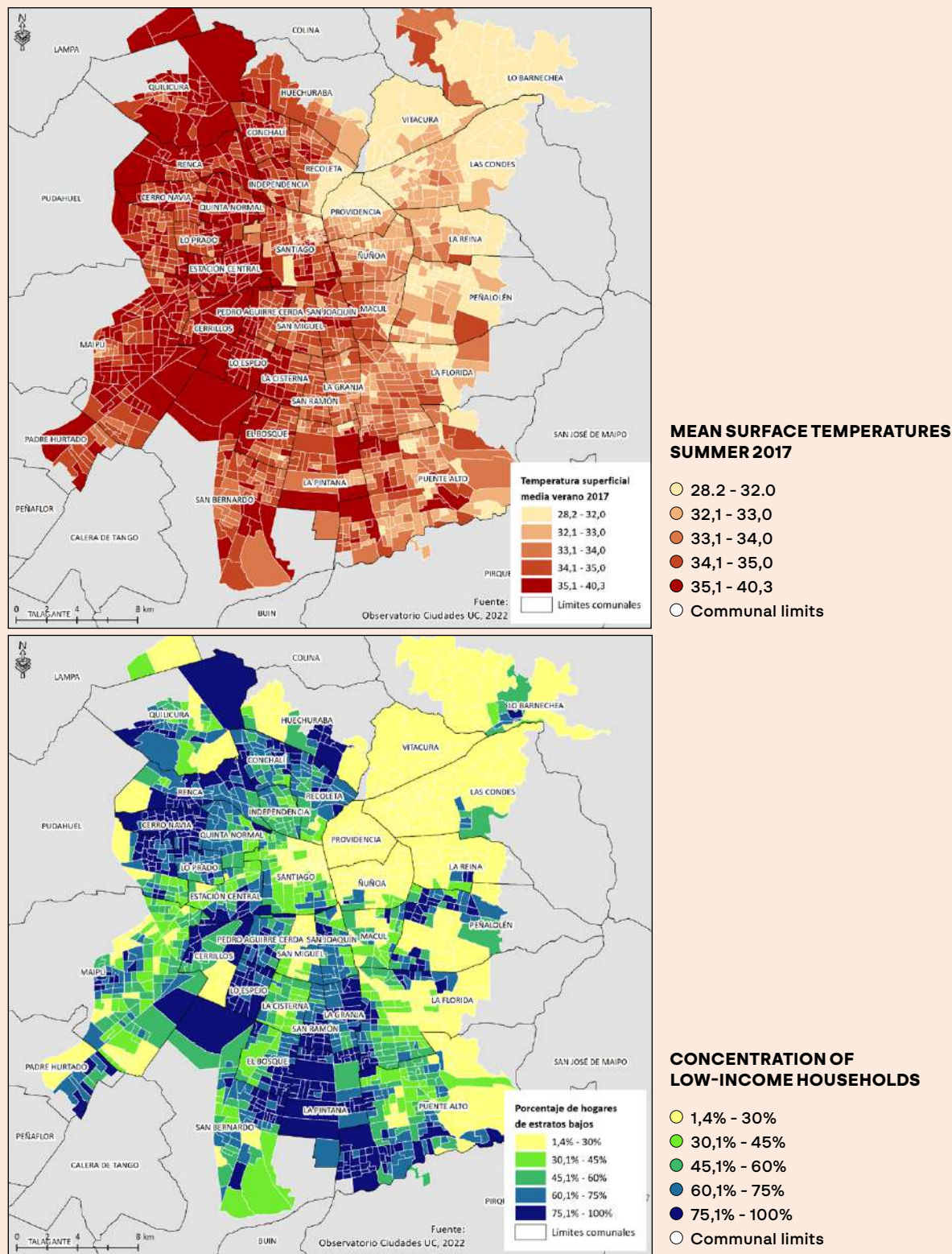
In Greater Santiago, Chile, two detailed analyses of temperature data—one focused on the summers of 2005–2017,⁵⁹ the other on heatwaves in the decade up to 2023⁶⁰—have clearly identified the city's northwest as the hottest area, and large hot areas in the west and southwest of Santiago as well. The latter found differences of up to 6.7°C between west and east on the hottest day of a January 2020 heatwave. A comparison of urban heat and poverty levels across the city shows significant overlap between the two (Figure 2.4).⁶¹

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FIGURE 2.4. MEAN SURFACE TEMPERATURES IN SANTIAGO, CHILE, IN THE SUMMER OF 2017 (TOP) AND CONCENTRATION OF LOW-INCOME HOUSEHOLDS IN THE CITY (BOTTOM)



Source: Leniz (2024), with data from the Observatorio de Ciudades UC.⁶²

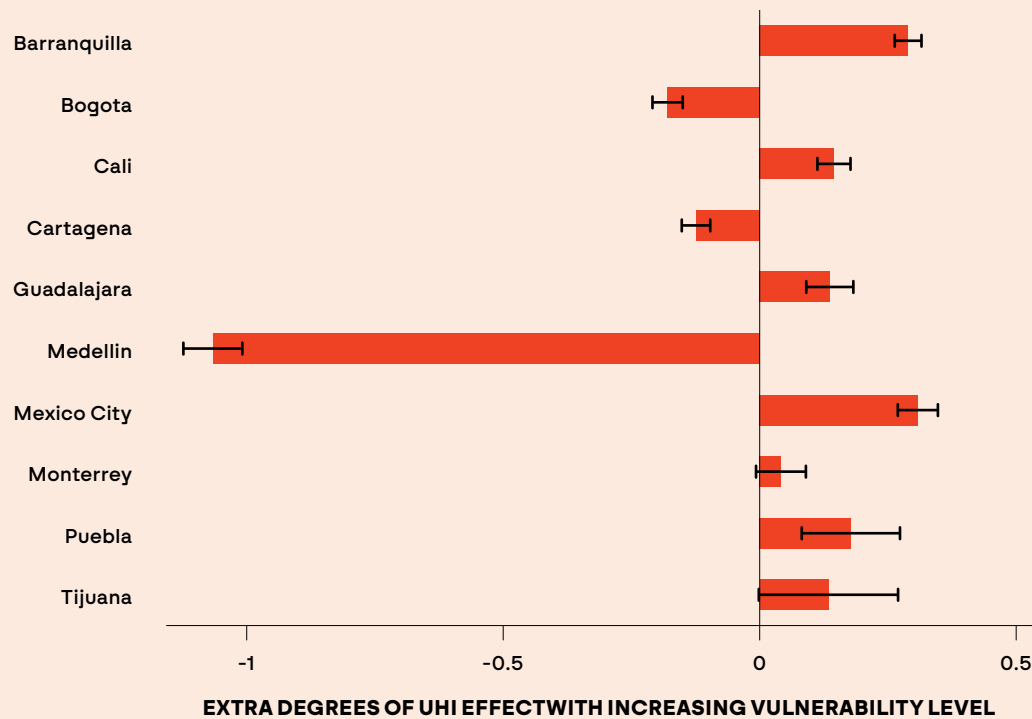
A study of urban heat in Lima, Peru, from 2017 to 2021, using block-by-block data, found that blocks with higher socioeconomic status were less exposed to UHI effects; it also found significant differences by ethnicity.⁶³ Ongoing research in Córdoba, Argentina, has found a strong correlation between urban heat and population density, with by far the hottest land surface temperatures in the city center and nearby neighborhoods.⁶⁴ These are not necessarily the poorest communities, but they do have a disproportionate share of older people.

Researchers have also highlighted a different form of thermal inequality: lower-income people are far less likely than wealthier ones to have the means to keep their homes cool (discussed further in section 3.1).⁶⁵ They may be more exposed to urban heat because they walk or use public transit instead of driving their own cars (section 3.4). Rapid urbanization in cities' peripheries, where many low-income people live, is also increasing UHI effects, as forests and farmland are replaced by buildings and roads. In El Salvador, for example, 93.5 percent of respondents to a 2024 nationwide survey said temperatures in their community were getting hotter, and 59.7 percent said they had seen a reduction in forest cover in surrounding areas.⁶⁶

In order to further examine links between socioeconomic vulnerability and surface UHI exposure, for this report, a novel dataset was used to compare block-level census data and high-resolution temperature data for five cities each in Colombia (Barranquilla, Bogotá, Cali, Cartagena, and Medellín) and Mexico (Guadalajara, Mexico City, Monterrey, Puebla, and Tijuana), each set corresponding to about one-third of each country's urban population.

The analysis showed a correlation between socioeconomic vulnerability and the intensity of the surface UHI effect in seven of the 10 cities studied (Figure 2.5). For example, in Barranquilla, census blocks that differed by one point on the vulnerability score also had local maximum temperatures that differed by about 0.3°C (higher in more vulnerable blocks). Similar patterns were found in Cali, Guadalajara, Mexico City, Puebla, and Tijuana. However, in Medellín, the opposite was true: a one-point increase vulnerability was correlated with a local maximum that was over 1°C cooler.

FIGURE 2.5. CHANGE IN LOCAL MAXIMUM TEMPERATURE ASSOCIATED WITH 1-POINT INCREASE IN SOCIOECONOMIC VULNERABILITY SCORE IN 10 CITIES IN COLOMBIA AND MEXICO



Source: World Bank analysis.

Note: The UHI effect is measured as the difference between the yearly median block's 95th percentile of all Landsat 8/9 LST images from 2020 to 2022 temperature and the lowest 95th percentile within the city. In a nutshell, this measure captures how much hotter a given city parcel is compared to the coolest area in the same city. This comparison is performed using a proxy for the maximum registered temperature. Vulnerability is measured on a scale of 1–6 scale (6 is most vulnerable), based on a composite of indicators covering housing, demographics, education, labor, and health; the composite vulnerability index is the average of the scores within each dimension. The data were sourced from the 2018 Colombian population census conducted by the National Administrative Department of Statistics (DANE) and 2020 Mexican population censuses conducted by the National Institute of Statistics and Geography (INEGI). Temperature data came from the Landsat Thermal Infra-Red Sensor measurement of land surface temperature (LST). While air temperature would be more easily compared with critical thresholds of metabolic stress, LST was chosen due to its availability at a higher resolution (100 m²), which enabled a finer-scale analysis within cities.

As noted above, a neighborhood's relative heat exposure depends on multiple factors, which may or may not track closely with socioeconomic conditions. Higher temperatures occur in highly built-up areas with little green space, for example, which are often poorer neighborhoods. But in Bogotá, for example, while the poor live in neighborhoods with less tree cover, but they also tend to live at higher elevations, where it is cooler. Similarly, in Medellín, there are large informal settlements on the hills at the edge of the city, surrounded by forest. In many places, poor people are concentrated in low-lying coastal areas, but in Barranquilla, they live mainly inland, forgoing the cooling effects of sea breeze. Figure 6 shows how different factors correlate with social vulnerability.

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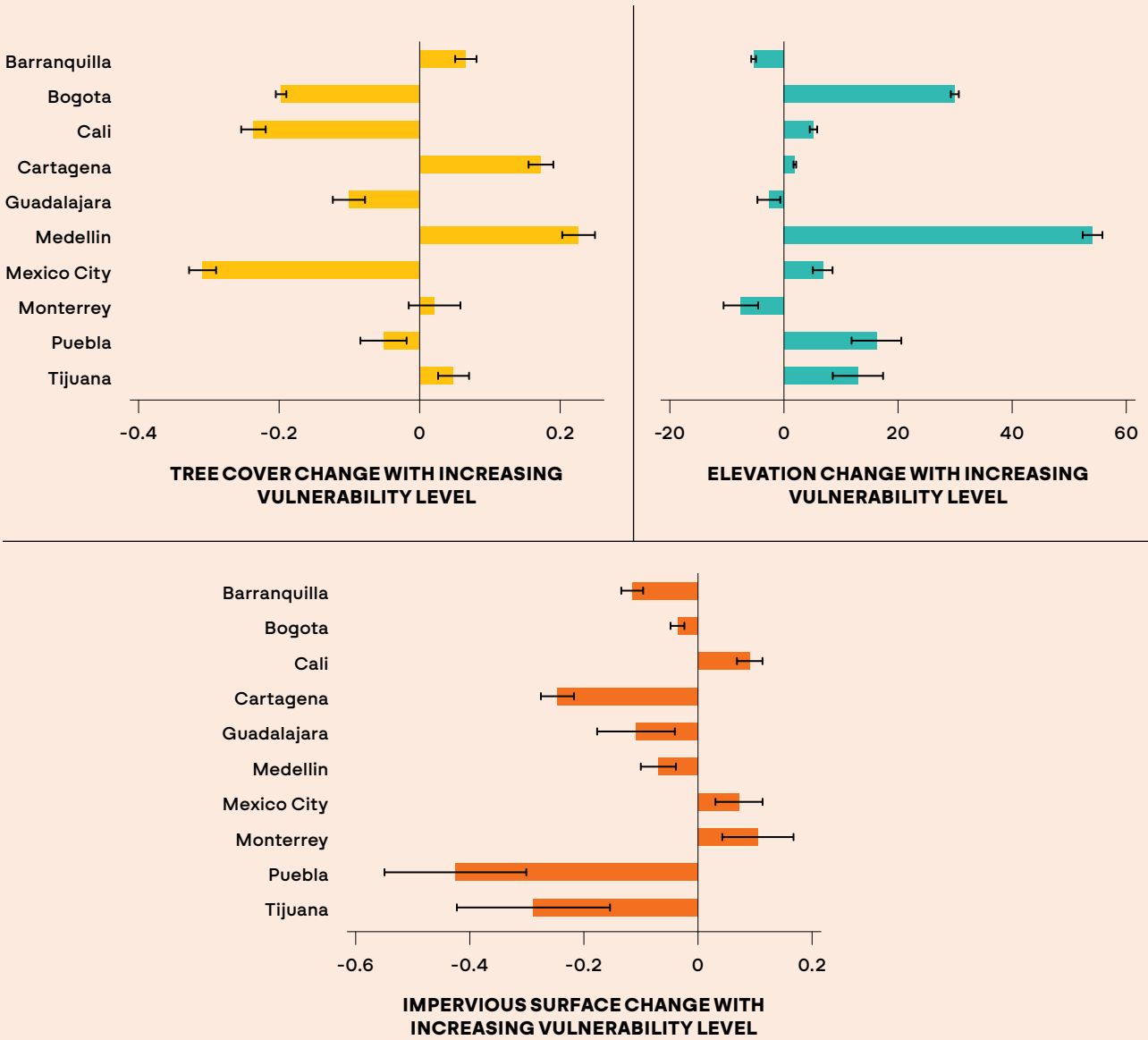
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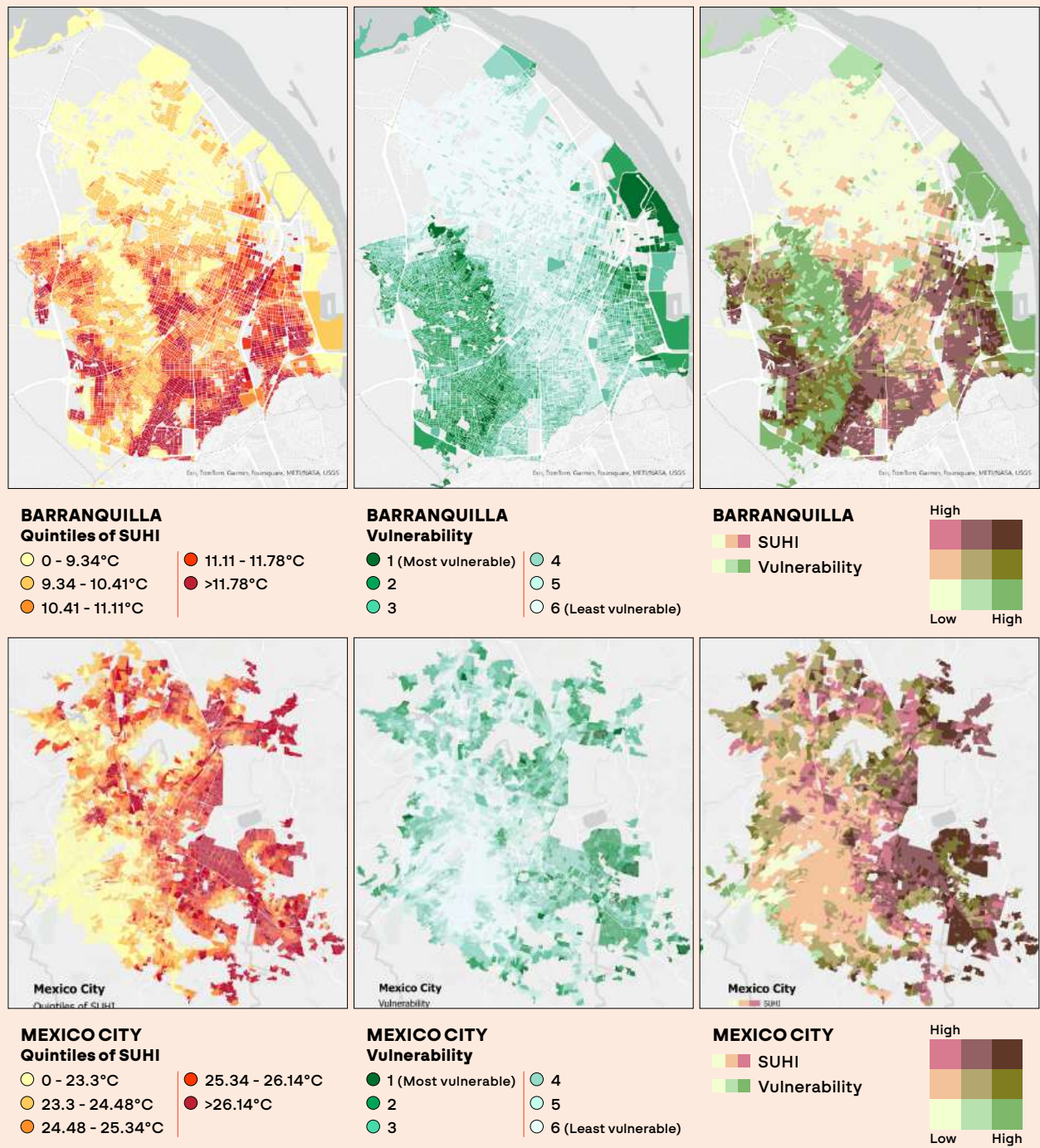
FIGURE 2.6. CORRELATION BETWEEN TREE COVER CHANGE, ELEVATION, AND SHARE OF IMPERVIOUS SURFACE AND A 1-POINT INCREASE IN SOCIOECONOMIC VULNERABILITY SCORE IN 10 CITIES IN COLOMBIA AND MEXICO



Source: World Bank analysis.

Figure 2.7 offers a closer look at the two cities with particularly large thermal inequalities: Barranquilla and Mexico City. In both, there are large areas where high heat exposure (darker red color in graph at left) and high vulnerability (darker green in the middle graph) overlap. This is clearest in the graph at right, where both measures are overlaid. In Barranquilla, there are pockets of overlap in the west and south of the city. The affluent neighborhoods in the north, closer to the coast, show lower heat exposure. In Mexico City, a majority of the poor live in neighborhoods to the east, where they face some of the highest temperatures in the city. These areas were also the most affected by the May 2019 heatwave, as discussed in section 2.2.

FIGURE 2.7. SEVERITY OF UHI EFFECT BASED ON LAND SURFACE TEMPERATURE (LEFT), SOCIOECONOMIC VULNERABILITY (MIDDLE), AND OVERLAP BETWEEN THE TWO (RIGHT) IN BARRANQUILLA, COLOMBIA (TOP) AND MEXICO CITY (BOTTOM).



Source: World Bank analysis.

Note: SUHI means surface urban heat island effect.

Section 3.1 examines the challenges of inadequate housing, including conditions in informal settlements, as well as passive cooling strategies that can reduce indoor temperatures, often at a low cost, and effective solutions when active cooling is needed.

CHAPTER

3



Well-built infrastructure is designed to fit local conditions, including the range of temperatures that can be expected in a given place. In Latin America and the Caribbean as in much of the world, that means that infrastructure is often not designed to withstand extreme heat. As temperatures rise, infrastructure systems are increasingly proving inadequate. Without adaptation measures, heat-related malfunctions and failures could cause a cascade of disruptions to critical services such as electricity, communications, transport, and water.⁶⁷

Such vulnerabilities are of particular concern in Latin America and the Caribbean because the region has substantial infrastructure deficits, with millions lacking basic services. To meet the Sustainable Development Goals (SDGs) by 2030, one study estimated that the region would need to invest of 3.12 percent of its GDP per year—a total of US\$2.2 trillion.⁶⁸ Of this, 41 percent would be to maintain and replace assets, and 59 percent to build new infrastructure.

This section examines the implications of rising temperatures for three infrastructure systems. Section 3.1 explores how building design and materials exacerbate heat problems, and section 3.2 presents key strategies to make homes and other buildings cooler. Section 3.3 discusses cities' electricity supplies, and section 3.4, transport systems.

3.1 POOR HOUSING DESIGN AMPLIFIES HEAT RISKS, TURNING HOMES INTO HAZARDS

When Europeans arrived in what is now Latin America and the Caribbean, they found a wide array of Indigenous architecture tailored to the local climate: from the thick-walled, straw-roofed adobe houses of Mesoamerica and the Andes, to the sturdy, but well-ventilated round bohíos of the Caribbean islands, made from palm leaves, straw, and wood.⁶⁹ The colonists adapted Indigenous techniques for staying cool and brought some of their own, such as building around courtyards and creating verandas and other well-shaded outdoor spaces.

Today, few of those traditional buildings remain, especially in cities. And while some architects have found innovative ways to tailor designs to specific climates,⁷⁰ and even to build with traditional materials such as earth,⁷¹ most buildings in the region today follow similar patterns regardless of the local climate. Houses are typically built from reinforced cinderblock, brick, or wood, and many people live in large multi-unit apartment buildings. Luxury and modernity often mean extensive use of glass and steel. The poorest people, meanwhile, often live in overcrowded and poor quality homes.

In the mild climates that many cities in Latin America and the Caribbean have long enjoyed, even woefully inadequate buildings may still maintain comfortable temperatures. With climate change, however, many homes, schools, workplaces, and many other structures are becoming unbearably hot during heatwaves and even for extended periods. As discussed in Section 4, the human impacts can be severe, particularly for small children, pregnant women, older adults, and anyone performing heavy physical labor.

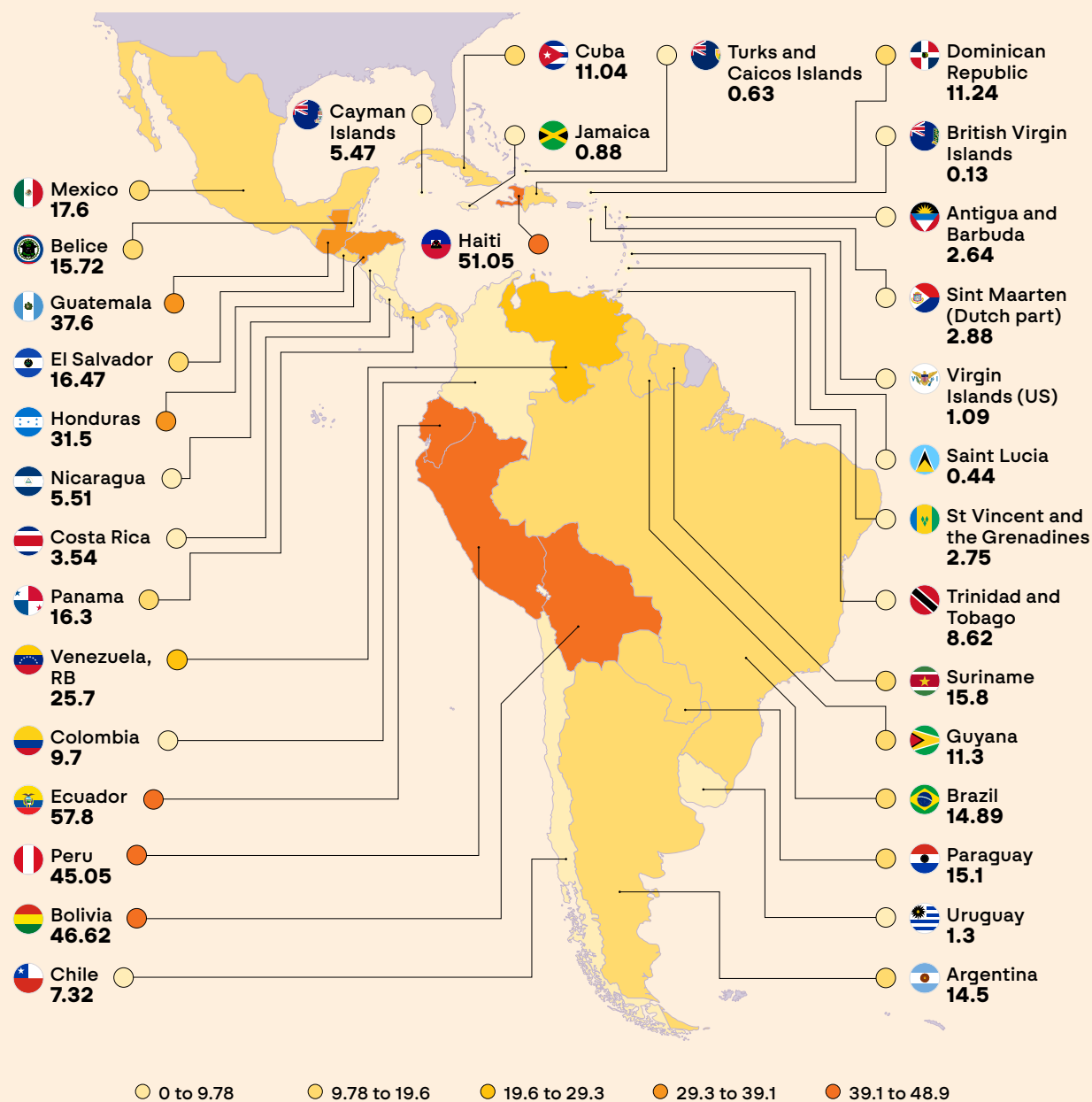
A recent analysis that included Argentina, Bolivia, Brazil, the Dominican Republic, Paraguay, and Peru found 45 million urban poor people in the six countries were highly vulnerable to heat exposure due to low-quality housing, limited electricity access, and overall poverty.⁷² Another 88 million lower-middle-income people in the six countries were deemed to be at medium risk.

This section examines some of the key reasons why houses and buildings in the region's cities are ill-prepared for an increasingly hot climate, and what can be done about it. First, however, it is important to recognize the severe vulnerabilities of the roughly one-fifth of households in the region who live in slums, informal settlements or inadequate housing, in conditions that may be life-threatening during extreme heat.

In many cities in Latin America and the Caribbean, population growth has significantly outpaced housing construction, creating large housing shortages. Some governments have made major efforts to add and improve housing, but the results have been mixed, and in some countries, efforts have been cut back or privatized in recent years.⁷³ As a result, housing deficits remain high, and an estimated 93.4 million people—or 16.9 percent of urban dwellers in the region—lived in slums, informal settlements, or inadequate housing as of 2022, UN data show.⁷⁴

Urban housing poverty exists in all countries in the region, but at dramatically different rates: from 0.4 percent in Saint Lucia, 1.3 percent in Uruguay, and 3.5 percent in Costa Rica, to 37.6 percent in Guatemala, 45.1 percent in Peru, and 51.1 percent in Haiti (Figure 3.1).⁷⁵

FIGURE 3.1. SHARE OF URBAN POPULATION LIVING IN SLUMS, INFORMAL SETTLEMENTS, OR INADEQUATE HOUSING, 2020



Source: Adapted from Urban and Cities Platform of Latin America and the Caribbean, ECLAC.⁷⁶

These settlements range from densely built-up neighborhoods of small, poor-quality houses made from cinderblock or brick, like Rio de Janeiro's *favelas*, to shantytowns and squatter camps where people live in shacks improvised from whatever materials were on hand (Figure 3.2). Slums concentrate poverty, social vulnerability, and often also climate risks such as exposure to extreme heat.⁷⁷ The experience of chronic heat stress has been well documented in slums in cities in the tropics in particular.⁷⁸ As discussed in Section 1, with climate change, similarly hot conditions are becoming increasingly common even in temperate zones.

FIGURE 3.2. EXAMPLES OF INFORMAL SETTLEMENTS IN TEGUCIGALPA (LEFT), RIO DE JANEIRO (RIGHT), AND LIMA (BOTTOM)



Sources: José Matute and Jean Carlos, UNSPLASH, and Ksenia Ruta, Flickr, licensed under Creative Commons.⁷⁹

Homes built without professional help, with inadequate materials, tend to be particularly vulnerable to extreme climatic conditions and thermal discomfort.⁸⁰ Moreover, informal settlements often lack essential infrastructure, basic services such as safe potable water—a must-have during hot spells—and sanitation, urban amenities such as parks and street trees, or reliable public transit. All this exacerbates residents' susceptibility to heat-related health risks.

Moreover, the urban poor—not just slum dwellers, but also residents of social housing—are often pushed to the peripheries of cities, where land is cheaper, but infrastructure is lacking.⁸¹ This spatial inequality results in limited access to public services and amenities that could mitigate the effects of extreme heat, such as health care facilities and cooling centers.⁸²

3.1.1 MANY HOMES IN THE REGION ARE NOT BUILT FOR THERMAL COMFORT

Thermal insulation is not a common feature of housing in Latin America and the Caribbean—except in places where it gets cold—and low-income urban residents tend to be even less protected from heat, as their houses are typically built with industrialized hollow bricks without a glazing system.⁸³ Roofs are often wood structures with industrialized clay roof tiles or corrugated metal. Corrugated metal has practically no insulation value, and without other measures such as a reflective coating, adequate ceiling height and ventilation, it becomes nearly impossible to withstand climate extremes. Dark-red roofs also absorb large amounts of heat; a 2024 experiment in Mexico City found a 30°C difference between the peak temperatures reached by roof surfaces painted white vs. ochre: 40°C and 70°C, respectively.⁸⁴

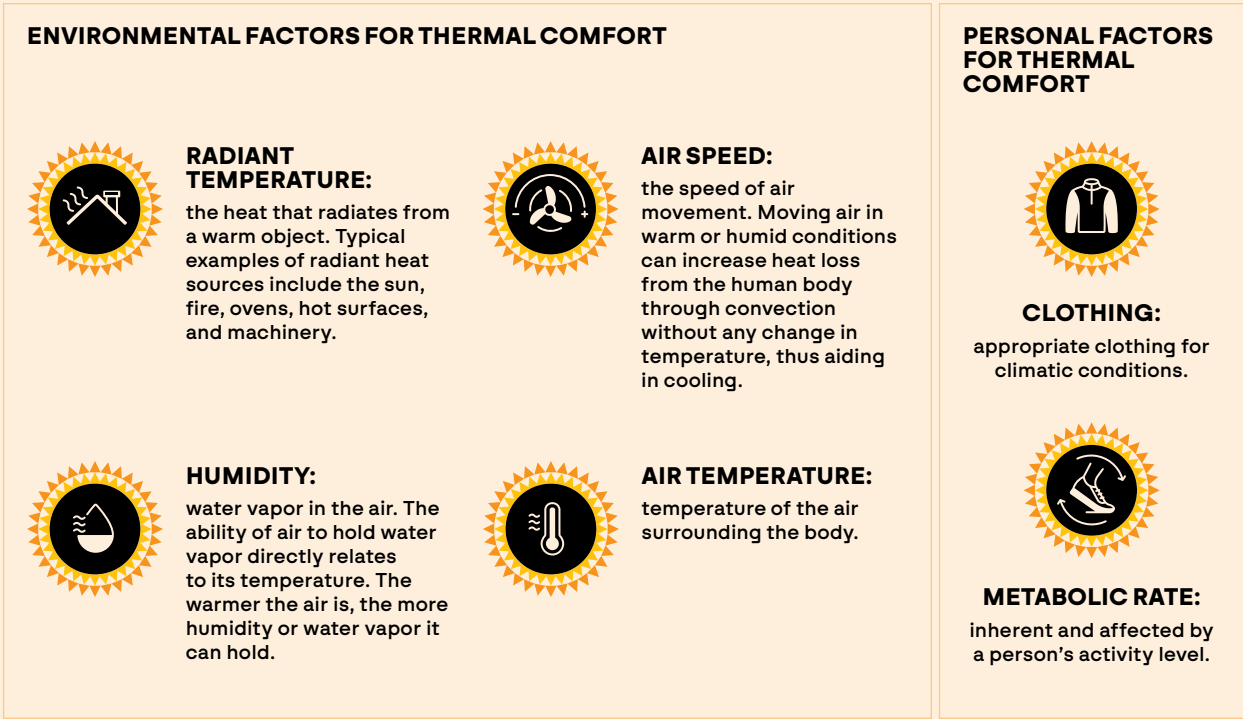
Moreover, an analysis of census data in Mexico found that poor roof materials (cardboard and corrugated metal roofs) were most prevalent in the poorest and hottest states, such as Chiapas, Tabasco, and Oaxaca.⁸⁵ Results from Colombia's 2023 National Quality of Life Survey show a similar pattern: departments with warmer, predominantly tropical climates tend to have a larger share of households who lack adequate flooring and wall materials.⁸⁶ They were also likelier to have dirt floors and exterior walls made from rough wood, boards, or zinc—or no walls at all. This suggests that along with the thermal inequalities discussed in section 2.3, cities in countries' hotter regions may also have higher poverty levels overall.

Mexico's 2020 National Housing Survey also revealed that only 6 percent of houses had some type of insulation.⁸⁷ About whether they were satisfied with how their homes protected them from rain, cold, heat and wind, 42 percent of respondents said they were only somewhat, little, or not at all satisfied, suggesting that a significant proportion of homes in Mexico are inadequate to protect their inhabitants from the elements—much less from extreme weather. This is closely linked to energy poverty, as the same households who lack adequate housing typically lack the means to pay for efficient fans and/or air conditioning.⁸⁸ Indoor thermal comfort is more than a convenience; as Section 4 highlights, it is important for human health and well-being, good educational outcomes, worker productivity, and more. Most heat-related fatalities occur inside the home, primarily affecting older adults who spend as much as 90 percent of their time indoors.⁸⁹ This highlights the need to prioritize indoor environmental conditions and housing quality to mitigate heat-related mortality.

While understanding of outdoor heat exposure has advanced considerably, the impacts of high indoor temperatures remain less understood.⁹⁰ Most guidelines on heat exposure are based on outdoor temperatures, overlooking the fact that indoor and outdoor temperatures can differ significantly depending on building design, materials, and cooling access. Studies from office environments show that in a temperature range of 25–32°C, every 1°C increase correlates to a 2 percent drop in employee performance,⁹¹ underscoring the productivity and well-being benefits of controlled indoor environments.

As shown in Figure 3.3, humidity also plays a role in perceived comfort relative to heat. For instance, research in Bogotá found that the operative comfort temperature in office buildings was 23.47°C, with comfort levels influenced by indoor relative humidity between 29 and 70 percent.⁹² Higher humidity levels decreased perceived comfort temperature, showing that humidity control is essential in indoor environments to manage comfort relative to heat.

FIGURE 3.3. DETERMINANTS OF HUMAN THERMAL COMFORT



Source: Adapted from ESMAP (2020), Figure 1.2.⁹³

3.2 WHAT CAN BE DONE? MAKING HOMES AND BUILDINGS SAFER IN THE HEAT

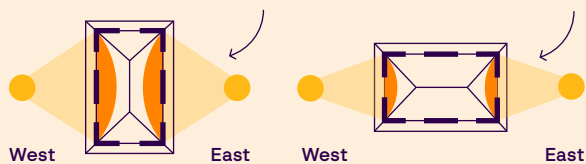
As noted at the start of this section, historically, vernacular architecture in this region provided thermal comfort without heating, ventilation, and air conditioning (HVAC) systems. Instead, traditional buildings relied on so-called “passive cooling” through design strategies tailored to local climates. However, modern, industrialized materials and homogenous building types have spread widely, often disregarding climate-specific solutions, and this shift has increased dependency on mechanical (or active) cooling. Given the energy consumption associated with AC use, especially (see section 3.2.2), and its limited affordability, it is crucial to make the most of opportunities for passive cooling.⁹⁴ In Latin America and the Caribbean, this involves reviving traditional approaches as well as adopting new strategies.⁹⁵

3.2.1 INCORPORATE PASSIVE COOLING STRATEGIES FOR NEW AND EXISTING STRUCTURES

In new construction, improving indoor thermal comfort starts with building design and the selection of materials. As summarized in Figure 3.4, key strategies in warm tropical climates include optimizing building orientation—to avoid direct sunshine during the hottest hours, for example; incorporating shading; maximizing natural ventilation by ensuring good airflow and inviting cool breezes in; and avoiding colors and materials that absorb heat (e.g. black roofs), instead choosing surfaces with high albedo.

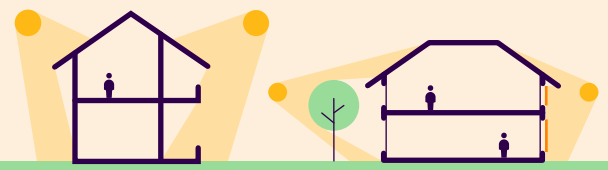
FIGURE 3.4. DESIGN STRATEGIES FOR CREATING A COMFORTABLE HOME IN THE TROPICS

SITE ORIENTATION



- Prioritise rooms that need the most natural ventilation and position them to take advantage of prevailing winds.
- Orient the shorter sides of your home to face the east and west sun, except where this compromises natural ventilation.

SUN SHADING



- Have large roof overhangs or covered outdoor areas for shading the north and south facing walls.
- Use vertical screens or shutters to shade west and east facing openings.
- Plant trees and other vegetation to shade east and west walls and to provide cooler surroundings.

NATURAL VENTILATION



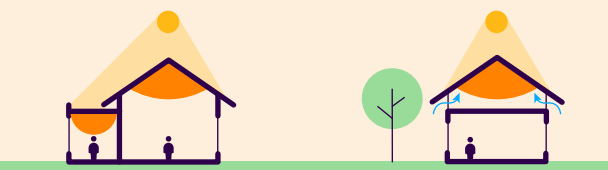
- Have large window and door openings on two or more walls of each room to promote cross ventilation.
- Use upper-level windows or vents near the roof to allow rising hot air to escape.

WALL MATERIALS AND CONSTRUCTION



- Thermal massing materials like concrete walls and slabs are not ideal unless they are shaded. These store heat absorbed during the day and releases it into the room during the night.
- Consider using lightweight materials and framing construction instead since these will cool quickly.

ROOF DESIGN



- Use framed, high pitched roofs. High roofs keep warm air high above the people in the room.
- You can also incorporate light coloured, reflective roof covering materials.
- Use a double roof system especially when concrete is the layer underneath.



Natural ventilation

is widely regarded as one of the most effective passive cooling strategies, particularly in tropical and temperate climates. It can be achieved by optimizing the geometry of the building to enhance airflow and reduce heat accumulation. Key techniques include: (i) cross ventilation, such as designing openings (windows and doors) on opposite sides of the building to allow for continuous airflow; (ii) buoyancy ventilation or leveraging the height of the building to allow warm air to rise and escape through high-level openings; and (iii) maximizing ventilation during cooler evening hours to remove accumulated heat. Studies have shown that wind-driven and buoyancy ventilation are particularly cost-effective solutions for low-income households.



Roof design, materials and color

are particularly important, as in hot climates, roofs account for 50–60 percent of a building's cooling load,⁹⁷ as the sun shines directly on them. Roof design thus plays a critical role in passive cooling strategies. Higher ceilings and vents at roof levels can improve air circulation and facilitate buoyancy ventilation. Just as light-colored and reflective coatings are being used to increase the albedo of roads, cooling them (section 3.4.4), similar strategies are being used to make “cool roofs.” Based on the roof experiment described in section 3.1, for instance, Mexican climate experts advised painting rooftops white.⁹⁸ Material selection is also important: in hot tropical climates, lightweight roofs with reflective coatings often perform better than heavy concrete roofs, as the latter can retain and radiate heat.

A notable example of large-scale cool roof implementation is the Million Cool Roofs Challenge, launched in 2019, which installed over 1.1 million square meters of cool roofs within two years in several low- and middle-income countries, including Mexico.⁹⁹ Participants reported indoor temperatures were at least 2°C cooler. High-albedo roofs have also shown promise in Argentina and Chile, though more work is needed to identify the best materials and most suitable settings.¹⁰⁰ A recent study that combined modeling with field testing in locations with different climates found that cool roofs achieved energy savings averaging 32.8, 35.7, 15.0, and 25.0 percent, respectively, in temperate, tropical, hot-dry, and composite climatic zones.¹⁰¹

A 2012 study by a top proponent of cool roofs found that widespread adoption of light-reflecting urban surfaces, particularly roofs and pavements, could reduce global temperatures by 0.01–0.07°C.¹⁰² However, as with cool pavements, there may be trade-offs: both cool roofs and “green roofs” (covered with vegetation; see section 5.1.1) can affect wind speed, humidity, and radiant temperature outside the building.¹⁰³ A Harvard University study published in late 2024 found large-scale use of cool roofs and pavements might suppress rainfall in surrounding areas.¹⁰⁴ If widely adopted in wealthy neighborhoods, but not in poor ones, cool roofs could also unintentionally exacerbate thermal inequalities, the authors warned.



Green roofs—covered with vegetation—

have also shown promise for reducing indoor temperatures and enhancing biodiversity resilience. In Córdoba, Argentina, the internal surface temperatures of rooms under green roofs were 5–6°C cooler than those covered by conventional roofs.¹⁰⁵ Native plant species have been found to bring additional benefits, such as improving biodiversity and being more resilient to environmental stress.¹⁰⁶

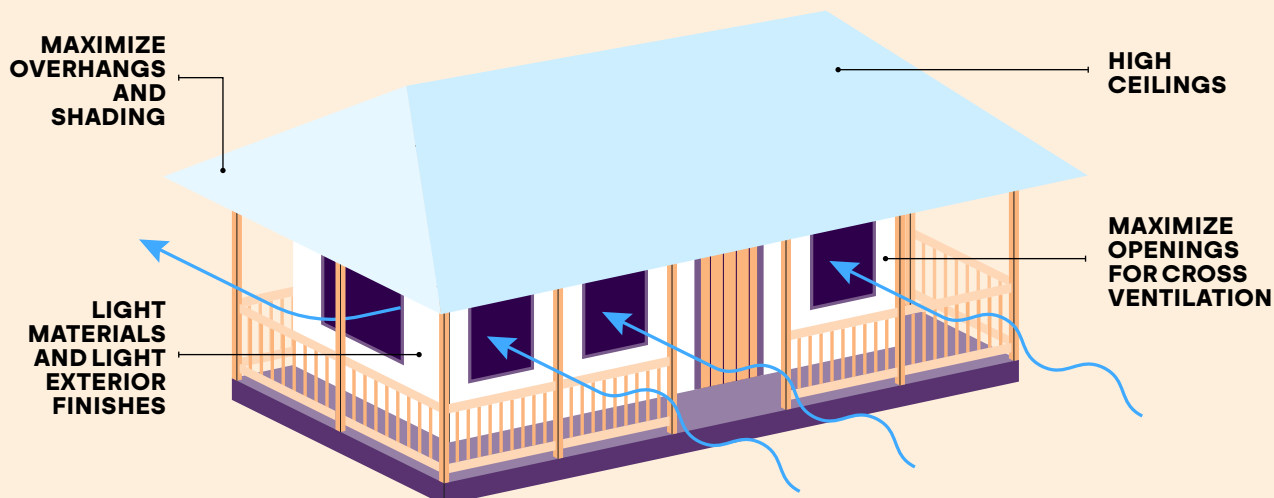
It is important to note that green roofs are more challenging than cool roofs, as soil or another growing medium must be applied, at a thickness sufficient to support the species selected, and this plus the plants and any water they absorb will add weight that the roof must bear. In places where stormwater management is highly valued, green roofs can have a net economic benefit. Otherwise there remains a moderate cost premium over other roof options. However, there are many co-benefits beyond cooling and water absorption, such as biodiversity, aesthetic value, and the possibility to grow food or create additional green space for people's enjoyment.



Shading strategies

are critical in preventing direct solar gain, especially for windows and walls that receive the most sunlight. External shading devices, such as overhangs and awnings, are more effective than curtains or blinds. Semi-outdoor spaces, such as porches and balconies, are also common in tropical climates, as they create buffer zones that reduce indoor heat gain while offering culturally familiar spaces for occupants (Figure 3.5). Research in Honduras has shown that semi-outdoor spaces contribute significantly to cooling apartment buildings.¹⁰⁷

FIGURE 3.5. COMBINING SHADE, ROOF DESIGN, AND VENTILATION FOR COOL HOMES IN HOT-HUMID CLIMATES



Research indicates that well-designed passive strategies can reduce indoor heat by up to 25 percent, even in hot and humid climates.¹⁰⁹ To be most effective, passive design strategies are adapted to the specific local climatic conditions. No single strategy is likely to suffice to achieve optimal thermal comfort in warm, tropical contexts or during episodes of extreme heat in any city; a combination of strategies will be required. Most studies to date have focused on climates outside of the Latin American region, leading to a gap in localized solutions for tropical and subtropical environments. However, there is a growing body of research from the region.¹¹⁰

A study in Mexico, for example, modeled the potential effectiveness and cost of adopting a package of passive cooling techniques in affordable housing in the tropical city of Mérida, Yucatán.¹¹¹ It found that the yearly time of thermal discomfort could be reduced by half, and energy savings of about 20 percent could be achieved due to reduced cooling loads, and the additional construction costs would not exceed (a still substantial) 36 percent of the base home value.

In Colombia, an experiment in social housing in Cali found that solar chimneys, which could be installed at a low cost, could significantly reduce what is often unbearable daytime heat.¹¹² In Mendoza, Argentina, an addition to a house was used to successfully demonstrate a package of passive cooling approaches.¹¹³

Passive design strategies are usually cost-effective and environmentally sustainable, but given the diversity of the region's climates, solutions for one city or one building may not work in another and are not easily replicated. Moreover, passive measures may not be enough as temperatures rise due to climate change. Shading and reflective roofs will remain effective in mitigating heat and will help reduce cooling loads in buildings that incorporate AC, but buildings designed for cross-ventilation may need to be modified for AC use, as mechanically cooled spaces require airtight enclosures to prevent heat exchange. The challenge lies in balancing a permeable envelope (which allows ventilation) with the need for airtightness when AC is introduced. Determining whether buildings should be designed to accommodate AC from the outset remains a complex question, as this depends on the local climate. In milder climates, natural ventilation will continue to be an effective measure.

BOX 3.1**ENHANCING THE RESILIENCE OF ‘SELF-PRODUCED’ HOUSING IN MEXICO**

The Mexican government has been working for several years now to improve the quality of “self-produced” housing—that is, homes built entirely under the direction of their owners, from land use decisions, to design, to construction, whether or not contractors are hired.

As of 2022, an estimated 62.8 percent of Mexico’s housing was self-produced.¹¹⁴ Aiming to improve the quality and resilience of these homes and promote new construction, the government developed a self-production strategy under the National Housing Program 2021–2024.¹¹⁵ To inform the development of the strategy and its implementation, a pilot study was conducted with 32 homes in four different climate zones.¹¹⁶

The study identified an array of weatherization and energy efficiency interventions suitable for each

climate zone, with both priority and complementary measures. For example, in hot and humid climates, priority measures included smooth, light-colored walls, reflective roof coatings, alignment to shield from the sun, cross-ventilation, and roof ventilation. Overall, simulations suggested that homeowners could reduce their annual energy costs by up to 33 percent, while enhancing their thermal comfort.

The pilot found that several measures were easy and inexpensive to implement even in older homes, while others—such as improved windows for ventilation—were cheapest and more feasible in new construction or additions.¹¹⁷ The national self-production strategy aims to raise awareness of the need for resilient construction, expand access to finance so families can afford to build higher-quality homes, and provide enhanced technical support and capacity-building.¹¹⁸

3.2.2 INCREASE THE EFFICIENCY OF ACTIVE COOLING TECHNOLOGIES

Historically, most people in Latin America and the Caribbean have not used air conditioning (AC). As noted in Section 1, large parts of the population live in cities where the climate has usually been mild, with few, if any, very hot days. Even in places with hotter climates, houses and other buildings were designed in ways and built from materials that helped them stay cool.

With both temperatures and incomes rising, however, the use of cooling technologies has grown rapidly. Ownership of ceiling and portable fans in Brazil nearly doubled from 2010 to 2020, for example,¹¹⁹ and in 2023 alone, about 5.1 million AC systems were sold in the country.¹²⁰ AC ownership in Latin America and the Caribbean is still relatively low, 15 percent as of 2022,¹²¹ about half the global average—though with large differences across and within countries. (For example, while only 14 percent of households across Mexico owned AC as of 2016, 73 percent in Sonora and 77 percent in Sinaloa did. Similarly, while as of 2018, AC ownership in Brazil was 20 percent, in Manaus, the rate was 69 percent.¹²²)

By 2050, under countries’ stated policies, the IEA projects that AC ownership will roughly triple in Mexico and Colombia and roughly double in Argentina, Brazil, and Costa Rica.¹²³ This will not only strain power systems, but also many households’ budgets: a study of eight industrialized countries found households with AC spent, on average, 35–42 percent

more on electricity than those without AC.¹²⁴ Energy poverty already exacerbates the impacts of thermal inequalities in Latin America and the Caribbean, as discussed further in section 2.3. In 2022, for example, an estimated 28.7 million people in poor urban settings in Brazil were at high risk from heat for lack of access to cooling.¹²⁵ Another 57.7 million Brazilians were lower-middle-income, able to buy a fan or AC unit, but likely only a cheap and inefficient one.

Those gaps are expected to grow. By one recent estimate, by 2050, 75 percent of high-income households in Argentina, Paraguay, and Uruguay will have AC, but only 50 percent of low-income households.¹²⁶ In Mexico, these figures drop to 50 and 15 percent, respectively, while in El Salvador, less than 10 percent of households may have AC access. Such disparities are likely to make poorer households even more disproportionately vulnerable to heat-related mortality, illness, mental health impacts, educational losses, and more (see Section 4).

An integrated strategy is needed to address indoor space cooling needs sustainably. This starts with reducing cooling loads through passive design strategies (section 3.2.1). It is also crucial to adopt ambitious energy efficiency standards for cooling technologies such as AC. Existing technologies and strategies, if widely implemented, could meet cooling needs with significantly less energy.¹²⁷ Yet the average efficiency of room air conditioners sold today is less than half that of the most energy-efficient units available for sale. Along with using more efficient AC, automation and controls can be used to optimize the performance of the equipment.

Energy efficiency standards for AC can make cooling more affordable and ease pressures on the power grid during hot days. As of 2021, 10 Latin American countries had mandatory minimum energy performance standards (MEPS) for AC, one had voluntary standards, and one was planning to adopt them.¹²⁸ When mandatory, these standards are powerful tools since they ensure that only equipment that meets them can be sold or utilized. Regional collaboration can accelerate progress, especially in smaller countries; for example, in 2022, with support from the IEA, the Central American Integration System (SICA) introduced its first regional regulation on energy efficiency, specifically for inverter AC units.¹²⁹

Efficient electric fans are another key part of the solution, as they can be highly effective, are more affordable than a standard AC unit, and use far less electricity. Fans are the most widely used active cooling equipment today, with more than triple the ownership rate of AC globally, and even larger gaps in many countries in Latin America and the Caribbean.¹³⁰ Fans come in many styles and sizes; in some countries, evaporative coolers or misting fans are also common. Fans typically use less than 10 percent of the energy consumed by a room AC for an equivalent space.¹³¹ As with AC, however, efficiency varies, and in extreme heat, a fan may not suffice.

3.2.3 LEVERAGE BUILDING CODES AND ENERGY EFFICIENCY STANDARDS THROUGH REGULATIONS

For policy makers, it is important to recognize that the large-scale uptake of energy-efficient technologies, building designs, and passive cooling approaches is typically driven by public policy. Building codes generally cover structural integrity, standards for electrical and plumbing systems, fire safety, and, increasingly, sustainability—including measures to improve thermal comfort and reduce energy use. Building codes and green building certification programs can incentivize improvements in building design, building envelopes and insulation that contribute to energy efficiency and can also increase resilience in the event of a power outage.

As shown in Figure 3.6, however, few countries in Latin America and the Caribbean have mandatory building energy efficiency standards. Some have voluntary building energy efficiency standards, but experience elsewhere suggests that progress depends on mandatory codes that are effectively enforced. As countries update their building codes, it is crucial to integrate energy efficiency provisions, to help ensure that new construction and renovated buildings are fit for purpose in an increasingly hot future.¹³²

FIGURE 3.6. KEY BUILDING SECTOR POLICIES IN SELECTED LAC COUNTRIES FOR EFFICIENT COOLING

COUNTRY	BUILDING CODES		APPLIANCES		COOLING	
	MANDATORY	VOLUNTARY	MEPS	LABELS	MEPS	LABELS
 Argentina						
 Chile						
 Cuba	✓	✓	✓	✓	✓	✓
 Ecuador						
 Panama						
 Peru						
 Brazil		✓	✓	✓	✓	✓
 Costa Rica						
 Mexico		✓	✓	✓	✓	✓
 Colombia		✓	✓	✓		✓
 Uruguay				✓	✓	✓
 Bolivia			✓	✓		✓
 Venezuela			✓	✓	✓	✓
 Paraguay	✓	✓				
 Nicaragua			✓		✓	
 Honduras					✓	✓

Policy implemented:  No  Yes

Note: MEPS = minimum energy performance standards.

Meanwhile, voluntary green building certification programs are increasingly popular. The most successful in Latin America is the Leadership in Energy and Environmental Design (LEED) Certification System, with more than 4,000 LEED projects and over 1,700 active LEED professionals as of 2020.¹³⁴ In 2023, Brazil and Mexico were among the top 10 countries in the world (outside the United States) for LEED projects, with 119 and 86 projects certified, respectively.¹³⁵ EDGE, a tool developed specifically for emerging markets by the International Finance Corporation (IFC), part of the World Bank Group, offers another option for developers to identify cost-effective energy efficiency solutions and obtain certification.¹³⁶

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3 , RISING TEMPERATURES IMPACT HOMES, ENERGY, AND TRANSPORT

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BOX 3.2

URBAN MYTH: HIGHLY ENERGY-EFFICIENT BUILDINGS HAVE A HIGH COST PREMIUM

Another constraint to the wider uptake of energy efficient buildings that optimize indoor temperature regulation and cooling is the perceived high cost of such buildings. However, multiple studies point to the fact that these costs are often overestimated by the public and even by developers and investors.¹³⁷

First, it is important to consider that passive design and other strategies to improve energy efficiency are most cost-effective when integrated during a building's design and construction phase, when incremental costs are lowest. Retrofitting existing buildings later is typically far more expensive. As building codes become stricter and supply chains for green materials and technologies mature, these upfront costs are expected to decline further over time.

Second, over the lifetime of a building (about 30 years), the cumulative energy costs associated with active cooling of an inefficient building can be higher than the initial investment required to construct a more energy-efficient one. The IEA notes that buildings that are not built with energy efficiency in mind lock in high energy use and costs over decades, while even modest efficiency improvements can result in substantial long-term savings.¹³⁸

Third, a recent World Bank report suggests that many low-carbon and resilient building investments can also generate new revenue streams, in addition to reducing costs.¹³⁹ For instance, rooftop solar installations may not only lower electricity bills but also allow for energy sales back to the grid. Energy efficiency retrofits often result in major savings that can, in some cases, fully cover the investment. Financing mechanisms such as property-linked finance, energy service agreements, or public-private partnerships (PPPs) can help capture these benefits and channel them toward repaying upfront costs.

Finally, multiple analyses points that the cost premiums for energy efficient buildings is relatively low, of 1–7 percent in the United States, or 5 percent premiums for certified energy efficient buildings in Singapore, a particularly hot and humid climate, where the additional costs are offset by savings from reduced energy and water consumption within three to six years. The IFC tool EDGE points to a payback period of energy efficient building construction in developing countries of one to two years.¹⁴⁰

3.2.4 DEVELOP COOLING DISTRICTS

District cooling systems chill water in a centralized location and distribute it through insulated underground pipes to cool multiple buildings in a given area.¹⁴¹ This centralized approach enhances energy efficiency and also avoids a common problem with distributed systems: expelling heat into the environment. These systems can also leverage economies of scale, resulting in significant cost savings.

District cooling systems were first developed in the United States, to serve university campuses and other building complexes, including the Pentagon. They have since been successfully implemented around the world, especially in Japan and, particularly in recent years, in the United Arab Emirates and other Persian Gulf countries.¹⁴² The first system developed in Latin America was La Alpujarra District Cooling Plant in Medellín (see Box 3.3), which since 2016 has provided air conditioning for multiple government buildings, including City Hall.¹⁴³

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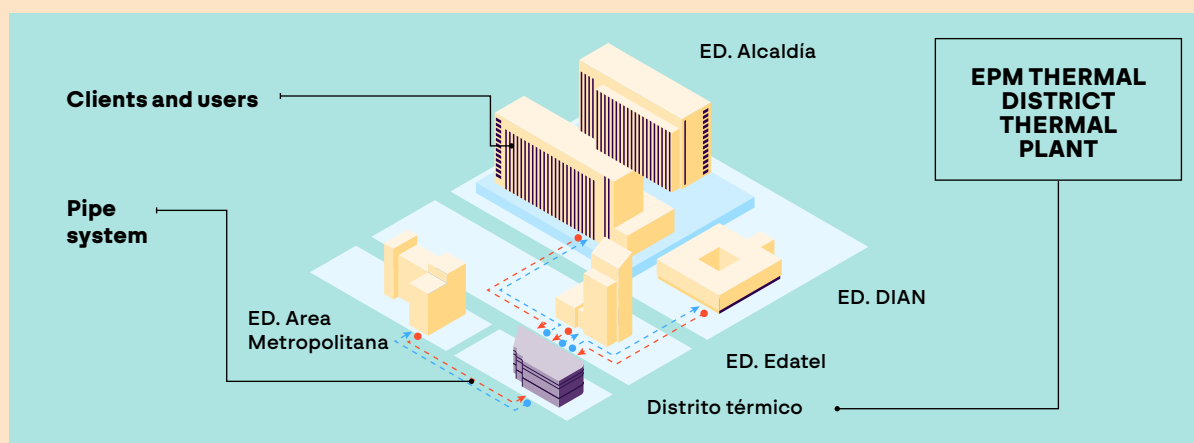
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BOX 3.3

THE ALPUJARRA COOLING DISTRICT, MEDELLÍN

La Alpujarra District Cooling Plant was developed by Empresas Públicas de Medellín (EPM), Medellín's public utility company, in cooperation with local and national government agencies. Co-financing from the Switzerland State Secretariat for Economic Affairs (SECO) and the Multilateral Fund to implement the Montreal Protocol helped to de-risk the investment for EPM and ensure the capacity to develop this pioneering project.



La Alpujarra District Cooling Plant initially served three existing government buildings, replacing their energy-intensive cooling equipment with a more efficient system. The underground distribution network has since expanded to 1.5 kilometers, now serving a total of seven government and institutional facilities.

The involvement of the national government in promoting tax-exempt status and encouraging the use of refrigerants with zero ozone-depleting potential and global warming potential was crucial for the project's success. The key to successful implementation includes strong municipal engagement, appropriate urban planning, and leveraging international partnerships for financing and technical support.

La Alpujarra demonstrates how district cooling can provide significant environmental and economic benefits, making it a potentially attractive solution for other cities. District cooling systems can also integrate with district heating and combined heat and power systems, further enhancing their efficiency and sustainability by utilizing locally available renewable resources. In Colombia, where individual air conditioning systems are increasingly straining the National Interconnected System—particularly during dry periods and peak hours—district cooling has the potential to alleviate grid congestion, improve energy security, and reduce emissions.

However, there are some disadvantages and considerations for implementing district cooling systems. The initial cost of setting up the infrastructure, including the central chiller plant and the insulated pipe network, can be high, and the logistical challenges can be significant. The efficiency gains from district cooling systems can also be partially offset by the energy required for pumping and by thermal losses in the distribution system.

The feasibility of district cooling systems depends on the scale of cooling loads, density, and the diversity of cooling needs in the area. They are most suitable for densely populated urban areas with significant cooling demand over extended periods. Districts with rapid growth in a concentrated area—such as when a large new housing or mixed-use complex is being built, and/or multiple large projects are completed within a short period—may also be a good fit; this is how district cooling has grown rapidly in the Middle East.¹⁴⁴ Developing clear methodologies to estimate cooling demand, as well as establishing supportive policy and institutional frameworks, are crucial steps for enabling district cooling to scale in cities across Latin America. It is thus essential to select sites carefully and weigh the projected costs and savings.

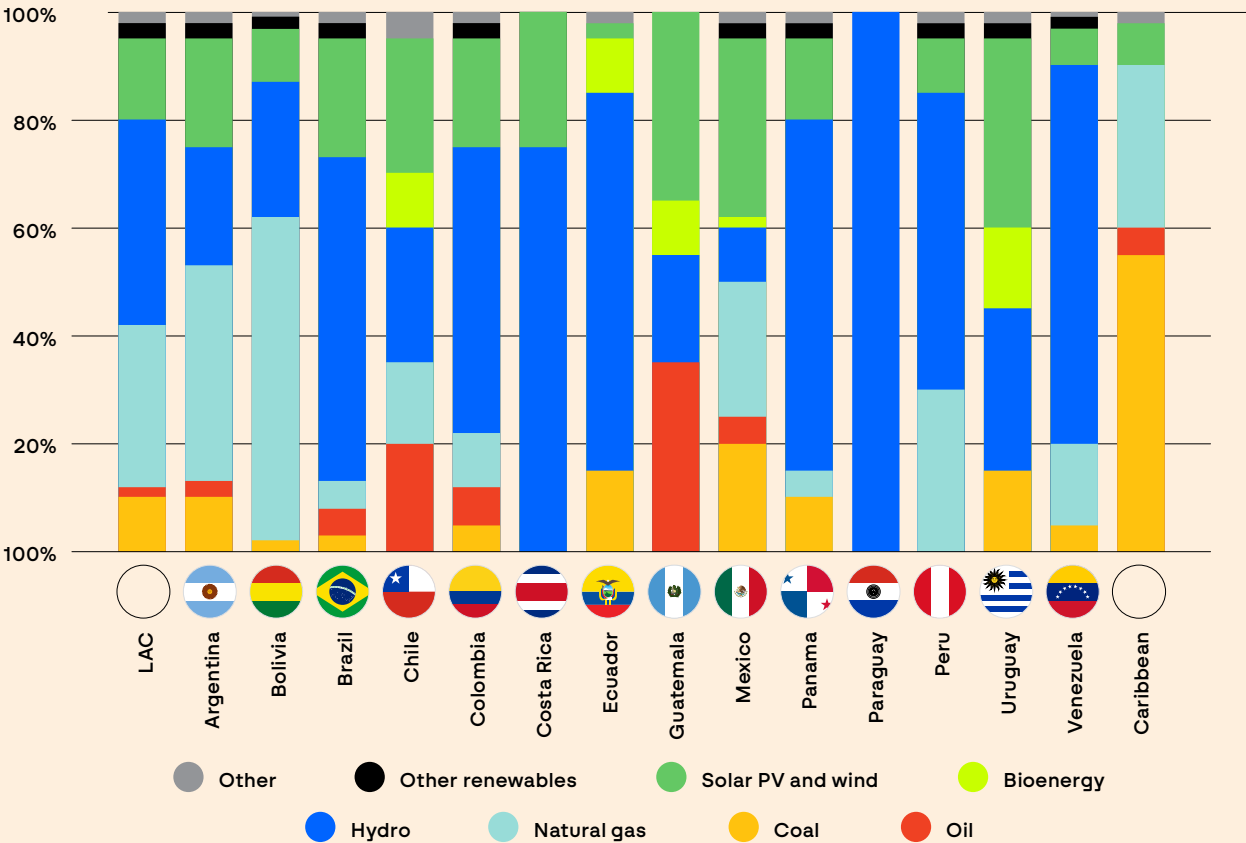
A recent study in Colombia, for instance, examined 13 metropolitan areas and identified 37 potential clusters for district cooling—particularly in Medellín, Barranquilla, Cartagena, and Cali—with a combined demand for 642 MW of cooling.¹⁴⁵ The sites include industrial parks, tourism hubs with multiple hotels, convention centers, hospitals, and schools, among others. Further research is needed to better understand cooling demand in those areas, including technical, environmental, and economic factors and potential other users, such as homes.

3.3 ELECTRICITY SYSTEMS ARE FAILING UNDER HEAT STRESS

Rising temperatures have implications for electricity production, transmission and distribution systems, and demand. Heatwaves in recent years have tested the reliability of power systems in many countries, leading to wide-ranging discussions about their resilience and resource adequacy.¹⁴⁶ Given the central role that electricity plays for the urban economy, the delivery of basic services, and human well-being, in a region where almost all people live in urban areas, it is important to understand and urgently address these risks.

The electricity supplies in Latin America and the Caribbean are diverse, dominated by hydropower in several countries, such as Brazil, Colombia, Costa Rica, Ecuador, Paraguay, and Venezuela, and by natural gas in others, such as Argentina, Bolivia, and Mexico. Some countries also rely on coal, bioenergy (e.g., Guatemala), and, increasingly, on solar (mainly photovoltaics, or PV) and wind. In the Caribbean, especially, oil remains important to the power systems (Figure 3.7). Collectively, countries in the region have some of the cleanest power supplies in the world, with an average of 61 percent of electricity from renewables in 2022.¹⁴⁷

FIGURE 3.7. ELECTRICITY GENERATION BY SOURCE IN LATIN AMERICA AND THE CARIBBEAN AS A WHOLE, THE CARIBBEAN, AND SELECTED COUNTRIES, 2022



Source: Reproduced IEA (2023), Figure 1.14.¹⁴⁸

As Figure 3.7 shows, hydropower is a key source of clean and reliable electricity for the region—45 percent of the total power supply in 2022.¹⁴⁹ However, it is also highly susceptible to extreme heat and drought, which often come together. This can result in large fluctuations in hydropower production. Brazil is a prime example: it has even had to temporarily shut down some plants during recent droughts, and it may lose significant capacity in the long term.¹⁵⁰ In 2011, Brazil generated 428.3 TWh of power from hydro, but in 2015, production was just 359.7 TWh.¹⁵¹ From 2020 to 2021, production dropped by about 8.5 percent, from 396.4 to 362.8 TWh.

Reduced hydropower capacity is only one of several threats from a hotter climate, however. As overall temperatures rise, and heatwaves become both more common and more severe, the region's power systems are showing multiple vulnerabilities. In May 2024, for example, amid a blistering heatwave, Mexico's National Center for Energy Control (CENACE) called a state of emergency twice within three days, as the grid could not meet demand.¹⁵² Even after systems were restored, many cities across the country experienced intermittent blackouts. As discussed in Section 4, power outages during extreme heat can imperil people's health.

3.3.1 HEAT SIMULTANEOUSLY INCREASES ENERGY DEMAND AND REDUCES ITS SUPPLY

At the heart of any energy network are the generation facilities, transmission lines, transformers, and substations that deliver electricity to consumers. Extreme heat tends to occur across broad geographical areas, affecting assets across regional electric systems. Sharp increases in demand, especially for space cooling, can further strain power systems. At the same time, extreme heat reduces the capacity of many components of those systems:¹⁵³

Extreme heat reduces the capacity of **transmission lines** and increases line losses at a time when electricity demand is surging. This is of particular concern in countries where grid capacity is already inadequate; in both Chile and Mexico, for example, renewable energy production has frequently been curtailed due to grid congestion.¹⁵⁴ Lines can also sag under high load and high heat conditions, increasing the risk that they will make contact with a nearby object, leading to an outage. Underground lines are affected as well, as higher air and soil temperatures can reduce line capacity and cause underground cables with defects to fail.

High temperatures can also challenge **transformers** and may reduce transformer capacity and, over time, their useful life. In combination with increased demand for electricity for cooling, heat can even lead to catastrophic failure of the transformer. For example, in January 2022, during a severe heatwave in Paraguay, transformers failed, causing blackouts in Asunción and nearby cities.¹⁵⁵ Despite efforts to upgrade transmission and distribution systems, they had been unable to handle a surge in demand due for air conditioning.

Thermal generation plants can experience diminished capacity when higher air and water temperatures reduce cooling efficiency.¹⁵⁶ Drought, often associated with heat extremes, also limits the supply of cooling water and can even require shutdowns.

As noted above, **hydropower generation** is affected by the droughts that often accompany heatwaves, which can reduce reservoir storage levels in plants with storage, or the flow of water of a run-of-river plant.

Solar PV generation is affected by extreme heat, as most panels are designed for peak capacity around 77°F (25°C) and begin to lose capacity at higher temperatures. Power output can decrease by 0.3–0.5 percent for every degree above 25°C.

Energy storage is also less effective in hot conditions. For example, lithium-ion batteries have an ideal operating temperature range of 15–35°C.¹⁵⁷ Temperatures above that range can damage the battery and significantly reduce the amount of energy that it can store over time. These performance issues need to be taken into account in efforts to build system resilience by combining solar PV with storage (see section 3.3.2).

When power outages occur during—or as a result of—a heatwave, they can be highly disruptive, as illustrated by Ecuador’s recent experience (Box 3.4). It can even be deadly, as air conditioning, a crucial source of cooling, becomes unavailable, resulting in increased indoor heat exposure.

BOX 3.4

ECUADOR’S ELECTRICITY SUPPLY AMID HEAT AND DROUGHT

Ecuador is facing rising temperatures and more intense droughts due to climate change. It is also periodically affected by the El Niño Southern Oscillation (ENSO), which warms Pacific sea surface temperatures and brings hotter weather while reducing rainfall. In 2022–2024, the combined effects of climate change and El Niño led to Ecuador’s most severe drought in 60 years.

The drought sharply reduced water levels in Ecuador’s rivers and in the reservoirs of hydropower plants. This affected power generation in both dam-based and run-of-river systems—a major concern given that hydropower supplies almost three-quarters of the country’s electricity.¹⁵⁸ The situation reached a crisis point in September–November 2024, at a time when a widespread drought also disrupted hydropower in Brazil, Bolivia, Colombia, Peru, and Venezuela.¹⁵⁹

The drop in hydropower production led created major power shortages, leading the government to shut off the electricity for up to 14 hours per day in many regions,¹⁶⁰ starting in late September, triggering a state of emergency in 15 provinces. Industries and essential services were disrupted, including public transit and public lighting. In Cuenca, for example, the tram system had to reduce nighttime operations and even halt service unexpectedly during daytime outages.¹⁶¹ By mid-October, the labor ministry said more than 3,500 jobs had been lost due to the blackouts, and industry bodies said the economy had lost at least \$2 billion.¹⁶²

The crisis continued to escalate in November. The Mazar Dam, which feeds the Paute-Molino hydropower complex—three plants that together supply about 38 percent of the country’s electricity—reached such low water levels that the plants could only operate at reduced capacity, and were even shut down at least twice in November.¹⁶³ Notably, the dam was built with enough capacity to withstand 45 days without rainfall, but that limit is now frequently exceeded.

The government arranged for emergency electricity imports from Colombia, encouraged “self-generation,” such as through rooftop solar, and has sought to diversify the country’s energy mix.¹⁶⁴ However, such solutions take time, and blackouts and rationing continued into December 2024.¹⁶⁵

Power outages not only affect economic activity and public services, but also people’s ability to stay cool in their homes. While Ecuador’s worst heat in 2024 was earlier in the year, some parts of the country, including Guayaquil, have faced extreme heat during the outage period.¹⁶⁶ Severe wildfires around Quito in September 2024 filled the city with smoke, injuring dozens of people and making many more sick, and requiring more than 100 families to be evacuated from their homes.¹⁶⁷

Climate change is exposing critical vulnerabilities in Ecuador’s reliance on hydropower. As the government has acknowledged, the country urgently needs to develop alternatives to hydropower, and generally to upgrade its power infrastructure to account for climate uncertainties.

3.3.2 WHAT CAN BE DONE? MAKING POWER SYSTEMS MORE RESILIENT TO HEAT

Governments and electricity system operators worldwide are increasingly addressing the vulnerabilities of electricity systems to extreme weather events and climate change described above through multi-pronged approaches that are intended to make these systems more resilient—stronger, more flexible and smarter.¹⁶⁸ Key approaches include:¹⁶⁹

Improved energy efficiency: Energy efficiency is often called the “first fuel” in clean energy transitions, because it yields savings that reduce the amount of clean generation capacity that needs to be added. By reducing electricity demand, it also eases pressure on the grid, including peak loads. Moreover, it holds down energy costs for households and businesses alike at a time when cooling needs are likely to increase those costs (discussed further in section 3.2.1). A recent review found about 70 percent of Latin American countries required energy efficiency labels for common household appliances, and most also have mandatory minimum energy performance standards (MEPS) for items such as refrigerators, air conditioners, and lamps.¹⁷⁰ Early implementers such as Brazil and Mexico have tightened some MEPS three or four times, with energy savings of 15–20 percent each time. Combining MEPS and labels with public awareness campaigns and incentives can further help lower demand.

Demand-side management: Many system operators have also implemented measures to incentivize lower electricity use during periods of high demand, such as through rebates or higher prices.¹⁷¹ In the United States, “demand response” programs have played a key role in moderating electricity demand during heatwaves in California, Texas, and Arizona, for example, by paying large consumers to use less power.¹⁷² Households can be offered similar incentives. For example, a pilot rebate-based emergency demand response program in southwestern China, enrolling over 205,000 households, was able to reduce participants’ electricity use by more than 7 percent during peak times, without imposing new financial burdens on vulnerable populations.¹⁷³ The growing use of two-way “smart meters,” which help utilities to better track and manage demand, facilitates the use of such incentives and has also been shown to promote overall energy efficiency just by allowing people to compare their usage with their neighbors’.¹⁷⁴

Infrastructure upgrades and improved maintenance: Owners of thermal power plants can install technologies that use less water—such as dry and wet-dry hybrid cooling systems or new wind and solar PV projects—to make their plant more resilient in the face of heat and drought.¹⁷⁵ Utilities and grid operators need to modernize and expand outdated and inadequate transmission and distribution systems and then ensure that system maintenance and renovation are adequate. They also need to make the grid more flexible and better able to integrate renewable and distributed energy resources by expanding transmission capacity and energy storage and improving forecasting and scheduling. “Smart grids” equipped with real-time monitoring and early warning systems can help utilities detect and respond to overheating infrastructure before failures occur. These

systems can automatically adjust supply and demand, rerouting energy as needed and preventing overloading of critical components.

Rooftop solar, storage, and microgrids: Along with extreme heat, many countries in the region, particularly the Caribbean islands, face hurricanes and tropical storms that can damage power systems and cause prolonged outages. Solar PV is increasingly being used to enhance resilience to both kinds of threats, a clean alternative to diesel generators, though careful system design is key.¹⁷⁶ Solar PV can significantly ease the load on the grid during the day, but can create new challenges as peak demand shifts to after sunset.¹⁷⁷ Storage is thus crucial: California and Texas, for example, have avoided blackouts during recent heatwaves by investing in both solar and storage.¹⁷⁸ “Microgrids”—which isolate the power supply for a building, complex, or community from the main grid—can add another layer of resilience, enabling hospitals, shelters, cooling centers, schools, and others to use their own generation to keep the power on during an outage, with the potential to save lives.¹⁷⁹

Diversifying electricity supplies: While hydropower remains a key energy source for the region, several countries are diversifying their power supplies by investing in other renewables, such as wind, solar, and—to a lesser extent—geothermal energy.¹⁸⁰ The IEA projects that solar PV and wind alone will double by 2030, from 11 percent of the region’s power generation in 2022, and reach 80 percent by 2050.¹⁸¹ Geothermal energy also holds untapped potential in the region, with countries such as Mexico, Costa Rica and El Salvador already exploiting it as a low carbon, climate-resilient energy source.¹⁸² Inter-regional connections can also increase resilience to climate shocks such as heatwaves and droughts.

Planning and designing for resilience: Electricity system operators need to incorporate vulnerability assessments and their results into their system planning and investment programs. One obvious measure is to consider wider extreme weather conditions when planning and designing system capacity, including reserve margins.¹⁸³ A comprehensive methodology to guide operators and governments is being developed by the Electric Power Research Institute.¹⁸⁴ The methodology includes: (i) guidance on climate data to enable assessments; (ii) a consistent approach to apply climate information, including extreme weather and localized climate data, with guidance for specific asset/ system vulnerability analyses; and (iii) a risk-informed approach to prioritize hardening and adaptation options and apply a cost-benefit analysis to identify specific investments to further climate resilience along with other electric system objectives.

By proactively adapting to a hotter climate, cities and countries in Latin America and the Caribbean can significantly improve their power systems’ resilience. Failure to act quickly may result in more frequent blackouts and brownouts, resulting in economic losses, social disruption, and severe human impacts in the region’s cities and beyond.



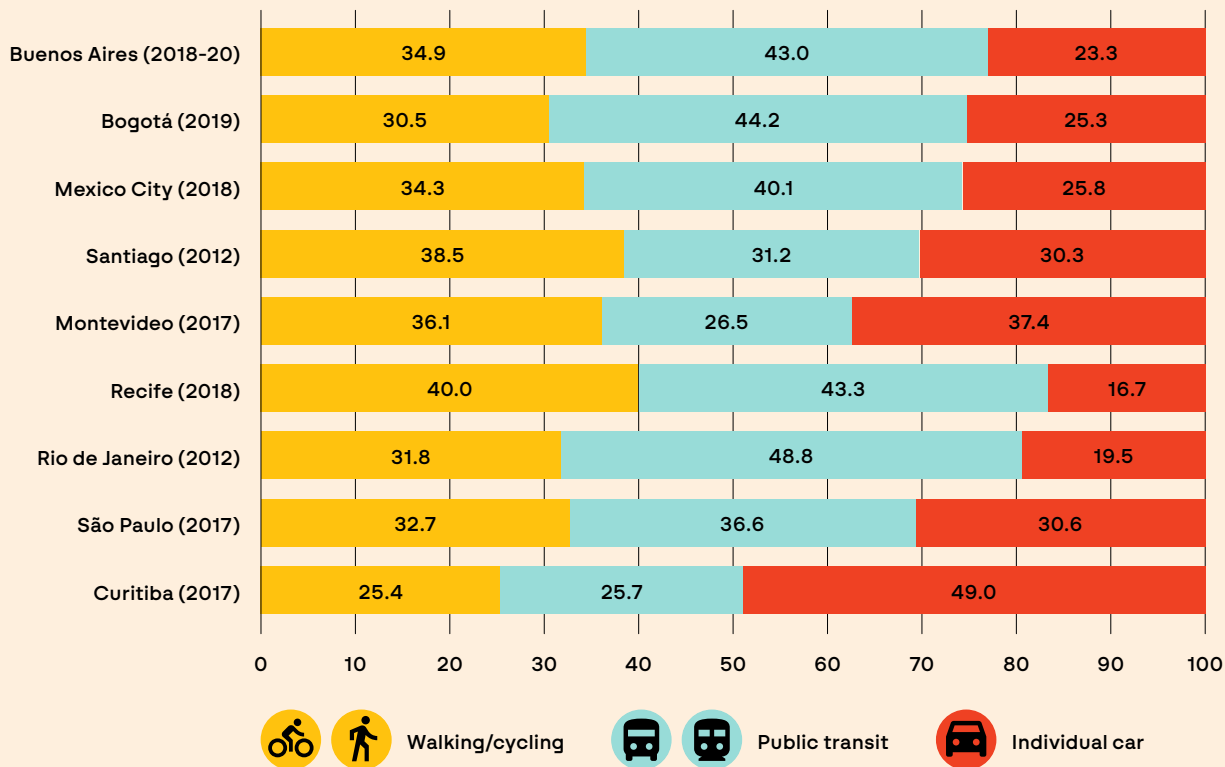
3.4 TRANSPORT SYSTEMS ARE NOT READY FOR EXTREME HEAT

Transport systems are vital for urban economies, enabling the movement of people and goods and providing access to jobs, services, and urban amenities. However, rising temperatures can put a significant strain on transport infrastructure and vehicles, resulting in heat-related outages and failures, shorter lifespans, higher maintenance costs, and increased safety risks.¹⁸⁵ Even if travel is not disrupted, users may be forced to endure extreme heat.

To a great extent, this happens because—in this region and globally—transport infrastructure was designed for historical temperature ranges that are now frequently exceeded.¹⁸⁶ Not only are roads and bridges at risk, but public transit systems, the main mode of transport for many people in cities across Latin America and the Caribbean, are being pushed to their limits as well. And walking, which accounts for about a quarter of all urban trips in the region,¹⁸⁷ can be particularly arduous on hot days, as streets and sidewalks absorb and retain heat.

This section examines some of the key challenges faced by urban transport systems as temperatures rise. It begins with a look at road infrastructure, then discusses public transit, then pedestrian infrastructure, and ends with an overview of potential solutions.

First, however, it is important to note that urban mobility varies greatly across Latin America and the Caribbean, reflecting differences in urban form, transport infrastructure, and demographics. As shown in Figure 3.8, public transit is the most widely used transport mode in a sampling of major cities in the region, but the share of trips made by car varies almost threefold.

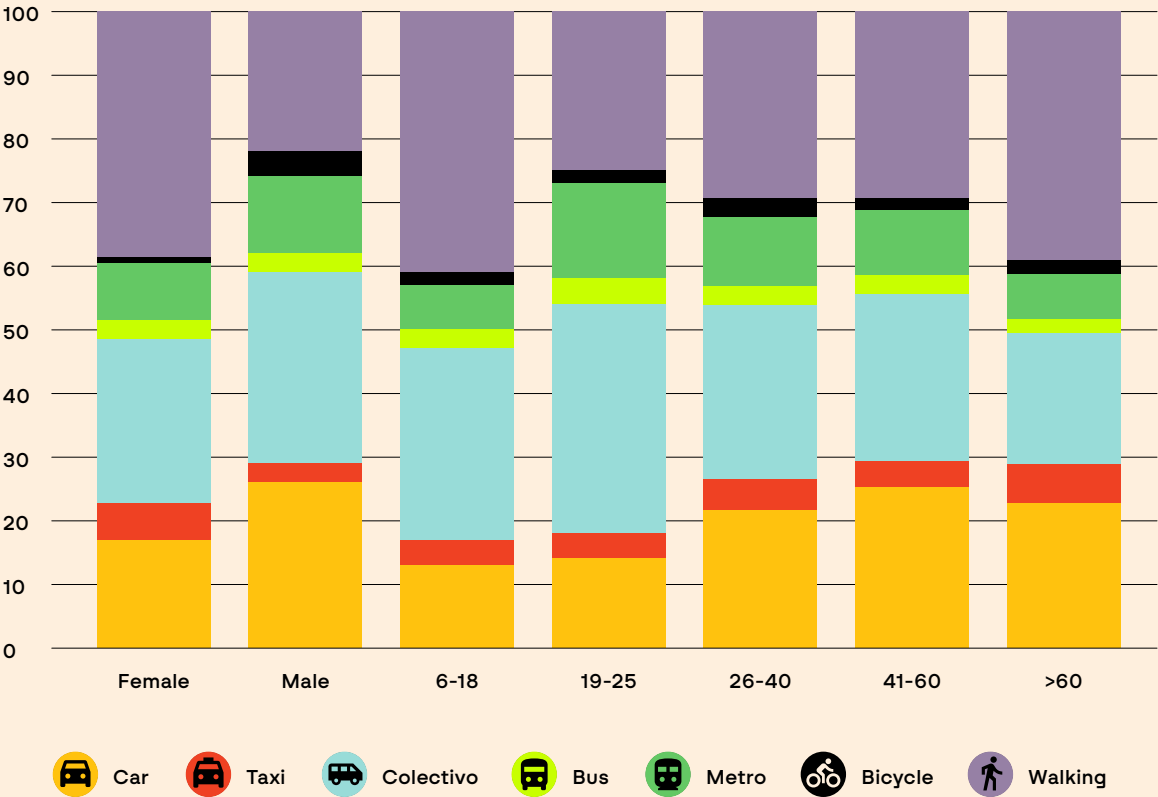
FIGURE 3.8. SHARE OF TRIPS MADE BY CAR, PUBLIC TRANSIT, AND WALKING/CYCLING IN SELECTED LATIN AMERICAN CITIES

Source: World Bank, based on data from CNI (2023), Table 1.¹⁸⁸

Even within a single city, how people travel can vary greatly by income group,¹⁸⁹ age group, and gender. An analysis of seven Latin American cities found women generally made fewer trips by car and more by public transit or on foot than men, with gender gaps in each mode's share of trips of 4.9–17 percent, 5.6–23 percent, and 1.1–15.8 percent, respectively.¹⁹⁰ The same analysis also found men held almost 71 percent of driver's licenses in Costa Rica, 75 percent in Chile, 73 percent in Colombia, and 78 percent in Ecuador.

Figure 3.9 shows a detailed analysis of modal split by gender and by age group for the Valley of Mexico Metropolitan Area.¹⁹¹ Notably, women, children aged 6–18, and adults over the age of 60 make more trips on foot than by any other mode, making the thermal conditions for walking of particular concern to them. In contrast, men are likelier to drive than to walk—though across all age groups and among both men and women, far more trips are made on foot, by public transit, or on colectivos (shared minibus taxis) than in private cars or taxis. Understanding different groups' mobility patterns can help policy makers evaluate heat-related risks across transport networks and make more equitable adaptation choices.

FIGURE 3.9. TRANSPORT MODAL SHARE BY GENDER AND AGE GROUP IN THE VALLEY OF MEXICO METROPOLITAN AREA, 2017



Source: World Bank, synthesizing analysis presented in Harbering and Schlüter (2020),¹⁹² figures 5 and 7, which used data from INEGI (2017).¹⁹³

Note that due to rounding in the source material, the percentages for the female, 41–60, and >60 categories do not add up perfectly to 100. Categories in the source material have been consolidated; bus includes autobus, RTP, and trolebus; metro includes metro, Metrobus, and Mexibus. Colectivos are shared microbus taxis. Car refers to personal vehicles.

3.4.1 HEAT STRESS COMPROMISES THE STRUCTURAL INTEGRITY OF URBAN ROADS AND BRIDGES

For the millions of people in the region who drive their own cars, public transit users, and even cyclists and pedestrians, the condition and safety of urban roads is of vital importance. This means that the growing exposure of roads in Latin America and the Caribbean to extreme heat requires serious attention, as it poses significant risks to the durability and safety of essential transportation networks.

There is growing evidence that extreme heat poses a serious risk to road safety, increasing the likelihood of car crashes. High temperatures can negatively affect both a driver’s physical and mental health, leading to irritability, recklessness, fatigue, and impaired decision-making.¹⁹⁴ In addition, heat can worsen environmental conditions, reducing visibility and traction on the road. The combination of all these effects increases the risk of collisions—and traffic-related injuries and deaths.¹⁹⁵

Moreover, prolonged exposure to high temperatures softens materials such as asphalt, leading to rutting and structural fatigue. Temperature fluctuations also cause pavement to expand and contract, which can lead to cracks, warped surfaces, and safety hazards if not promptly repaired.¹⁹⁶ Both primary and secondary roads are vulnerable to these stresses, degrading their load-bearing capacity and increasing vulnerability to damage under heavy traffic conditions.

In Montevideo, Uruguay, the impacts of extreme heat were demonstrated during a heatwave in December 2022, when a “blow-up” incident on General Flores Avenue caused the asphalt to expand, rupturing the pavement.¹⁹⁷ This sudden expansion posed a serious hazard, disrupting traffic and requiring immediate repairs. Such incidents highlight that urban road systems in the region are not designed to withstand the growing frequency of extreme heat events, and road construction largely fails to incorporate heat-resistant materials.

High temperatures can also accelerate the deterioration of road infrastructure, resulting in higher maintenance costs. A study found that an increase in temperature of just 1.8°C could reduce the average lifespan of pavement by 75 percent over the course of a century, decreasing its durability from 16 years to only four.¹⁹⁸ In Santa Quitéria, Brazil, in August 2023, a newly resurfaced section of the CE-257 highway melted shortly after completion, as extreme heat liquefied the asphalt binder.¹⁹⁹ This incident, compounded by construction flaws, caused significant road damage and posed safety risks for pedestrians and drivers, underscoring the urgent need for heat-resilient materials and standards.

The financial implications of inaction are steep. A study of about 800 roads in the United States found 35 percent had inadequate pavement due to outdated assumptions about maximum temperatures, which could increase maintenance costs by 31–64.5 percent, depending on the road type and how wrong the asphalt grade was.²⁰⁰ Modeling under two climate scenarios (RCP4.5 and RCP8.5) showed that, without adaptation, rising heat could increase the cost of building and maintaining roads over 30 years by 3–9 percent.

Research on climate risks to roads in Latin America and the Caribbean is still relatively sparse and often focuses more on risks from extreme rainfall, floods, and landslides, though heat is also considered. One such study estimated that without adaptation, Bolivia would need to spend \$155.2 million per year by the end of the century to maintain its road infrastructure, due to the effects of increased precipitation and rising temperatures.²⁰¹ With adaptation, however, the costs could be reduced by more than half, to about \$78 million per year.

Bridges, crucial to urban transportation networks, also face heightened risks from heat-induced stress. Expansion joints are built to accommodate a specific range of temperatures and can suffer from fatigue under extreme heat, while steel components such as beams and suspension cables weaken due to expansion. In Latin America and the Caribbean, where many cities rely on aging bridges, the potential for heat-induced structural issues is an urgent concern. Without adequate allowances for thermal expansion, bridges risk structural misalignment or collapse, as evidenced by smaller-scale incidents during regional heatwaves.

3.4.2 EXCESSIVE HEAT IN PUBLIC TRANSIT LEADS TO TECHNICAL FAILURES AND STIFLING CONDITIONS

Every day, millions of urban residents in Latin America and the Caribbean ride public buses and, in some cities, also bus rapid transit (BRT), cable cars, trams, and/or underground metro lines to get to and from work, school, and all that cities have to offer. An analysis of 29 metropolitan areas, using 2014 data, found an average of 42 percent of trips were made on public transit.²⁰² Modal splits vary significantly across cities, however. A recent comparison of Bogotá and Lima found 33.1 and 70.0 percent of trips, respectively, were made on public transit, though private car use was similarly low in both: 11.6 and 8.5 percent of trips, respectively.²⁰³ Official data for Buenos Aires show 46.1 percent of trips in 2022 were made on public transit.²⁰⁴ In Brazilian cities, the share of trips made on public transit ranges from about 26 percent in Curitiba, to about 37 percent in São Paulo and Brasília, to 47–49 percent in Rio de Janeiro.²⁰⁵

As highlighted by Figure 3.9 above, the public transit modes used by people—bus, BRT, metro, or colectivos, for instance—depend to a great extent on where they live and where they are going. BRT systems, for instance, which are generally newer, more comfortable, and more technologically advanced than regular buses, tend to serve only selected corridors within a city. The same is true of metro lines, though, with World Bank support, several Latin American cities have added BRT and metro lines in recent years that serve lower-income neighborhoods.²⁰⁶

Extreme heat can directly affect the performance of public transit systems by overheating engines, causing train tracks to expand and potentially buckle when a train runs over them, and making catenary lines—the overhead wires that trains connect to—expand and droop.²⁰⁷ Transit riders in the region have already experienced such problems. During a December 2022 heatwave in Rosario, Argentina, for example, the aging fleet of public buses struggled with overheating engines, and many broke down or were stopped preemptively.²⁰⁸ During the heatwave, temperatures in parts of Argentina were up to 10°C higher than the seasonal norm for several days, leading to service delays and reduced service capacity.²⁰⁹

Many buses and trains are also unequipped to keep passengers cool when the weather gets hot, with peak-hour crowds further increasing temperatures and limiting air flow. In Lima, the local transit authority reported 65 medical incidents on BRT buses in January 2024 alone, including two faintings—leading a local newspaper to publish a “Metropolitano survival guide.”²¹⁰ In February 2024, another media outlet found the temperature inside a BRT bus was 32.7°C, even though outside it was 31°C.²¹¹ On regular buses, it was as hot as 32.9°C, and passengers said this was a common occurrence.

In April 2024, temperatures on Mexico City’s STC Metro trains reportedly reached 39°C during peak hours, leading passengers to plead for fans to be turned on, saying they were “roasting” and “dying from the heat.”²¹² The public pleas continued in June, as STC Metro passengers faced long delays on some lines, frequent breakdowns, and prolonged idling in the heat.²¹³

Some public transit systems keep vehicles much cooler than others. For example, in Brazil, São Paulo, Rio de Janeiro, and Cuiabá have air conditioning on more than 80 percent of their buses, but other cities, such as Aracaju and Curitiba, have no cooling on public buses at all.²¹⁴ The buses in Rosario, Argentina, mentioned above, had AC, but passengers said it was not being used, so they had to endure stifling heat.²¹⁵

During a 2019 heatwave in Santiago, Chile, temperatures inside non-AC buses reached 38°C, while metro trains, which are more expensive for passengers, maintained an average temperature of 20°C.²¹⁶ This highlights the unequal burden of extreme heat borne by lower-income urban residents, who often also have longer commutes than wealthier people.²¹⁷

The shortcomings of public transit systems are not limited to the vehicles themselves. Poorly ventilated and cooled metro stations and a lack of shaded areas at bus stops can also significantly increase discomfort and put passengers at risk of health complications (see section 4.1) and even injuries. For instance, studies have shown that bus stop benches exposed to high temperatures can pose a risk of skin burns.²¹⁸

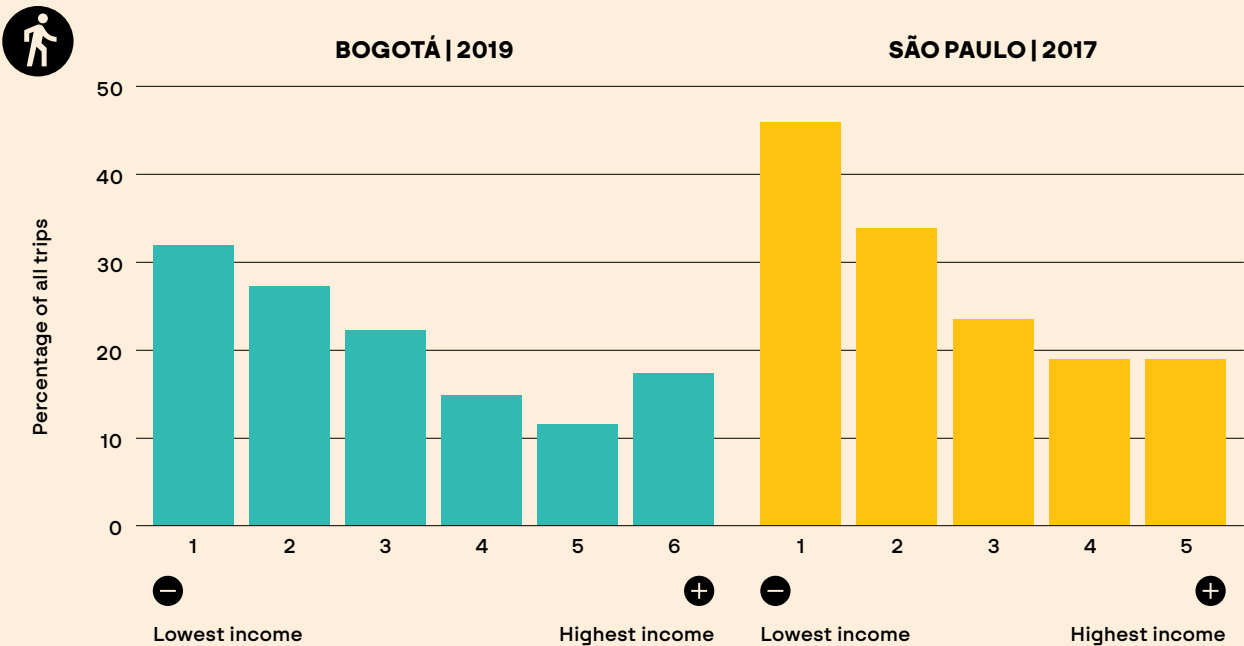
Given how much extreme heat is already affecting cities in Latin America and the Caribbean, it is crucial to upgrade public transit systems so they can function properly in hotter weather and keep passengers safe and comfortable. Addressing issues such as vehicle cooling, climate-resilient designs, and passenger awareness of heat risks is essential to ensuring safe, reliable, and comfortable transit amid rising temperatures.

3.4.3 WALKING INFRASTRUCTURE NEEDS PARTICULAR ATTENTION

As noted at the start of this section, about a quarter of trips in cities across Latin America and the Caribbean are made on foot.²¹⁹ In some cities the share is far higher—about 43 percent in Guadalajara, for instance,²²⁰ 38 percent in Bogotá,²²¹ and 35 percent in Belo Horizonte, Brazil.²²² Evidence from multiple cities also indicates that women and older adults make significantly more trips on foot than men and working-age adults.²²³

The lowest-income people walk far more than wealthier groups, as they often cannot afford any alternative.²²⁴ In Santiago, Chile, for instance, people earning more than 3 million CLP per month (about US\$3,270) make only about 10 percent of trips on foot, but among those earning less than 500,000 CLP (about US\$545), it is 30 percent.²²⁵ Figure 3.10 shows similarly stark differences in Bogotá and São Paulo.

FIGURE 3.10. SHARE OF WALKING TRIPS IN TOTAL TRANSPORT, BY INCOME LEVEL, IN TWO LATIN AMERICAN CITIES



Source: Adapted from Rivas and Serebrisky (2021), Figure 2.1.²²⁶

To the extent that the poorest people are relegated to the outskirts of cities, where public transit service is most limited, their need to walk will be greater—even just to reach the nearest bus or train.²²⁷ As temperatures rise, this means they may face similar health risks from heat exposure as those faced by outdoor workers (see sections 4.1 and 4.3). The situation is particularly dire in cities with tropical climates (see section 1.3) and/or very hot summers. A recent study highlighted this problem in the Aracaju, Brazil, a coastal city of about 645,000 inhabitants with a hot tropical climate. The city has invested in bike and pedestrian infrastructure, but there are too few street trees for shade and parks are poorly maintained, so few people walk—most drive.²²⁸

Without deliberate efforts to ensure that people can stay cool, residents of densely built-up city centers, which are increasingly prized for their walkability, may also find it unpleasant, even unsafe, to walk. It is thus crucial to explicitly plan for pedestrians as part of transportation infrastructure upgrades and climate change adaptation measures.

3.4.4 WHAT CAN BE DONE? ADAPTING TRANSPORT SYSTEMS TO RISING HEAT

A great deal is already known about how to adapt roads and bridges to be more resilient to heat; indeed, many places in the world are already as hot as—or hotter than—most cities in Latin America and the Caribbean can expect to become, and they show what can be done. For example, to prevent pavement from melting or buckling, the key is to select

asphalt binders with a performance grade (PG)—that is, a temperature range for adequate performance—consistent with future projections for the local climate, including potential extreme heat days.²²⁹ Aggregates and modifiers may also enhance heat resilience.²³⁰ Systematic annual maintenance and more frequent small repairs help as well. For example, Portugal has saved significantly by conducting crack seals on roads three, six, and 12 years after construction.

There has also been significant research and development on “cool pavement” materials and techniques that can extend the lifespan of roads and reduce UHI effects. A key reason why pavement gets so hot is that it has low albedo (light reflection). New materials can make both asphalt and (less common) concrete pavement lighter and more reflective. Thermochromic materials, which can be blended into the asphalt binder or applied as a surface coating, add to the costs of road construction, and some coatings may decay with sun exposure, but advances have been made on both fronts in recent years.²³¹

Adopting cool pavements that absorb less heat from the sun’s rays has reduced ambient air temperature by as much as 3°C in some cases.²³² However, recent U.S. studies on reflective pavements have shown that in some contexts, they may subject pedestrians to oppressive levels of radiant heat from the ground.²³³ Drawing on lessons from Phoenix, Arizona, one study suggested avoiding cool pavements in locations with high pedestrian traffic around midday.²³⁴

With careful site selection, cool pavements could play an important role in mitigating urban heat in Latin America and the Caribbean, though evidence from the region is still limited. Another option is to use of porous pavements that absorb rainwater, allowing for evaporative cooling, facilitating groundwater recharge, and helping to reduce flood risks.²³⁵ Permeable pavements are already used for sidewalks, public plazas, bike lanes, parking lots, streets, and even some larger roads across the region, and there is significant potential to use it more widely.²³⁶

Addressing heat in public transit systems is arguably a more complex task, as there are multiple elements to consider: from making key infrastructure such as catenary lines and railroad tracks more heat-resilient, to ensuring that vehicles function reliably, to improving conditions for riders, including at stops and stations. A good place to start is the detailed guidance published in 2024 by the global Community of Practice for Extreme Heat Management in Public Transport Systems.²³⁷ It lays out a process for assessing heat risks and working with key stakeholders to identify and implement solutions. Some of the key recommendations are:

	Establish a long-term vision and funding for heat resilience planning.		Address riders' safety and thermal comfort at all three phases of their trip:
	Integrate passive cooling in infrastructure construction and renovation (see section 3.2).		CONNECTING PHASE:
	Shorten waiting times to reduce crowding and heat exposure.		Improve shaded walkways and provide hydration points along transit paths; ensure accessible routes for vulnerable populations.
	Mandate heat impact screenings to protect infrastructure and people.		WAITING PHASE:
	Enable predictive maintenance to protect infrastructure and staff.		Enhance transit stops with shaded seating, cooling systems, and real-time information displays.
	Improve warnings and updates on heatwaves and service delivery.		RIDING PHASE:
			Retrofit vehicles with efficient cooling systems; minimize overcrowding to reduce heat exposure inside transit vehicles

Making cities safer and more comfortable for walking, meanwhile, requires both general measures to mitigate urban heat, discussed in section 5.1, and targeted interventions as part of transport infrastructure planning and urban design. Too often pedestrians are forgotten—or, at best, an afterthought—when designing roads, and very little transport funding goes to walking infrastructure: just 2.8 percent in Chile in 2010–2016, for instance.²³⁸ Yet, as highlighted by the example of Acaraju above, if people cannot walk comfortably, they will often drive, increasing traffic congestion.²³⁹ Those with no alternative, meanwhile, will suffer unjustly.

Street trees, awnings on buildings, and other sources of shade can improve conditions for everyone in the city. Acaraju, for instance, has set out to plant 5,000 trees per year, while also reviewing the condition of existing trees.²⁴⁰ Some cities have been even more ambitious; for example, Medellín created “Green Corridors” lined with trees and shrubs for use by pedestrians and cyclists (see section 5.1.2).²⁴¹

Cities across Latin America and the Caribbean may also want to consider installing public drinking water fountains, which are already ubiquitous in many European cities. Buenos Aires, which has dozens of water fountains (*bebederos*), includes them on its Climate Shelter Network map.²⁴² Yet the city still has just 0.84 water fountains per 100,000 residents, a recent analysis of OpenStreetMap data found.²⁴³ Port-au-Prince, Haiti, has the largest concentration in the region, 63 fountains per 100,000 people, but most cities have very few free potable water sources: Bridgetown has just 0.91 per 100,000 people; Panama City, 0.57; Managua, 0.49; Rio de Janeiro, 0.14; and Santo Domingo, 0.12. The Pacific Institute has produced guidance for cities on how to expand and properly maintain their water fountain networks.²⁴⁴

CHAPTER

4

THE HUMAN AND ECONOMIC TOLL OF HEAT



Across Latin America and the Caribbean, people are already experiencing the combined impacts of rising temperatures, urban heat islands, and large infrastructure deficits on their lives. Vulnerable groups, including children, older people, and those living in poverty are disproportionately affected.

This section examines three key types of human impacts—on health, on education, and on the livelihoods of low-income people—and considers the implications for urban economies. These impacts are closely interconnected, and mitigating them will require a broad range of interventions. Some sector-specific solutions are presented in the relevant sections; however, broader infrastructure investments, as well as the structural and policy measures that are the focus of Section 5, are equally crucial.

4.1 HEAT HAS SERIOUS ADVERSE HEALTH IMPACTS

Of all the impacts of rising temperatures and heatwaves, arguably the most critical are those on human health. Extreme heat can be deadly, in both visible and more subtle, hard-to-detect ways.²⁴⁵ Exposure to high temperatures has been shown to exacerbate many conditions, including cardiovascular disease and diabetes, and to increase adverse pregnancy outcomes. It can limit people's physical and cognitive abilities, and negatively affect mental health.

It is these impacts that make extreme heat such a serious concern for schools, as discussed below, as well as for urban livelihoods, and that lead to a large share of the economic costs tallied in section 4.4, as heat stress can make workers slower and weaker and increase their risk of workplace accidents and sickness.²⁴⁶ They also impose direct costs on health care systems and even larger costs on society through disability and premature death. Moreover, high temperatures worsen air pollution—already a major problem across Latin America and the Caribbean—and intensify its effects,²⁴⁷ and they are a key reason why the incidence of vector-borne diseases such as dengue is increasing with climate change.²⁴⁸

A 2024 World Bank study that considered these and other effects of climate change on health in 69 low- and middle-income countries, including the 11 largest in Latin America and the Caribbean, projected that between 2026 and 2050, they would result in about 95–151 million additional cases of selected diseases and about 271,200–274,500 premature deaths in the region.²⁴⁹ Depending on the climate and socioeconomic scenarios and methodology used, the study estimated the economic cost of those health impacts at US\$285.3–763 billion, or 0.19–0.45 percent of the 11 countries' projected GDP over that period.

Along with their broad implications, the health impacts of heat are of particular concern to cities in Latin America and the Caribbean for two key reasons: the large inequalities and socioeconomic vulnerabilities discussed in Section 1, and the fact that the region is aging faster than most of the world. Already in 2022, 13.4 percent of the region's population was over 60 years old—nearly 90 million people. By 2050, this share is projected to rise to 25 percent, or 193 million.²⁵⁰

The rest of this section delves deeper into the effects of extreme heat on human health, the evidence from Latin America and the Caribbean, interactions between heat and air pollution, and impacts on mental health and violence, as well as the growing incidence of vector-borne diseases, especially dengue. Key public health interventions are also discussed briefly.

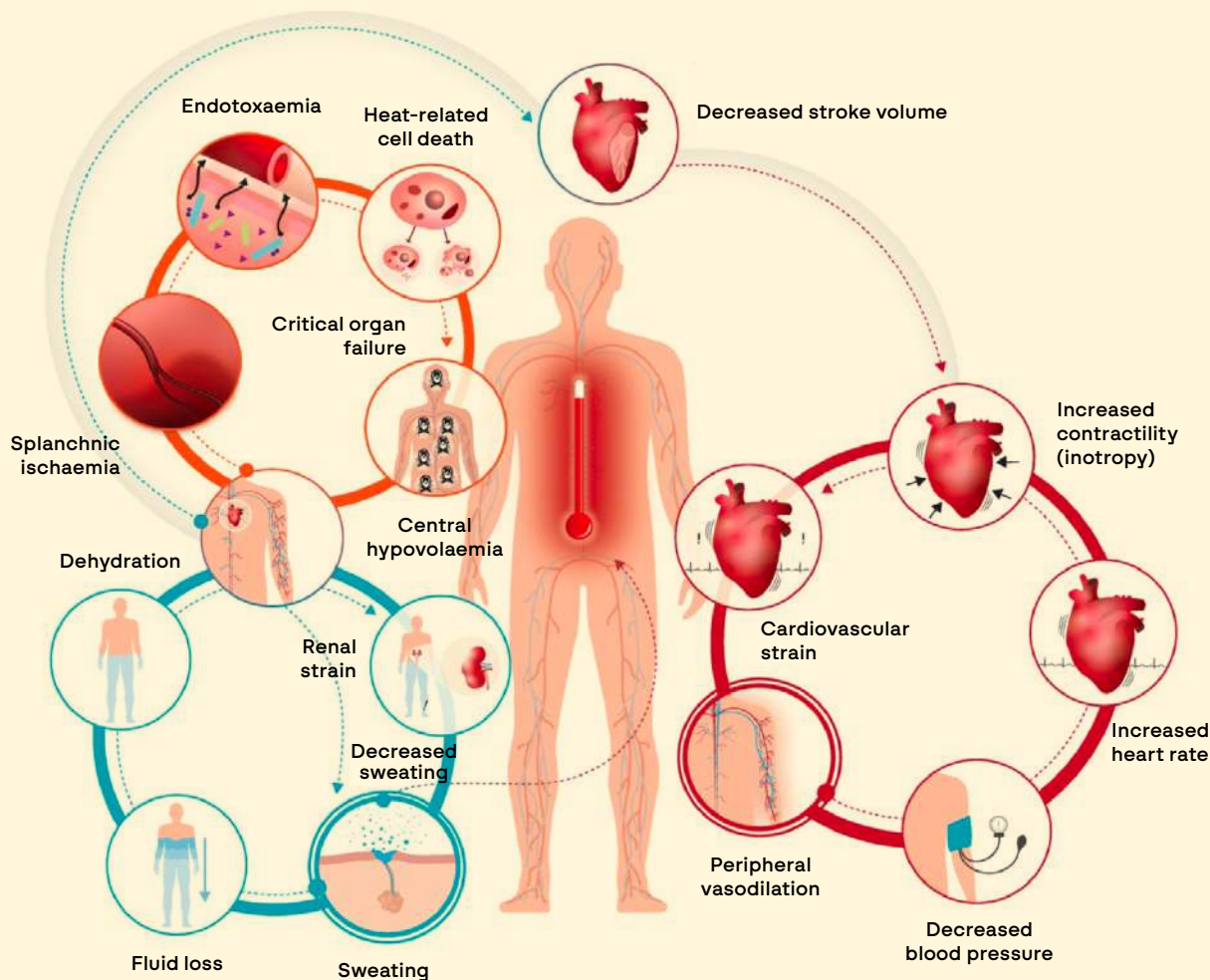
4.1.1 EXTREME HEAT EXPOSURE INCREASES THE RISK OF ILLNESS AND DEATH

Human beings can acclimatize to a wide range of conditions, and can withstand both extreme cold and heat for limited periods.²⁵¹ The body has different ways to keep internal organs at a safe, stable temperature—usually within a degree or two of 37°C—but as the severity of conditions and/or the length of exposure increase, so does the risk of lasting harm or even death.

The body manages heat stress mainly through two mechanisms: (i) increasing blood flow to the skin to release heat (vasodilation) and (ii) producing sweat that evaporates, cooling the body (perspiration).²⁵² However, many factors can significantly affect how hot people feel and how well the body can cool itself, such as humidity, wind speed, clothing, direct sun exposure, dehydration, and physical exertion. Moreover, as shown in Figure 4.1, thermoregulation can come at a cost. For instance, pushing blood to the skin requires the heart to pump harder and faster, and it may not be able to get the oxygen it needs. For people with pre-existing cardiovascular conditions, this can result in a heart attack.

In addition to straining the heart, excessive sweating can lead to dehydration, which further worsens cardiovascular stress and can damage the kidneys.²⁵³ Respiratory distress is also common during heatwaves. When the body cannot cool itself sufficiently, heat stress can progress to heat stroke (hyperthermia), which can be fatal and, if survived, cause lasting damage to the brain, heart, lungs, liver, and other organs. Even after treatment, individuals may face persistent organ dysfunction and a higher risk of premature death.

FIGURE 4.1. THE PHYSIOLOGICAL PATHWAYS OF HUMAN HEAT STRAIN



Source: Ebi et al. (2021).²⁵⁴

Some people are also more sensitive to heat—and less able to cope—than others. Older adults are particularly vulnerable and account for a disproportionate share of fatalities.²⁵⁵ Infants and small children are also at high risk, as are pregnant people (see Box 4.1) and those with cardiovascular disease, diabetes, and other conditions. Research has found that sex, body morphology, metabolism, other diseases (neurological, metabolic, genetic), and some injuries affect heat tolerance as well.²⁵⁶ It also matters what conditions a person is accustomed to: a lifetime in a hot city like Barranquilla, for instance, or in a cool, high-elevation city like Bogotá. All this means that there is no universal temperature threshold for “dangerous” or life-threatening heat.²⁵⁷

BOX 4.1**HEAT, PREGNANCY AND CHILDBIRTH**

Women face distinct and heightened health risks from extreme heat, driven by physiological factors—as discussed in section 4.1.1—as well as socioeconomic and cultural factors. Pregnant women are particularly vulnerable: there is growing evidence, globally and within Latin America and the Caribbean, that heat exposure is associated with higher rates of pregnancy complications, low birth weight, preterm birth, and stillbirth.²⁵⁸

Normal physiological changes during pregnancy can reduce a person's ability to regulate body temperature, increasing susceptibility to heat-related health problems. Pregnancy typically entails weight gain, for example, making it harder to cool off, and it also increases hydration needs—and the risk of dehydration. When a pregnant person's body overheats, the fetal heart rate can be affected, blood flow to the placenta can be altered, and other complications can arise that can cause preterm contractions or affect fetal growth. Studies have also suggested links between heat and congenital birth defects, though more research is needed overall.

A study of births in urban areas in Brazil, Chile, and Mexico in 2010–2015 found that, after controlling for a range of other factors—such as climate zone, maternal age and education—higher temperatures during pregnancy were associated with lower birthweight, particularly in Mexico and Brazil.²⁵⁹ The largest effects were in the last three months of gestation. Other global-scale studies have found similar links and also associated heat exposure with increased risk of hypertensive disorders in pregnancy, including preeclampsia.²⁶⁰

Altogether, the evidence points to an urgent need to raise awareness of the risks of heat exposure during pregnancy and help ensure that pregnant people have the resources to stay cool—a particular concern for those with lower incomes and/or in marginalized communities.

Indeed, recent research suggests that commonly used safety thresholds may be too high even for healthy young adults performing light physical tasks.²⁶¹ As discussed further in section 4.3, however, many workers are routinely exposed to heat for many hours per day. A meta-analysis of 111 studies in 30 countries, including Brazil, Costa Rica, El Salvador, and Nicaragua, found widespread health impacts.²⁶² For example, 35 percent of those who worked a shift at a wet-bulb globe temperature (WBGT)²⁶³ above 22°C or 24.8°C, depending on work intensity, suffered from occupational heat strain, and 15 percent of those who typically or frequently worked under heat stress experienced kidney disease or acute kidney injury.

Nevertheless, quantifying the mortality and morbidity associated with extreme heat remains a challenge. Heat is often called a “silent killer,” because unlike the death toll from other climate hazards, such as floods or storms, its impacts are rarely captured in official data.²⁶⁴ Deaths from heat-related complications are often attributed to the immediate cause, such as a heart attack, while heat exposure only appears in the rare cases of severe heatstroke.



Photo: María Fleischmann / World Bank

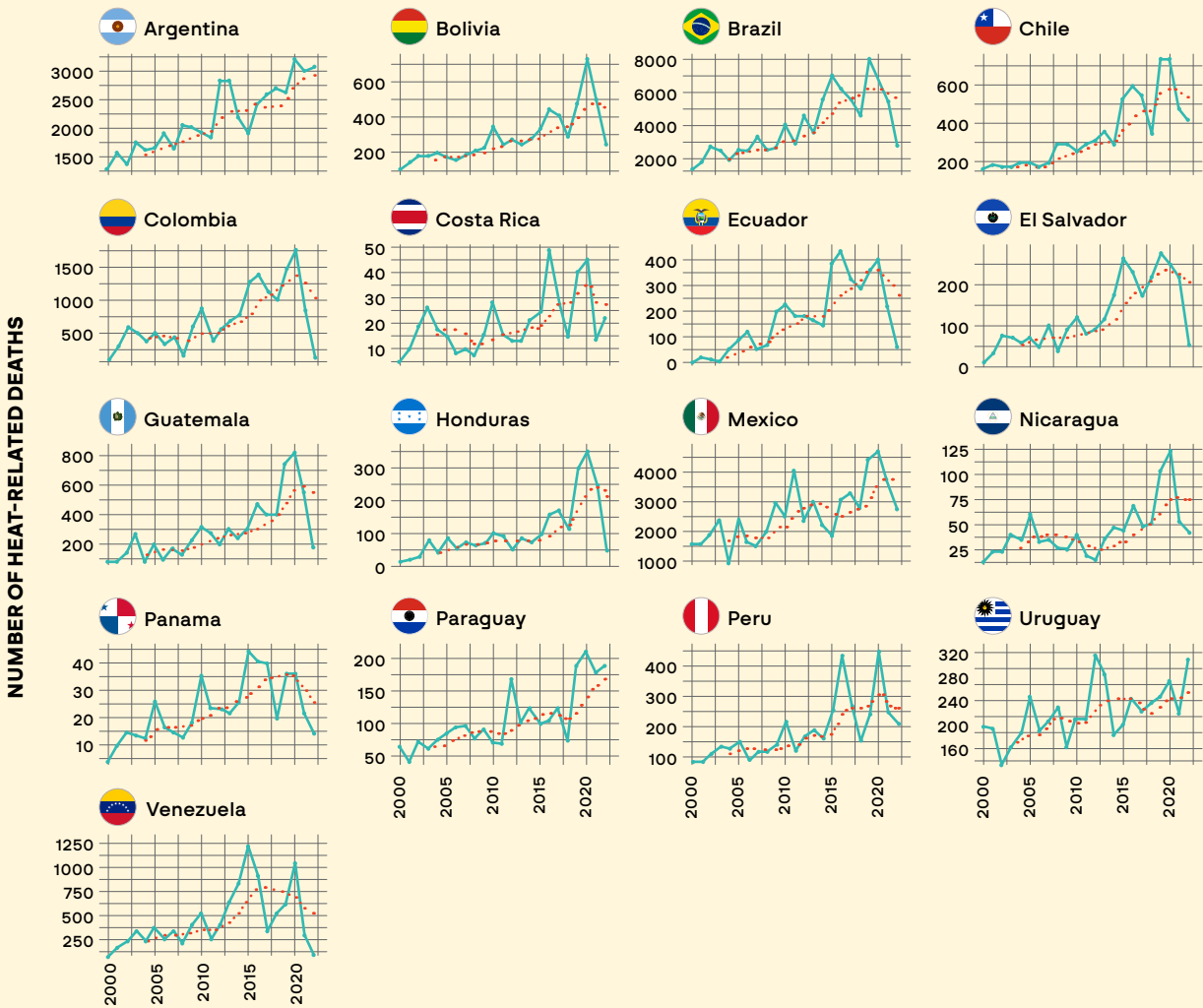
As a result, the official count of “heat-related deaths” severely underestimates the actual number. To try to uncover heat’s hidden burden, epidemiologists calculate “excess mortality” during periods of high temperatures, comparing death rates during these times with the rates under normal conditions. Below, the findings from studies analyzing this type of data, the best available, are explored. However, more comprehensive accounting of the health impacts of health is urgently needed to enable policy makers to better allocate resources for heat resilience.

4.1.2 HEAT-RELATED MORTALITY IS RISING

The *Lancet* Countdown on Health and Climate Change, a global collaboration of top experts, reports annually on the growing health impacts of climate change, including heat-related mortality.²⁶⁵ In 2023, the latest global update shows, nearly 415,000 people aged 65 and older, including over 48,000 in the Americas, died prematurely from heat-related causes.²⁶⁶ For comparison, from 2000 to 2022, a total of about 9,500 people died in tropical storms and hurricanes in Latin America and the Caribbean.²⁶⁷

The latest *Lancet* Countdown analysis for Latin America shows that the number of heat-related deaths among people aged 65 and older was 140 percent higher in 2013–2022 than in 2000–2009—a rapid and dramatic rise.²⁶⁸ As shown in Figure 4.2, the numbers fluctuate from year to year, but overall, the largest increases were in Ecuador (339 percent), El Salvador (230 percent), Honduras (204 percent), and Guatemala (202 percent), while the smallest were in Mexico (67 percent), Argentina (59 percent), and Uruguay (27 percent).

FIGURE 4.2. HEAT-RELATED MORTALITY OF PEOPLE AGED 65 AND OLDER, 2000–2022, BY COUNTRY

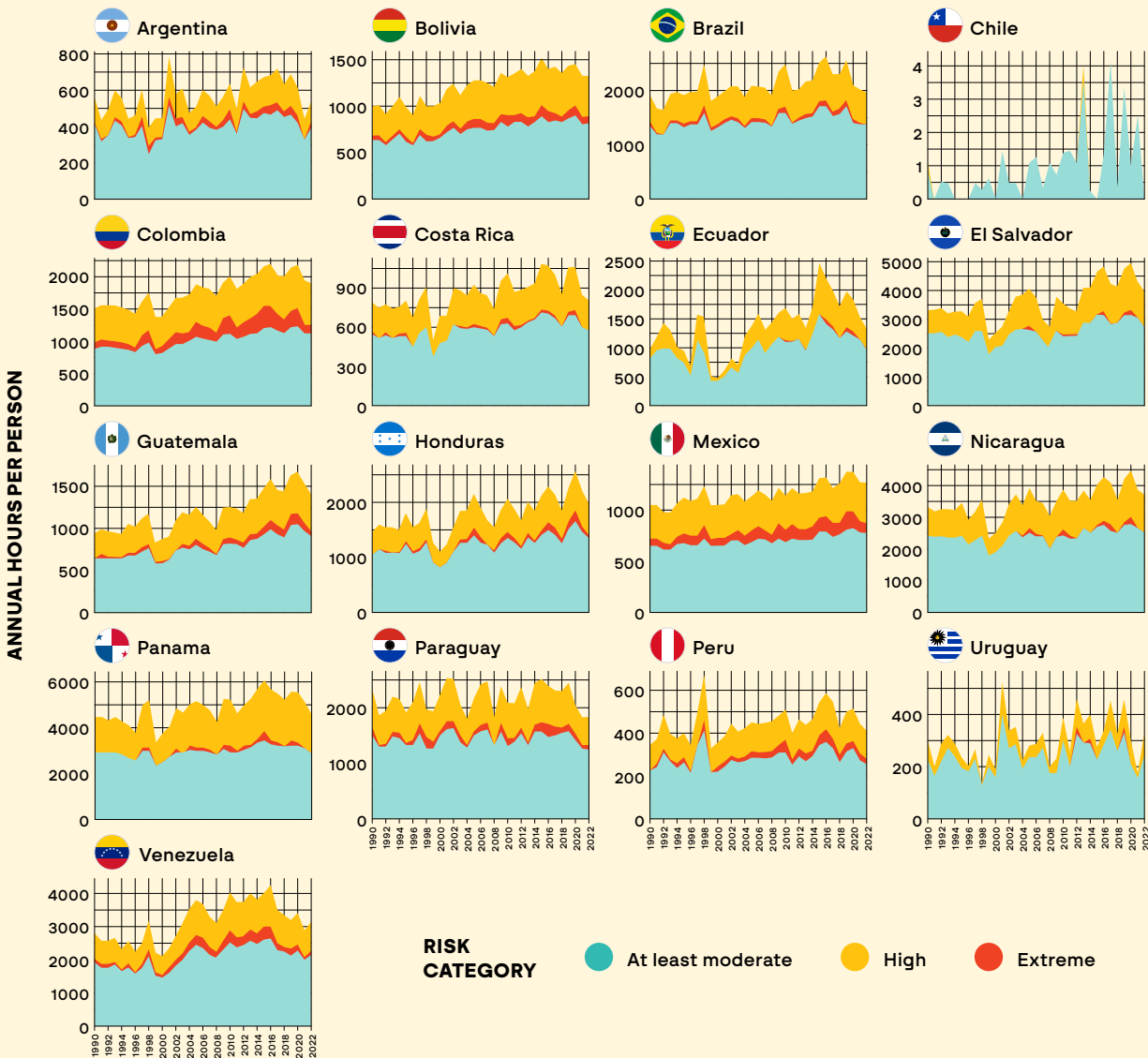


Source: Adapted from Hartinger et al. (2024), Figure A4.²⁶⁹

Note: Dotted lines represent a five-year rolling average.

The rapid spike in global heat-related mortality is closely linked to a rise in heatwave days—reaching a record 13.8 days per person in 2023.²⁷⁰ The hours during which ambient temperatures posed at least a moderate risk of heat stress during light outdoor exercise (e.g., walking) reached a record 1,512 per person globally in 2023, 328 more than the 1990–1999 annual average. In Latin America, compared with 1991–2000, there were 256 and 189 additional hours per year, per person in 2013–2022 during which ambient heat posed at least moderate and high risk of heat stress during light outdoor exercise, respectively (Figure 4.3).²⁷¹

FIGURE 4.3. AVERAGE NUMBER OF HOURS PER YEAR, PER PERSON, THAT LIGHT OUTDOOR PHYSICAL ACTIVITY ENTAILED AT LEAST A MODERATE, HIGH, OR EXTREME HEAT STRESS RISK, BY COUNTRY, 1990–2022



Source: Adapted from Hartinger et al. (2024),²⁷² Figure A3.

Other research, analyzing data for 2000–2019, has found a larger share of excess deaths attributable to heat in Latin America and the Caribbean—1.20 percent in 2016–2019—than in the world as a whole (1.04 percent).²⁷³ A follow-up study focusing on heatwaves—defined as two or more days of temperatures above the 95th percentile for the local climate—found a much smaller excess death ratio: 0.33 percent in 2010–2019 (the global average was 0.97 percent), but varying by a factor of four across countries.)²⁷⁴ This indicates that large numbers of heat-related deaths are occurring on hot days that are not part of documented heatwave events.

The largest study to date of temperature-related mortality in Latin America’s urban areas in particular, published in 2022, covered all the cities with 100,000 or more residents in nine countries—a total of 326—over the period 2002–2015.²⁷⁵ It found that about 0.67 percent of all deaths were attributable to heat, and 0.42 percent, to temperatures above the 95th percentile of city-specific observed temperatures. (The share of deaths attributable to cold was much larger, 5.09 percent, but this is to be expected, as prolonged exposure to even normal nighttime or seasonal temperatures in a large share of these cities can be unsafe for people without proper clothing or shelter.²⁷⁶)

The study found that marginal increases in observed hot temperatures—just 1°C—were associated with steep increases in mortality risk, especially among older adults and for cardiovascular and respiratory deaths.²⁷⁷ This highlights the severity of the risks faced by the region’s aging population even with less extreme heat than is common in other regions.

The findings also show no clear distinctions between cities with hotter or milder climates overall.²⁷⁸ However, there were large differences in the share of excess deaths attributable to heat across cities: from zero in San José, Costa Rica, Mexico City, and Santiago, Chile, for instance, to 2 percent in Buenos Aires, Argentina, and 7.8 percent in Puerto Vallarta, Mexico.

Researchers are beginning to examine how much of the rise in deadly heat is due to climate change. In June 2024, for example, as Mexico and northern Central America endured a deadly heatwave that, by then, had killed 125 people in Mexico alone, World Weather Attribution published a rapid assessment showing that climate change had made the five-day maximum temperature event about 35 times likelier than in pre-industrial times, and four times likelier than in 2000.²⁷⁹ The analysis found daytime temperatures were about 1.4°C hotter than in a heatwave without climate change, and nighttime temperatures, about 1.6°C hotter. By October, Mexico had logged 4,007 cases of heat-related illness and 331 deaths from heat stroke and dehydration alone.²⁸⁰ The larger toll on human health and mortality has not yet been estimated.

Looking ahead, global epidemiological studies show heat-related mortality continuing to rise—with particularly sharp increases in scenarios of unmitigated climate change.²⁸¹ In many regions, the rise in heat-related deaths is projected to match or exceed the projected decline in cold-related deaths, and in warmer climates, heat-related mortality

could surpass cold-related mortality as soon as the 2050s. Projections for Latin America are still limited, but one global study found that pattern for Mexico and Brazil, but not for Chile.²⁸²

4.1.3 INFECTIOUS DISEASE RISKS INCREASE WITH WARMING

Warmer weather can increase the geographic range of mosquitos that transmit dengue, Zika, malaria and other diseases, allowing them to survive and breed in more places. Warmer temperatures can also extend the disease transmission season. Thus, along with the direct impacts of heat, one of the greatest health concerns around climate change is the rise in vector-borne, waterborne, and other infectious diseases due to the combined effects of rising temperatures, changing precipitation patterns, and land-use change.²⁸³

The latest regional review of the Lancet Countdown project found the transmission potential for dengue by *Aedes aegypti* mosquitos had increased by 54 percent from 1951–1960 to 2013–2022, with the largest growth in Bolivia (145 percent), Peru (95 percent), Brazil (94.5 percent), and Guatemala (70.4 percent).²⁸⁴

WHO data show 2023 was a record year for dengue, with 6.43 million cases and 6,892 deaths reported worldwide, including 3.92 million cases and 1,946 deaths in South America.²⁸⁵ In 2024, the case numbers doubled, reaching 13.31 million by the end of October, including 12.46 million in the Americas. The death toll in the region also rose sharply, to 7,551 as of October. Brazil accounted for 9.89 million of those cases, and 5,696 of the fatalities.²⁸⁶

Large, densely populated urban areas in warm climates, where people live in close proximity to substantial mosquito populations, create optimal conditions for the transmission of vector-borne diseases,²⁸⁷ especially in places such as Latin America, where both the vectors and the pathogens are endemic, and temperatures are rising.²⁸⁸ Health experts now estimate that nearly 500 million people in the Americas are at risk of being infected with dengue.²⁸⁹ The situation is compounded by limited and unequal access to medical resources, alongside inadequate water and sanitation infrastructure, which hinders effective vector control.

The links between heat and waterborne illnesses such as cholera are more subtle, but also significant. Higher temperatures create conditions for pathogens and bacteria to proliferate in water sources. In urban areas, overcrowding and insufficient sanitation systems can exacerbate cholera outbreaks, as pathogens spread more easily in densely populated environments with poor water quality. Haiti's cholera epidemic from 2010 to 2019, the deadliest in 25 years, illustrates this vulnerability. Following a devastating earthquake, a hot summer, and subsequent heavy rains, conditions favored the proliferation of *Vibrio cholerae*, leading to successive waves of infection and nearly 10,000 recorded deaths.²⁹⁰ Together, these challenges highlight the urgent need for climate-adaptive health and infrastructure strategies in Latin America to mitigate the health risks associated with rising temperatures.

BOX 4.2

THE BIG PICTURE: HEAT IMPACTS ON HEALTH IN COLOMBIA

In 2023, the World Bank assessed the evidence on health impacts of climate change in Colombia to guide policy makers in planning effective adaptation measures.²⁹¹ The analysis drew on a review of mortality data for 1998 to 2013 by Guo et al. (2018),²⁹² which had found that 267,736 excess deaths during that period were linked to heatwaves.

The World Bank found that rising temperatures had also worsened existing health conditions, leading to increased rates of respiratory and cardiovascular diseases, as well as heat-related issues like rashes, cramps, exhaustion, and dehydration. This has led to a rise in emergency room visits, with an estimated 85,154 visits in 2010–2019 (1.5 percent of the total) attributed to high temperatures.

The Guo et al. (2018) analysis estimated future heat-related mortality under different climate and population scenarios, and found that even assuming low population growth, without adaptation, the number of excess deaths in 2031–2080 could be more than nine times than in 1971–2000 in a scenario of moderate climate change (RCP4.5).²⁹³ Similarly, the World Bank has estimated that under the SSP 3-7.0 climate scenario, emergency room visits related to heat would rise by 440 percent from 2030 to 2039, reaching 380,565 visits. This added burden on the health care system is expected to cost 50 billion Colombian pesos (COP) by 2039.

The Institute for Health Metrics and Evaluation (IHME) found that in 2021, dengue had accounted for 0.023 percent of total deaths in Colombia (0.16 deaths per 100,000 people), underscoring the health risks posed by warming in tropical regions. Children under the age of 5 are disproportionately affected (0.33 deaths per 100,000).

With projected mean temperatures in the 2050s ranging between 20.06°C (min) and 29.45°C (max), Colombia will likely experience an optimal range for mosquito reproduction. Consequently, by 2050, an additional 178,000 cases of dengue and 111,000 cases of malaria are expected, with economic costs surpassing US\$4 billion. To address these escalating health risks from climate change, Colombia will need to enhance resilience, strengthen adaptive capacity, and bolster the readiness of its health care system.

4.1.4 URBAN HEAT AMPLIFIES THE DANGERS OF AIR POLLUTION

Extreme heat also increases the risks from air pollution, one of the most serious threats to public health worldwide and in Latin American cities in particular. In 2019, World Health Organization (WHO) data show, about 4.2 million people globally, and about 288,000 in the Americas, died from illness attributable to ambient air pollution—mainly ischaemic heart disease, stroke, and respiratory infections.²⁹⁴

The latest regional *Lancet* Countdown analysis found that no major urban centers in Latin America met WHO air quality guidelines.²⁹⁵ Research from the Salud Urbana en America Latina (SALURBAL) project, meanwhile, focused on 366 cities with over 100,000 residents, found 58 percent of the population—172 million people—lived in areas with air pollution exceeding the WHO guidance for small particulate matter (PM_{2.5}) of 10 µg/m³ annual average.²⁹⁶

The most visible impact of extreme heat on air pollution is growing wildfire risks.²⁹⁷ Thousands of fires across northern Central America and Mexico's Yucatan Peninsula amid heatwaves in the first half of 2024 sent thick clouds of smoke through the region.²⁹⁸ South America faced a record 2024 fire season, too, with smoke covering spreading across more than half the continent.²⁹⁹ Wildfires release particulate matter (PM_{2.5} as well as the larger PM₁₀), nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOCs), among other pollutants.³⁰⁰

In Brazil, an analysis of 2 million hospital admissions nationwide in 2008–2018 due to cardiovascular and respiratory diseases found waves of wildfires were associated with a 23 percent increase in respiratory admissions and a 21 percent increase in cardiovascular admissions.³⁰¹ Notably, the mean PM_{2.5} concentration in Brazil during the study period was 15 µg/m³, well above the WHO guidance, and in some places it was as high as 30 µg/m³.

Heat can also intensify air pollution. Ground-level ozone (O₃), which can irritate the respiratory system and worsen or even cause asthma,³⁰² is formed when hydrocarbons and NOx react through exposure to sunlight. Heat accelerates those reactions, leading to higher ozone levels, sometimes visible as haze, that can reach dangerous levels in urban areas.³⁰³

The combined effects of heat and air pollution have been documented around the world. One major study, which examined over 22 million deaths across 620 cities in 36 countries (including six in the region) from 1995 to 2020 found that the increase in mortality associated with a rise in temperature—from the 75th to the 99th percentile of typical temperatures in each city—ranged from 5.3 to 12.8 percent, depending on the level of PM₁₀ in the air.³⁰⁴ In other words, heat was more harmful when air pollution levels were also elevated.

In places where temperatures are low enough to require heating, the warming that climate change is expected to bring could reduce some forms of air pollution, especially where firewood is used for heat. Indoor air pollution remains a serious health threat in the region, which is why public health experts have called for accelerating the transition to clean heating and cooking.³⁰⁵

4.1.5 WHAT CAN BE DONE? KEY HEALTH SYSTEM INTERVENTIONS

Mitigating the health impacts of rising heat in cities across Latin America and the Caribbean will require a multifaceted approach, combining public health measures, disaster risk management (DRM), infrastructure upgrades, worker protections, and other policy interventions. Some are discussed in more detail in section 4.3. This section highlights three key needs, building on a succinct overview published recently in *PLOS Climate*:³⁰⁶

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Heat-health warning systems: It is crucial to alert the public when heat is expected to reach harmful levels—not just based on air temperature—and provide actionable advice on how to stay safe and how to recognize signs of heat-related illness. Proactive public education campaigns, such as the “Verano Vigilante” initiative in Costa Rica,³⁰⁷ are important complements to emergency messaging. Designing these campaigns with a focus on the most vulnerable populations—such as women and informal workers—can improve their reach and relevance, particularly for those who face heightened exposure to extreme heat.

Strengthening public health systems: There are significant gaps in health care infrastructure, services, and access that urgently need to be addressed. It is also crucial to train health care professionals on how to manage heat-related conditions, and ensure that they have the equipment they need to treat patients during emergencies—not to mention, reliable access to water and electricity, which are basic necessities.

Community-based approaches: Cities need heat action plans, support networks to help vulnerable individuals, and safe, air-conditioned community cooling centers. Proactive community engagement can help ensure that people are prepared to mobilize to support their neighbors, and/or find the assistance they need.

4.2 LEARNING IN EXTREME HEAT PUTS EDUCATION AT RISK

Extreme heat poses serious challenges to educational systems worldwide, affecting children’s ability to learn and thrive—and increasingly harming their health. Young children are particularly vulnerable to heat because they cannot regulate their body temperature as well as adults, and children also generally spend more time outdoors.³⁰⁸

In 2020, an estimated 559 million children globally, including 123 million in the Americas, were exposed to high-frequency heatwaves.³⁰⁹ By 2050, almost every child on Earth, and in the region, is expected to face high-frequency heatwaves, even in a low-emissions scenario. A majority will also face high-duration heatwaves, of 4.7 days or more.

Recent work by the World Bank has highlighted the serious implications of extreme heat and other climate change impacts for children’s education and long-term prospects.³¹⁰ For example, between January 2022 and June 2024, an estimated 404 million students faced school closures in 81 countries due to extreme weather events, including heatwaves. Even when schools remain open, high temperatures can affect students’ concentration and ability to learn. As discussed above, extreme heat also worsens air quality, directly and by increasing wildfire risks. Broader impacts on livelihoods, food security, migration, and violence can also destabilize children’s lives and reduce school attendance and enrollment.

4.2.1 EXTREME HEAT ALREADY DISRUPTS LEARNING

The impacts of rising temperatures are being felt at schools throughout the region. A prime example is Mexico, where extreme heat in early 2023, with temperatures exceeding 35°C and even 45°C, led 18 states to adopt a range of emergency measures that affected the education of 13.1 million students.³¹¹ Nuevo León and Tamaulipas, for example, suspended in-person classes in 12,435 schools, affecting 1.7 million students. Chihuahua, Coahuila, and Sinaloa, meanwhile, ended the term early, closing 16,960 schools attended by 1.9 million students. Five other states shortened the school day, and 14 restricted physical activities. The crisis was exacerbated by infrastructure deficits, including no access to drinking water at 15 percent of schools nationwide—33,500 altogether.

Extreme heat returned to Mexico in 2024, with seven states facing daily maximums above 45°C, 10 above 40°C, and 11 above 35°C from April onward, leading to a new round of emergency measures.³¹² Still, some students suffered heat stroke,³¹³ and as the heat persisted into late May, at least one state sought to end the term early again.³¹⁴

Extreme heat has also disrupted education in Honduras. In March 2024, children and teachers in schools in Tegucigalpa were reportedly sick and fatigued from the heat,³¹⁵ with symptoms including heatstroke, headaches, vomiting, and nosebleeds. Two schools had suspended in-person classes. Two months later, amid continued heat, and with the capital shrouded in thick smoke from wildfires, President Xiomara Castro suspended in-person classes for four days across the entire Central District to protect children's health.³¹⁶

Schools in Argentina have been severely affected by extreme heat, too, exacerbated by infrastructure deficiencies. Amid a heatwave in Buenos Aires that brought temperatures up to 39°C in February and March 2023, students reportedly arrived home from school dizzy and nauseated.³¹⁷ Hundreds of schools were found to have poor ventilation and a lack of water, and teachers were not allowed to buy their own air conditioning units.³¹⁸ In March 2024, citing “very grave” conditions due to extreme heat, power outages, and a lack of water, the state teachers’ union called for a suspension of classes.³¹⁹

Similar crises are arising in other countries as well. In May 2023, a high school in Barranquilla, Colombia, lost power for weeks and was so hot that students reportedly could only be taught for three hours per day, in common areas outdoors.³²⁰ In February 2024, as the city of Piura, in arid northern Peru, endured highs above 40°C, educational leaders sought to delay the start of the school year, as most facilities were unsuitable for protecting students from excessive heat.³²¹ In September 2024, schools in eastern Santo Domingo, Dominican Republic, were reported to face a “grave crisis” due to the combination of “suffocating heat” and frequent power outages.³²²

4.2.2 HEAT-RELATED LEARNING LOSSES HAVE LONG-TERM IMPLICATIONS

Beyond physical discomfort, students and teachers routinely report having poor concentration and impaired learning during heatwaves. Research bears this out. A study in Costa Rica, for example, found that 11-year-olds performed language and logic tasks faster, and less-able pupils did significantly better overall, when air conditioning was used to cool their classrooms, which were normally about 30°C.³²³ A World Bank review of the global literature on climate change and education outcomes found evidence of “a significant and adverse relationship between heat and learning” overall, particularly when students are exposed to extreme heat.³²⁴

Studies are also showing the cumulative effects of exposure to high temperatures. An analysis of standardized achievement data across 58 countries found that every day above 80°F (about 26.7°C) within three years prior to testing decreased scores by 0.0018 standard deviations, which is equivalent to about one day of learning lost.³²⁵ A study in Colombia found a 1°C increase in the average daily maximum temperature in the preceding year led to a decline of at least 2 percent of a standard deviation in the math, Spanish, and overall scores of students in urban areas.³²⁶

As students face extreme heat year after year, these effects can add up to substantial learning losses and diminished human capital. Research in Brazil indicates that an average student in the poorest 50 percent of Brazilian municipalities could lose up to half a year of learning overall due to rising temperatures.³²⁷ Prolonged heat exposure also correlates with lower school completion rates. In Brazil, a one-standard-deviation increase in the share of days above 34°C was found to increase dropout rates by 0.36 percentage points, representing a 5.1 percent increase in the average dropout rate.³²⁸ The effects are concentrated in public schools, particularly in urban areas, where poor infrastructure amplifies the impact of heat.

Exposure to heat while taking exams can take a particularly severe toll, with major impacts during high-stakes tests that are critical for academic and career advancement. In Brazil, a one-standard deviation increase in temperature during the National High School Evaluation Exam (ENEM)—a key university admission test—lowered scores by 0.036 of a standard deviation.³²⁹ Test scores and school dropouts are also correlated. A study spanning Ethiopia, India, Peru, and Viet Nam found that higher test scores (one standard deviation) decreased dropout odds by 50 percent for children aged 8 to 15.³³⁰

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4.2.3 WHAT CAN BE DONE? ADAPTING SCHOOLS TO HOTTER CONDITIONS

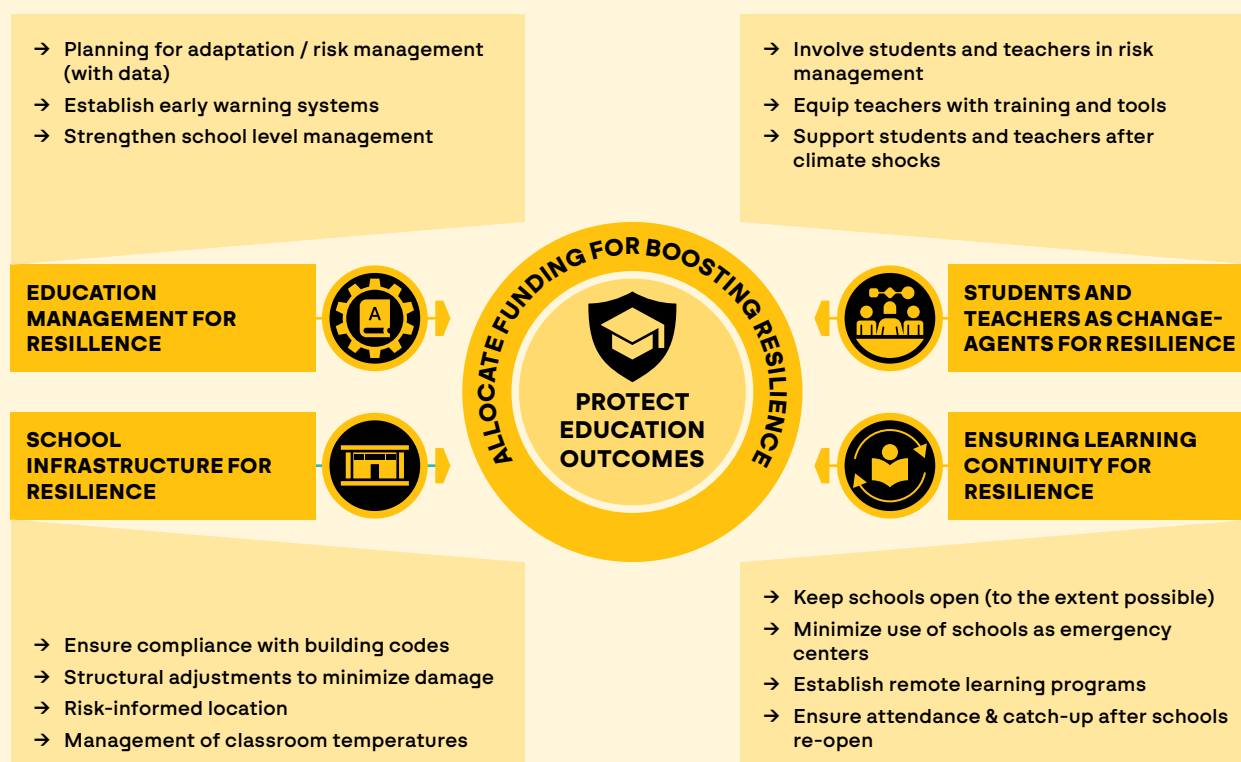
Exposure to frequent and/or prolonged heatwaves is still the exception, not the norm, in large parts of Latin America and the Caribbean, but conditions are deteriorating fast—and some countries, such as Argentina, El Salvador, Honduras, and Mexico, already face widespread heat-related crises.³³¹ This means adaptation measures are urgently needed.

The World Bank has developed a framework for protecting educational outcomes amid climate change, with a focus on proactive measures to make schools more climate-resilient, minimize school closures, and reduce the impact of unavoidable closures.³³²

As shown in Figure 4.4, it has four pillars:

- **Strengthening education risk management** by establishing early warning systems and integrating medium- and long-term strategies in education sector plans to minimize climate risks;
- **Involving students and teachers as agents for resilience**, trained in risk management and with the capacity to provide support after climate shocks;
- **Building more resilient school infrastructure**, with particular attention to schools with severe infrastructure deficiencies, such as no running water or power supplies that fail frequently and/or for extended periods;
- **Ensure learning continuity** by planning carefully to keep schools open to the extent possible, and/or investing in remote learning programs.

FIGURE 4.4. A FRAMEWORK FOR BOOSTING EDUCATIONAL SYSTEMS' CLIMATE RESILIENCE





The World Bank has also identified specific measures that schools can implement to reduce heat, including low-tech and low-cost options for addressing infrastructure deficiencies.³³⁴ Examples include painting rooftops white—which a project in Indonesia found could cool indoor temperatures by more than 10°C—and planting shade trees on school grounds. Adopting both measures would cost just about US\$1 per student. In new or renovated buildings, many other passive cooling strategies (see section 3.2.1) could be adopted for even greater benefits.

In Honduras, for example, as schools damaged by Tropical Cyclones Eta and Iota have been repaired and rebuilt, with World Bank financing, new features have been added, such as better window placement, improved roofs, and ventilation systems.³³⁵ The upgrades will not only make the storms more resilient to future storms, but also more comfortable on very hot days.

Some schools already have air conditioning or other cooling technologies, and to the extent that they can afford it—the World Bank estimates that adding air conditioning in classrooms would cost about \$11 per student—more are likely to add them over time. This could significantly increase energy costs, but in some contexts, it may be needed to keep students safe. By 2050, the UN study cited at the start of this section found, 17–27 million children in the Americas could face “extreme high temperatures,” defined as 84 or more days per year above 35°C.³³⁶

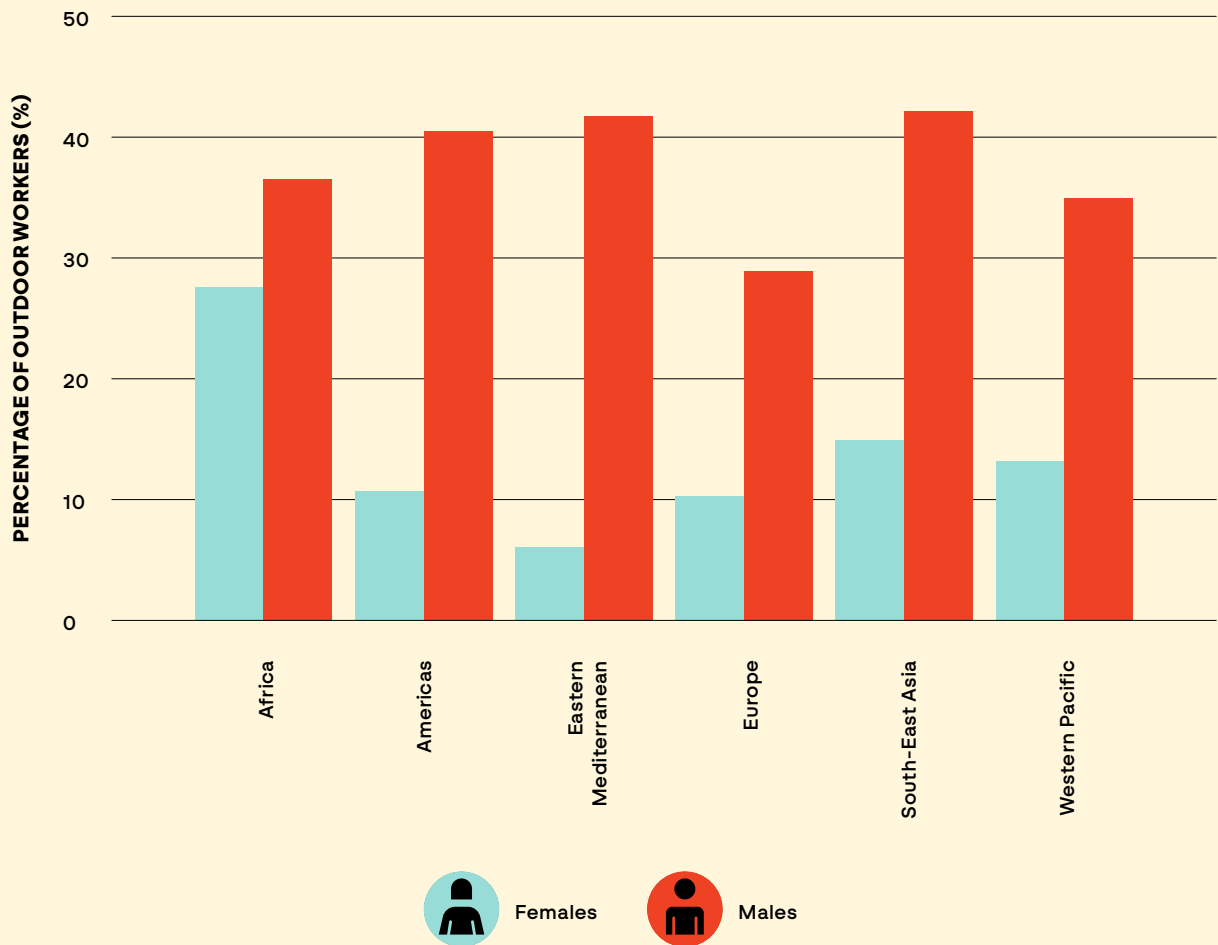
Educational systems also need to prepare better for heat emergencies, whether schools remain open or are forced to close.³³⁷ Careful planning can keep in-person classes viable for longer, avoiding harmful disruptions to children’s education. Investments in remote learning systems, online tutoring, and additional training for teachers can further mitigate harm—but the costs could be significant (an estimated \$6.50 per student for remote learning and \$19 per student for small-group, phone-based tutoring, for instance).

4.3 URBAN LIVELIHOODS ARE INCREASINGLY AFFECTED BY HEAT

Every day in cities across Latin America and the Caribbean, tens of millions of people earn a living by performing physical labor either outdoors—no matter how hot or sunny it may be—or indoors, but under conditions that still expose them to significant heat. As temperatures rise and heatwaves become more common, these livelihoods will become ever riskier.

Outdoor work is very common in the region, especially for men. The WHO has estimated that in 2023, about 200 million people in the Americas worked outdoors, including about four in 10 male workers aged 15 and older, one in 10 female workers, and more than 30 percent of those aged 30–54 (see Figure 4.5).³³⁸

FIGURE 4.5. WHO ESTIMATES OF SHARE OF OUTDOOR WORKERS (≥15 YEARS OLD), BY SEX, 2023



Source: Adapted from Romanello et al. (2024),³³⁹ supplementary figure 36.

4.3.1 HEAT AFFECTS DIFFERENT OCCUPATIONS

The extent to which a worker is at risk of heat stress depends not only on the individual’s physiology (as discussed in section 4.1.1), or on the ambient temperature, humidity, and air flow, but also on factors specific to the job and workplace (Figure 4.6). A key factor is the amount of physical exertion required, as high metabolic rates generate large amounts of heat. Even a low-intensity factory, retail, or restaurant work may entail two or three times the physical effort of a desk job.³⁴⁰ Heavy lifting, as is common in construction, farm work, and warehouse jobs, can easily require three or even four times the metabolic rate of a desk job—and very heavy work, such as pick-and-shovel tasks, even more. Protective clothing and gear may make it difficult to cool off, and equipment such as industrial machinery may also produce heat.

FIGURE 4.6. FACTORS THAT MAY EXACERBATE WORKPLACE HEAT STRESS RISKS—AND POSSIBLE IMPACTS



Source: Adapted from Flouris et al. (2024),³⁴¹ Figure 1.

As discussed in section 4.1.1, several factors can also make some workers more vulnerable to heat stress than others.³⁴² In general, women are likelier to get overheated from exercise than men, and they may find it harder to cool down; those working during pregnancy are at even greater risk (see also Box 4.1).³⁴³ Older adults' ability to do physical work is significantly reduced in hot conditions, and there is evidence that older workers are more susceptible to occupational injuries during heatwaves. Workers with pre-existing medical conditions, certain injuries, or a disability are also at risk.

Young, healthy workers, meanwhile, are typically assigned the most physically demanding jobs, so while their bodies can withstand more thermal stress, they may also be exposed to significantly more than their coworkers. They may lack the knowledge or authority to protect themselves—and, particularly if they are male, they may be driven to keep working without complaint even if they feel unwell.

Latin America and the Caribbean are also home to about 17.5 million migrants, mainly from within the region, many of whom are also in the workforce.³⁴⁴ Colombia alone hosted nearly 3.1 million migrants as of 2024, and Argentina, Mexico, Peru, and others also had large migrant populations. Migrant workers are considered highly vulnerable, as they are disproportionately employed in physically demanding jobs, such as construction (or, for women, housekeeping), may have language barriers that prevent them from understanding occupational health and safety (OSH) procedures, and may not be accustomed to the local climate.³⁴⁵

A final, very large category of highly vulnerable workers is those who are informally employed—on their own account or on the edges of the formal economy. In the first quarter of 2024, the average informal employment rate in 11 countries in the region for which data were available was 45.8 percent.³⁴⁶ A look at urban informal employment rates in particular reveals that while some countries were well below that rate (e.g., Brazil, at 33.2 percent, Chile, at 26.7 percent, and Costa Rica, at 32.7 percent), in some, a majority of employment in cities is informal: 52.9 percent in the Dominican Republic, 58 percent in Ecuador, 67.1 percent in Peru.³⁴⁷

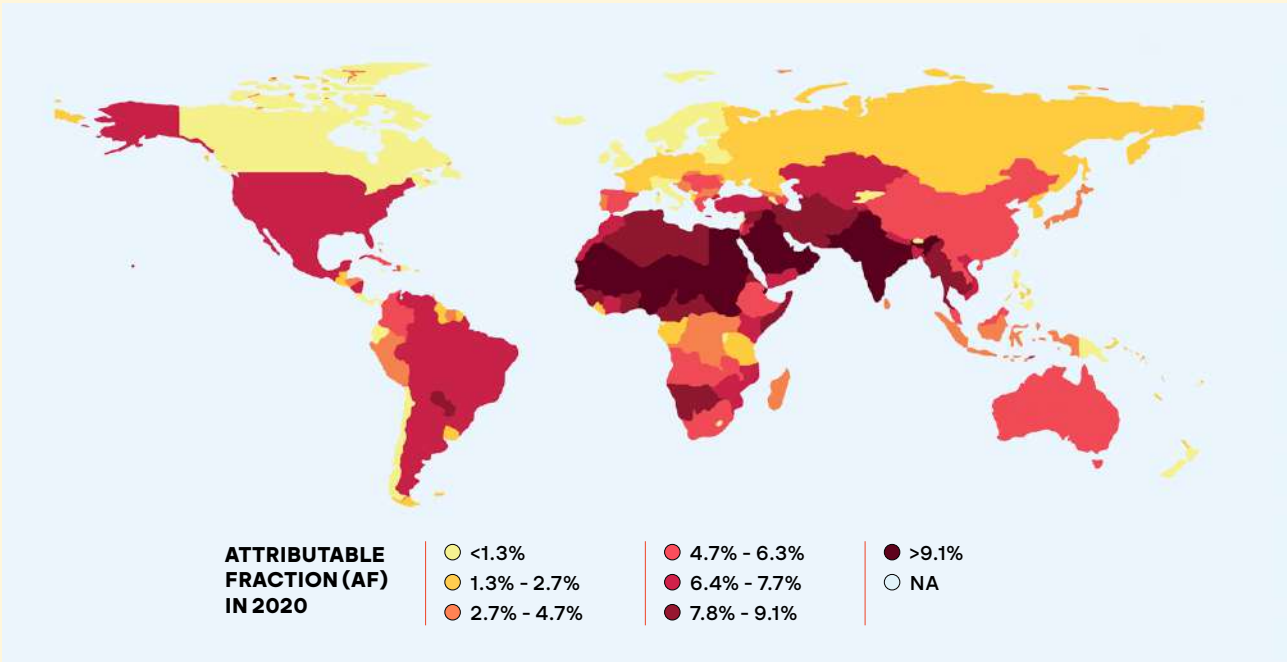
4.3.2 HEAT IS ALREADY TAKING A HEAVY TOLL ON WORKERS

Globally, the International Labour Organization (ILO) estimates, 2.41 billion workers—71 percent of the work force—were exposed to excessive heat in 2020, up 34.5 percent from 2000.³⁴⁸ That exposure had serious consequences, including an estimated 22.85 million injuries and 18,970 deaths; overall, 6.1 percent of fatal occupational injuries were linked to heat.

In the Americas, a follow-up ILO analysis found, 70 percent of workers were exposed to excessive heat in 2020.³⁴⁹ This resulted in an estimated 2.8 million injuries and accounted for 6.7 percent of occupational injuries leading to death—a larger share than any other region except Africa (Figure 4.7). Notably, heat exposure during heatwaves (defined as three or more days with temperatures exceeding 35°C) accounts for a disproportionate

share of fatal injuries: 22.1 percent globally, even though heatwaves made up about 9.6 percent of exposure days. In the Americas, the share of fatal injuries occurring during heatwaves more than doubled from 2000 to 2020. This highlights the importance of taking special precautions during heatwaves.

FIGURE 4.7. SHARE OF FATAL OCCUPATIONAL INJURIES ATTRIBUTABLE TO EXCESS HEAT, BY COUNTRY, 2020

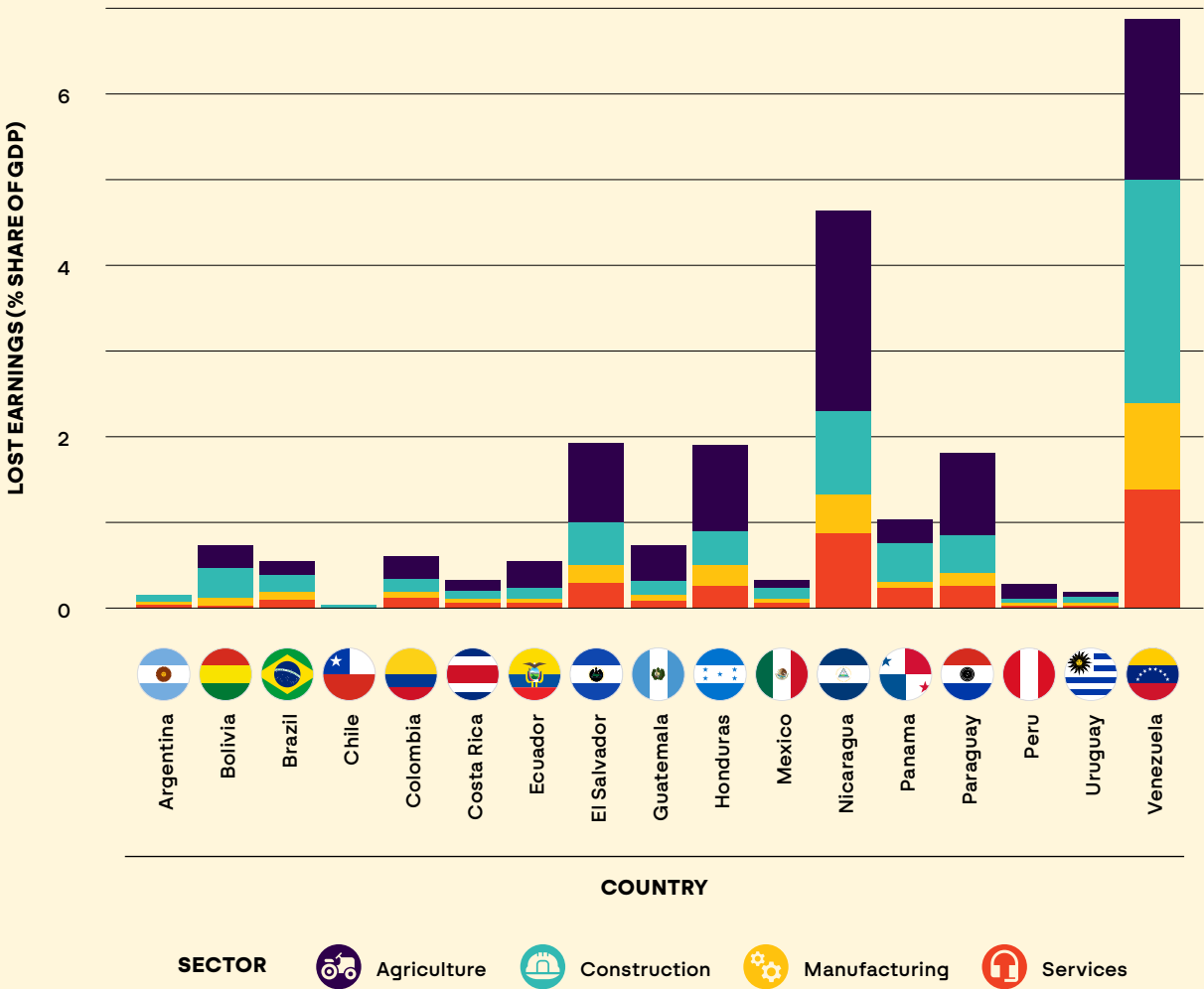


Source: Flouris et al. (2024),³⁵⁰ Figure 3.a.

Another way to think about the impact of heat on workers is in terms of their earnings. Reduced productivity can translate into less pay, affecting their entire family, the community, and the economy as a whole (discussed further in Section 5). In 2023, the global potential income loss from reduced labor capacity due to extreme heat reached a record US\$835 billion, the Lancet Countdown team found.³⁵¹ This was equivalent to 0.82 percent of gross world product.

In Latin America, in 2022, heat-related labor capacity reductions are estimated to have cost workers US\$1.78 billion in potential income losses, or 1.34 percent of GDP, on average.³⁵² There were large differences across countries, however, both in the scale of the lost income, and in the breakdown across sectors. Globally, agriculture is by far the hardest-hit sector, and it accounts for the largest share of forgone income in Latin America as well (40.6 percent), but construction, a more urban sector, accounts for 32.5 percent, and in some countries, services and manufacturing have also been affected significantly (Figure 4.8). Overall, Venezuela, Nicaragua, El Salvador, and Honduras show the largest potential income losses as a share of GDP: 6.9, 4.7, 1.94, and 1.94 percent, respectively, while Chile had the lowest smallest loss (0.02 percent).

FIGURE 4.8. LOSS OF EARNINGS FROM HEAT-RELATED WORK CAPACITY REDUCTIONS, BY SECTOR, 2022



Source: Adapted from Hartinger et al. (2024),³⁵³ Figure 9.

4.3.3 VULNERABLE WORKERS ARE PARTICULARLY AFFECTED

Workers whose situation is already precarious due to poverty, informality, migrant status, or other factors—a majority in many cities in the region, and numerous in most—face particularly significant threats to their livelihoods. If they work under dangerous conditions and get sick or have an accident, they may not be able to access timely and affordable health care, but if they do not work—by choice or due to their employer’s precautions—they may not be able to rely on safety-net programs to offset any lost income.³⁵⁴ The latter is also true if they are incapacitated by heat-related injuries and cannot work.

A study of informal waste pickers in Brazil by the Women in Informal Employment Globalizing and Organizing (WIEGO) network found that 85 percent reported experiencing abnormal heat or heatwaves while doing their work.³⁵⁵ Most work outdoors, but even when indoors, they may be exposed to heat, but they need to collect enough materials

to be able to support themselves. Key symptoms reported included dehydration, heatstroke and fatigue.

Media reports have documented the particular struggles of informal workers during recent heatwaves across the region: from produce sellers in Kingston, Jamaica,³⁵⁶ to buskers and peddlers on Mexico City's metro trains,³⁵⁷ to street vendors in Maracaibo, Venezuela, including many Indigenous women with small children.³⁵⁸ Workers commonly report feeling dizzy and ill, but working nonetheless out of necessity; cutting back on hours to avoid the worst heat; and seeing their incomes drop even as they must spend additional money to stay cool.

Governments can take many steps to protect workers from the adverse effects of excessive heat through labor regulations and outreach to employers, a topic discussed in detail in section 5.2.1. In addition, section 5.2.2 looks at how social protection can be used to enable vulnerable workers—including informal workers—to reduce their hours or avoid work entirely on the hottest days, and to help them support themselves in the event of a heat-related illness or injury.

4.4. THE ECONOMIC COSTS OF URBAN HEAT WILL BE SIGNIFICANT

The impacts of urban heat on people and infrastructure have significant economic implications. This section presents new analysis by the World Bank to estimate the potential effects of those impacts on the productivity of cities across Latin America and the Caribbean.

Any reductions in cities' output are of particular concern in this region, as not only is the population concentrated in urban areas, but individual cities generate large shares of countries' gross domestic product (GDP). For example, Mexico City generated 14.8 percent of Mexico's GDP in 2023,³⁵⁹ and São Paulo, 9.2 percent of Brazil's GDP in 2021.³⁶⁰ The shares in smaller countries are even more dramatic: Montevideo produces about 49 percent of Uruguay's GDP;³⁶¹ Greater Santo Domingo, 40.7 percent of the Dominican Republic's,³⁶² and Quito, 24.8 percent of Ecuador's.³⁶³

4.4.1 HEAT SLOWS DOWN URBAN ECONOMIES

Extreme heat can reduce the labor market supply, as workers opt out of work or reduce their hours—or employers pause or limit work to protect their teams (by choice or as required). Heat stress can also have an impact on physical capital, as extreme heat can damage infrastructure and machinery. As discussed in section 4.3.1, heat can also affect workers' physical and mental abilities, and thus reduce labor productivity—the quantity and effectiveness of human capital. Heat-related illness and accidents can further reduce workers' capacities.

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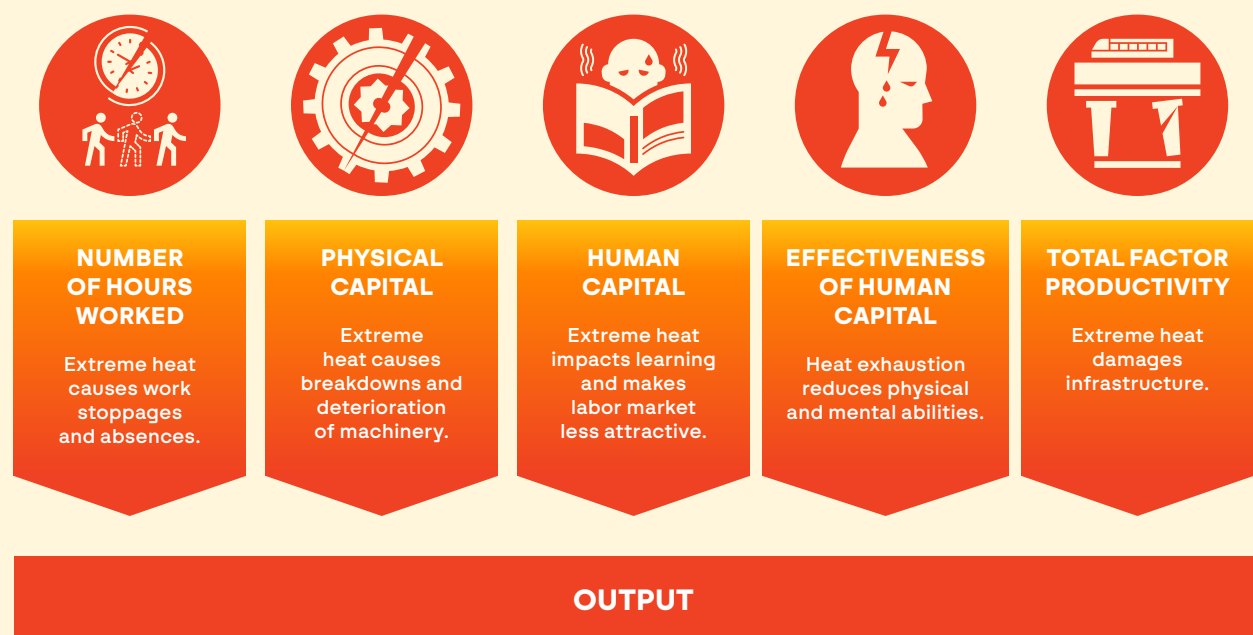
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Impacts on educational outcomes (section 4.2) could also affect the long-term supply of human capital. A city that becomes stiflingly hot, or where it is easy to contract a vector-borne disease, may also become less attractive to high-skilled workers.³⁶⁴ And when not designed to withstand extreme temperatures (Section 3), urban infrastructure services can also be affected, leading to a reduction of total factor productivity. Together, these channels can have an impact on a city’s aggregate economic output, as shown in Figure 4.9.

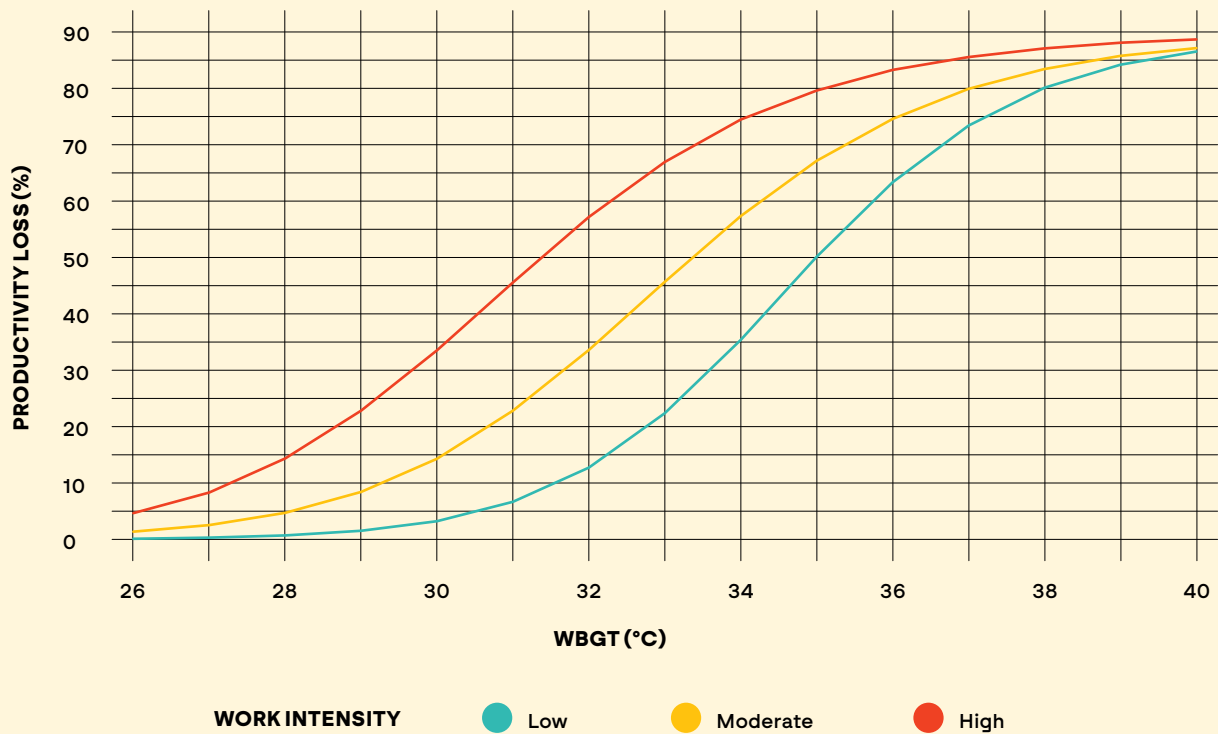
FIGURE 4.9. THE DIFFERENT CHANNELS THROUGH WHICH URBAN HEAT AFFECTS A CITY’S ECONOMIC OUTPUT



Source: World Bank.

Cities are affected differently by rising temperatures, depending on their sectoral composition and their underlying climate. One study found that impacts on work productivity start at wet-bulb globe temperatures (WBGT) as low as 24–26°C, particularly for high-intensity work, and by 32°C, productivity for high-intensity work has been more than halved; the same occurs for moderate-intensity work around 33–34°C, and for low-intensity work, around 35°C (Figure 4.10).³⁶⁵

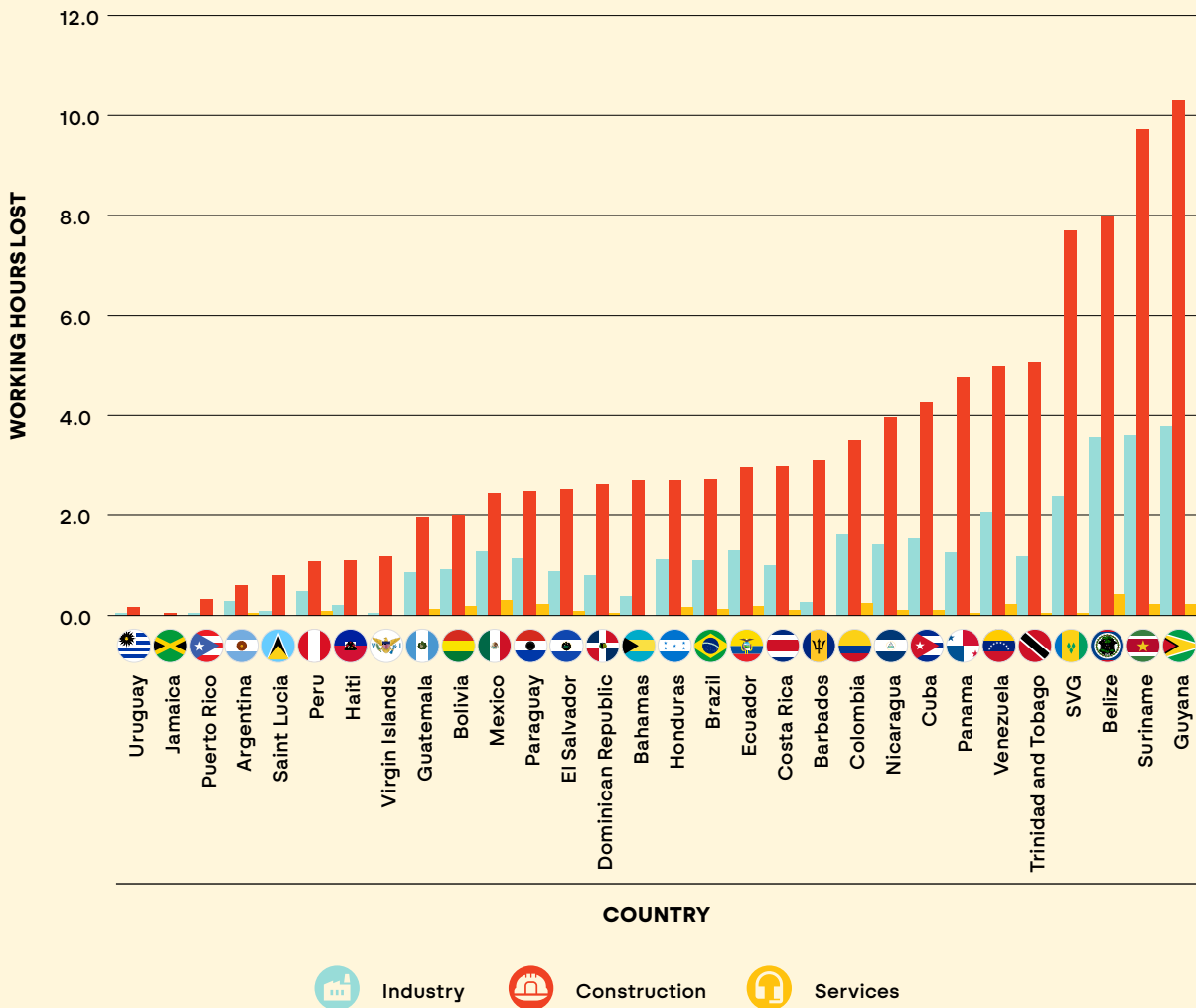
FIGURE 4.10. LABOR PRODUCTIVITY LOSS DEPENDING ON TEMPERATURE LEVELS AND WORK INTENSITY



Source: Adapted from Orlov et al. 2020

As discussed in section 4.3.2, extreme heat is already reducing workers’ incomes through lost earning potential. A key factor in this is a loss of working hours. In cities, construction is one of the sectors at greatest risk, as much of the work occurs outdoors, and even indoor work can be arduous and thus hot as well.

A recent global assessment of working hours loss due to heat stress found that the most affected countries in terms of percentage of working hours lost in Latin America and the Caribbean are Guyana, Suriname, Belize, Saint Vincent and the Grenadines, and Trinidad and Tobago (Figure 4.11).³⁶⁶ A comparison of industry, construction, and services shows that construction has by far the greatest projected losses by 2030.

FIGURE 4.11. SHARE OF WORKING HOURS LOST DUE TO HEAT STRESS BY SECTOR AND COUNTRY (PROJECTIONS FOR 2030)

Source: World Bank, using data from Kjellström et al (2019).³⁶⁷

Another factor that could affect the region's economy is the large share of employment that is informal (see section 4.3). Informal sector workers tend to be more exposed to outdoor conditions and substandard indoor conditions, and they often work without labor protections. Evidence from India and Ghana suggests that during heat waves, urban informal sector workers may withdraw from markets and have fewer customers, resulting in lower earnings. In addition to losing income, informal workers often have to spend money on personal adaptive measures, such as buying fans, building shelters, or purchasing more beverages to stay hydrated during heatwaves (see section 5.2.2).³⁶⁸

4.4.2 HOTTER AND POORER CITIES ARE HIT HARDEST BY HEATING ANOMALIES

Urban economic activity across the region is already being affected by extreme heat anomalies. The World Bank analyzed how extreme heat, measured as a city's temperature anomaly relative to its historical norm, impacts a city's nighttime light intensity as a proxy for economic activity. This follows the methodology developed for the East Asia counterpart to this report (Box 4.3).

First of all, extreme heat appears to affect economic activity in cities in low- and lower-middle income countries more than in wealthier countries. As shown in Figure 4.12 (panel a), cities in low- and lower-middle income countries show a 2.6 percent drop in nighttime light intensity, while those in upper-middle income countries show a 1.2 percent drop, and cities in high-income countries do not show a decline.

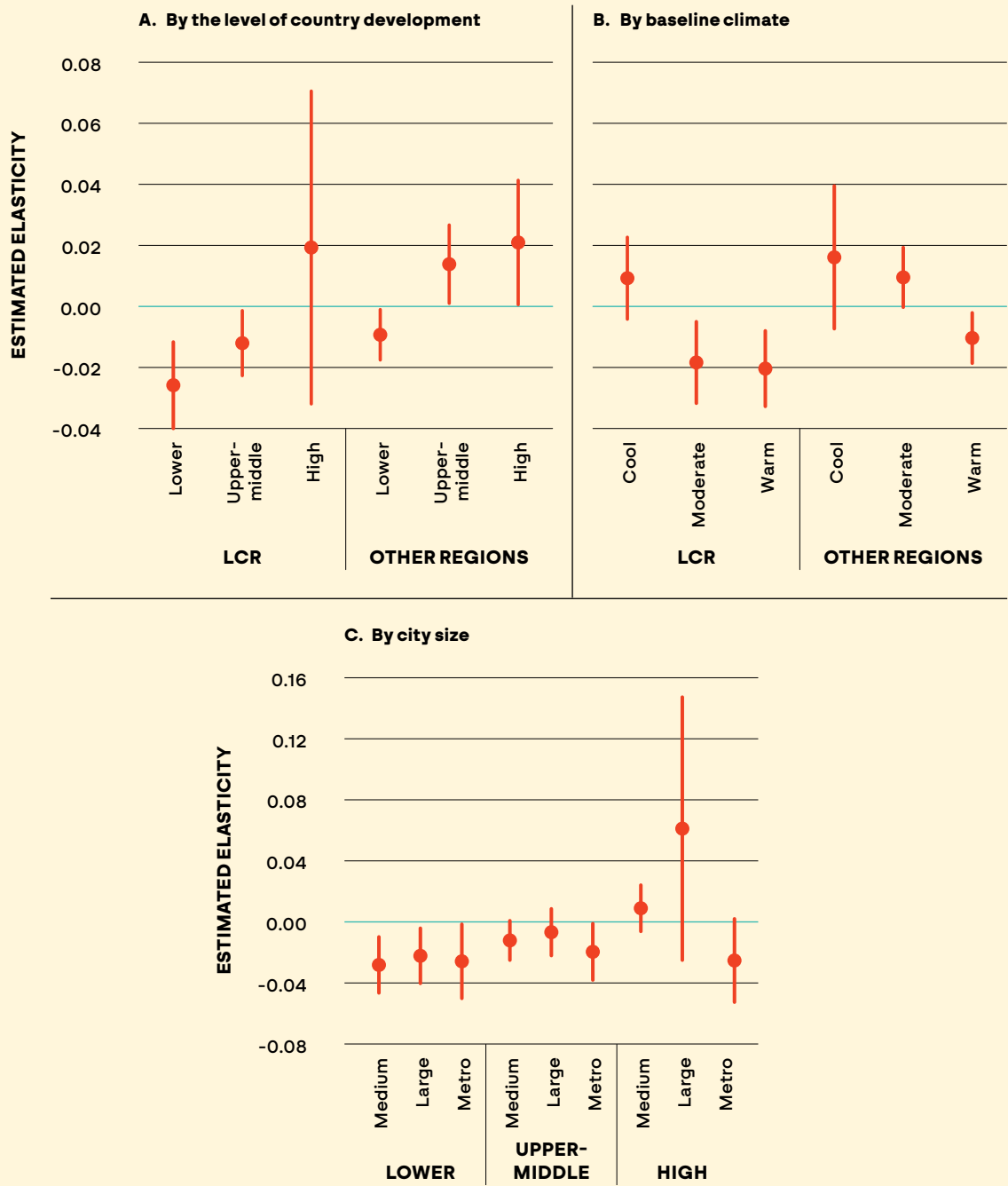
The analysis also revealed that the warmer a city's baseline climate, the larger the negative impact of extreme heat (Figure 4.12, panel b). In cities with warm and moderate climates, nighttime light intensity was found to decline by more than 2 percent and nearly 2 percent, respectively. For those with cool baseline climates, nighttime light intensity slightly increased, but was statistically insignificant. Because the frequency of extreme heat events is increasing over time, these results are especially worrying for cities with warmer baseline climates.

Lastly, results disaggregated by medium (200,000–499,999), large (500,000–1,499,999), and metropolitan areas (at least 1.5 million) in each country income class suggest that income classes matter more for economic resilience to heat than city size. In lower-income countries, the estimated impacts are negative regardless of city size, ranging from -2.3 percent for large cities, to -2.7 percent and -2.9 percent for metros and medium cities.

In upper-middle-income countries, metros darkened by about 2 percent on average when hit by extreme heat, while the estimated impacts are insignificant for smaller cities. This is in line with a previous finding that larger-scale built environment and human activities make heat stresses more severe in larger cities.³⁶⁹ In high-income countries, the estimated impact is negative only for metros (Figure 4.12, panel c).

Notably, on average, the extent to which cities are negatively affected by extreme heat anomalies is larger in Latin America and the Caribbean than in other world regions.

FIGURE 4.12. ESTIMATED IMPACTS OF EXTREME HEAT ANOMALIES ON NIGHTTIME LIGHT INTENSITIES FOR CITIES IN LATIN AMERICA AND THE CARIBBEAN VS. IN OTHER REGIONS, BY THE LEVEL OF DEVELOPMENT AND BASELINE CLIMATE, APRIL 2012–DECEMBER 2020



Source: World Bank calculations, based on the analysis of Visible Infrared Imaging Radiometer Suite (VIIRS) nighttime lights monthly composites (<https://payneinstitute.mines.edu/eoq-2/viirs/>) and monthly weather data from Climatology Lab, TerraClimate (<https://www.climatologylab.org/terraclimate.html>).

Note: Cities are defined as urban centers following the degree of urbanization methodology of the Global Human Settlement Layer (GHSL) Urban Centre Database. Each marker shows the estimated elasticity of an extreme heat anomaly on a city's nighttime light intensity. Vertical bars indicate the bounds of the 90 percent confidence interval associated with the corresponding estimates. In both panels, lower, upper-middle, and high are based on the World Bank's country income classification for the fiscal year 2023-24, where the lower class includes low- and lower-middle-income countries. In panel b, a city's baseline climate is classified based on the terciles of the distribution of long-run mean monthly temperatures across the globe. LCR = Latin America and the Caribbean Region. In panel c, a city's baseline climate is classified based on the terciles of the distribution of long-run mean monthly temperatures across the globe. In panel c, medium, large, and metro respectively correspond to the Organization for Economic Co-operation and Development's categories of medium cities (population of 200,000–499,999), metropolitan areas (population of 500,000–1.499,000), and large metropolitan areas (population of at least 1.5 million).

BOX 4.3**IMPACT OF EXTREME HEAT ANOMALIES ON URBAN ECONOMIC ACTIVITY IN THE REGION**

To what extent do extreme heat anomalies affect urban economic activities in the short run? To answer this question, spatially granular monthly data on temperatures were analyzed together with nighttime lights, a proxy for a city's aggregate level of economic activity. By measuring extreme heat as a monthly temperature anomaly relative to each city's historical norm, this analysis estimates how a city's nighttime light intensity changed during any month when the city experienced a heat anomaly between April 2012 and December 2020 (the period of analysis). This analysis includes 2,477 cities worldwide with a population above 200,000, of which 277 are in Latin America and the Caribbean.

For any given city, this analysis defines an extreme heat anomaly in any given month between 1958 and 2020 based on the number of standard deviations above the city's long-run average temperature for the same month. In mathematical term, an extreme heat in city c in month m of year y can be written as:

$$\text{Heat Anomaly}_{i,m,y} = \frac{T_{i,m,y} - \bar{T}_{i,m}}{SD_{i,m}}$$

where $T_{i,m,y}$ denotes the temperature in city i in month m of year y , while $\bar{T}_{i,m}$ and $SD_{i,m}$ refer to the city-specific long-run average and the standard deviation for month m , respectively, which are calculated for the base period January 1958–December 2000—up to the end of the 20th century. When the measure takes on a value of 2 or more, a heat anomaly is considered an extreme heat. The underlying gridded monthly temperature data (around 4 kilometers at the equator) is from TerraClimate. The idea behind the use of a relative measure of extreme heat is that:

- People—and human activities—react to unusual weather rather than high temperatures per se.
- People from different parts of the region have acclimated to different climatic conditions.
- Thus, for a cross-city analysis on a regional scale, a relative measure is more appropriate than an absolute one to characterize unusual weather that people perceive unusually hot.

Based on this relative definition, however, large standard deviations do not necessarily translate into severe events such as heat waves because the implications of an anomaly of a given size vary across cities according to their underlying climates. This analysis covers all the months during the period April 2012 to December 2020 for tropical cities located between latitudes 23.5° south and 23.5° north while covering only summer months (June, July, and August in northern hemisphere and December, January, and February in southern hemisphere) for cities outside the tropical regions.

4.4.3 HEAT WILL INFLICT A SUBSTANTIAL ECONOMIC BURDEN ON CITIES

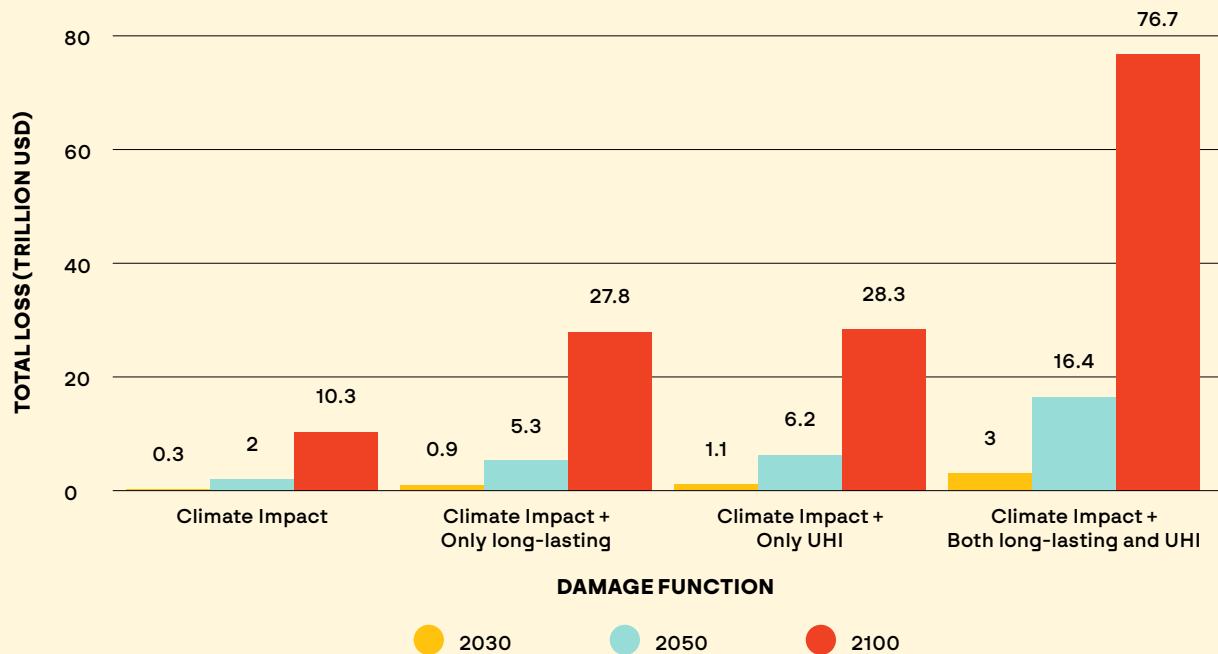
In the coming decades, cumulative toll of extreme heat on urban productivity is likely to be large. There are a variety of methods to estimate the projected economic impact of extreme heat for different climate scenarios. Most studies concentrate on assessing the impact on labor productivity and labor supply—discussed earlier in this section—on different climate scenarios, and covering different type of economic activities.

The most recent ones, conducted at the global scale, also take into consideration how countries and economic sectors adapt over time, such as by expanding the use of air conditioning, and how climate change impacts are amplified by the urban heat island (UHI) effect. Because the UHI effect increases the overall temperature, it can push cities into heat levels that are more economically harmful, as the economic effects of rising temperatures are not linear. For example, the negative impact of a 1°C increase in temperature—say, from 35°C to 36°C—is greater than that of an increase from 30°C to 31°C.³⁷⁰

Recent estimates suggest that in a middle-of-the-road-scenario (SSP2-4.5), the cumulative combined economic costs of climate change and the UHI effect to 2050 in Latin America and the Caribbean could add up to 1.2 to 2.5 times the region’s GDP in 2024.³⁷¹

The estimates are drawn from a climate economics model called CLIMRISK, which can project economic impacts from climate change in four ways: 1) considering just climate impacts as they happen; 2) accounting for the long-lasting effects of those impacts; 3) considering how the UHI effect exacerbates climate change impacts (as discussed in Section 1); and 4) considering both long-lasting effects and the UHI effect. Figure 4.13 shows the results for each approach (damage function). By 2050, the cumulative damages from long-lasting climate change impacts and UHI combined are eight times as large as from climate impacts alone, with projected losses for countries in Latin America and the Caribbean reaching nearly US\$16.4 trillion.

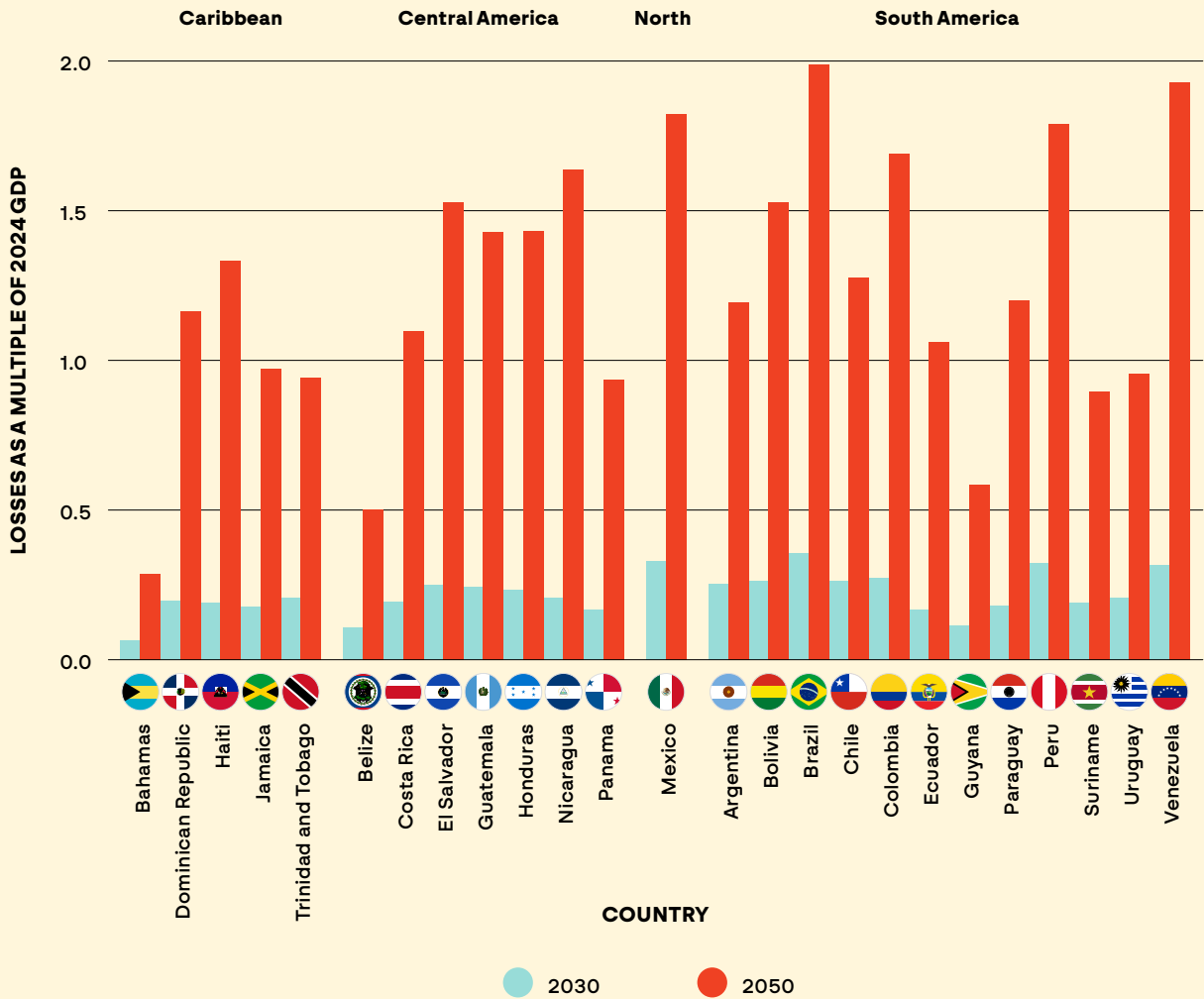
FIGURE 4.13. ACCOUNTING FOR BOTH LONG-LASTING EFFECTS AND UHI INCREASES PROJECTED GDP LOSSES EXPONENTIALLY IN COUNTRIES IN LATIN AMERICA AND THE CARIBBEAN



Source: World Bank, based on projections of Estrada and Calderón-Bustamante (2024) for Latin America and the Caribbean³⁷² in a middle-of-the-road-scenario (SSP2-4.5). Economic costs are reported as net present values calculated with 2010 as the base year, using 2024 as the baseline year for projections, with values presented for 2030, 2050, and 2100, using a discount rate of 1.5 percent.

In absolute terms, the analysis shows the largest losses by 2050 in Mexico, Brazil, Argentina, Colombia, Venezuela, and Peru. For example, in Brazil projected economic losses are US\$7.13 trillion (in 2010 dollars), close to twice the country’s projected GDP in 2024 (Figure 4.14).

FIGURE 4.14. PROJECTED CUMULATIVE LOSSES BY 2030 AND 2050, AS A MULTIPLE OF PROJECTED 2024 GDP

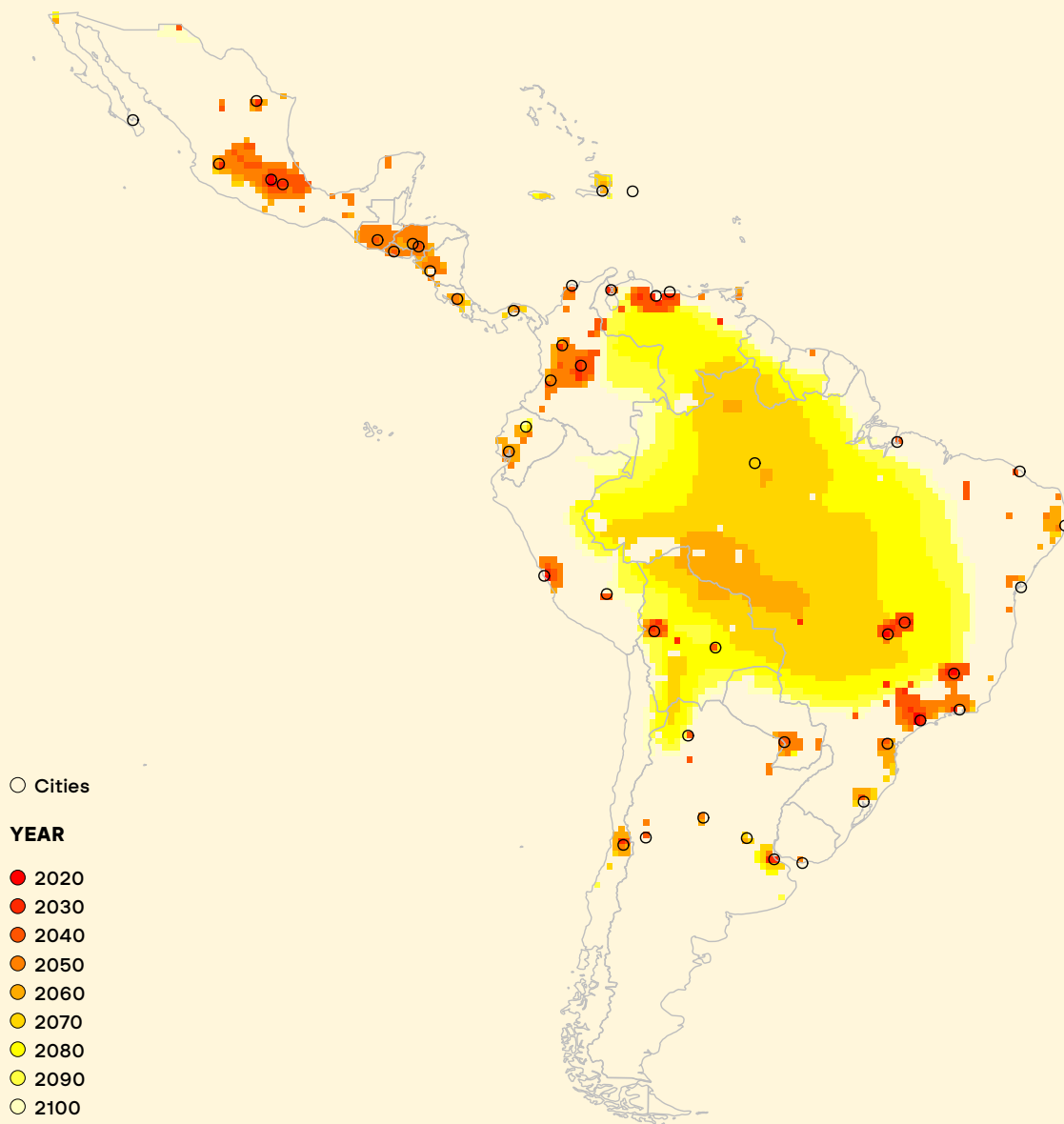


Source: Authors’ calculation from projection of Estrada and Calderón-Bustamante (2024) for Latin American and Caribbean countries, applying the damage function that incorporates both the UHI effect and long-lasting effects of climate change in a middle-of-the-road climate scenario (SSP2-4.5).

Note: Economic costs are reported as net present values calculated with 2010 as the base year, using 2024 as the baseline year for projections, with values presented for 2030 and 2050, using a discount rate of 1.5 percent.

Cities are already affected. Economic modeling reveals that climate impacts on major urban centers would be significantly more severe than on the broader continent.³⁷³ As shown in Figure 4.15, while most regions would not experience annual GDP reductions exceeding 5 percent until the 2080s or later, the CLIMRISK model indicates this threshold could be reached in capital cities by 2020–2030. Annual climate-related economic losses in other metropolitan areas are projected to surpass 5 percent in the 2040-2050s.

FIGURE 4.15. YEAR IN WHICH ANNUAL GDP LOSSES ARE PROJECTED TO EXCEED 5 PERCENT OF GDP



Source: Authors' calculation from projection of Estrada and Calderón-Bustamante (2024) for Latin American and Caribbean countries, applying the damage function that incorporates both the UHI effect and long-lasting effects of climate change in a middle-of-the-road climate scenario (SSP2-4.5).

Note: Economic costs are reported as net present values calculated with 2010 as the base year, using 2024 as the baseline year for projections.

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CHAPTER

5

KEEPING CITIES LIVABLE: PRIORITIES FOR ACTION



The analysis presented in this report confirms what millions of people in Latin America and the Caribbean already know firsthand: cities in the region are getting hotter—some dangerously so—and, without proactive adaptation efforts, the impacts on urban infrastructure and on human health, well-being, livelihoods, and urban economies will be significant.

Policy makers increasingly recognize the urgent need to build resilience to extreme heat. The good news is that effective solutions are within reach. Cities cannot stop temperatures from rising, but by mitigating the urban heat island effect, they can still make the heat more manageable. They can also protect people during extreme heat events, adapt infrastructure for hotter conditions, and limit the economic impacts.

There is a growing knowledge base on “what works,” including many low-cost interventions that fit within existing budgets and policy instruments. That is the focus of this section. Some key considerations in tailoring heat mitigation strategies to each city’s needs include:³⁷⁴



1. SPATIAL SCALE:

Addressing urban heat requires action from the national or regional scale (e.g., to improve energy systems or meteorological forecasts), to the city scale (e.g., rethinking urban design and land use plans), to specific neighborhoods or city blocks, to individual homes or other buildings or building complexes.



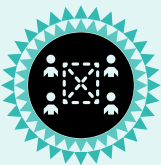
2. TIME HORIZONS:

Building heat resilience requires both urgent near-term action to prepare for and respond to heat emergencies, and medium- and longer-term actions to address urban heat. Cities must act promptly to protect the most vulnerable people and prevent serious illness and fatalities. Key policy measures, such as enhanced worker protections, may take a few years to adopt. And sustained efforts over years and decades will be needed to make cities cooler through improved urban design, more energy-efficient construction, and urban greening.



3 CO-BENEFITS:

Cities face multiple challenges, often with very limited resources. Many actions to mitigate urban heat can advance other objectives as well, such as improving air quality, managing flood risks, enhancing biodiversity, reducing energy costs, making homes more resilient to climate hazards, and improving disaster preparedness. Such co-benefits may increase buy-in and help cities make the most of available finance.³⁷⁵



4 **STAKEHOLDERS:**

Making cities resilient to a hotter climate requires a wide range of technical expertise and the engagement of many different stakeholders, from real estate developers, to employers, labor representatives, and community-based organizations. Bringing together such diverse perspectives can be challenging, but it is crucial to effective planning and successful implementation.

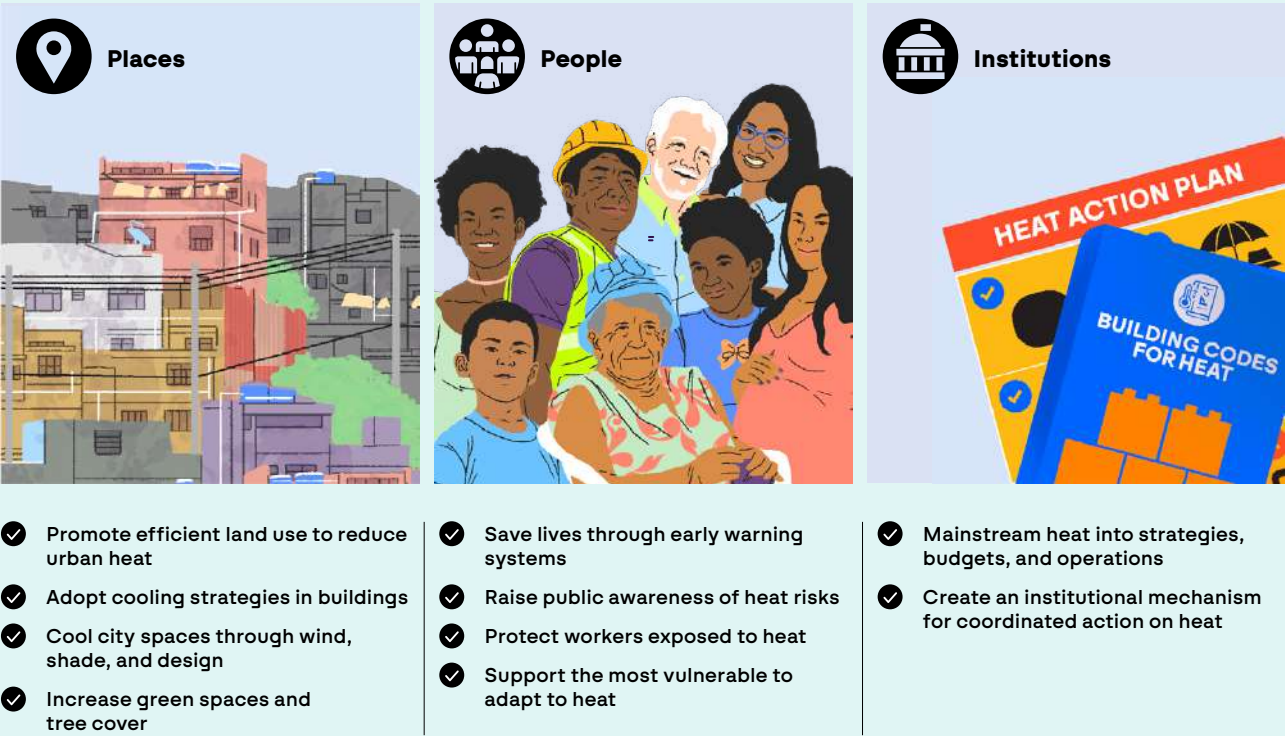


5 **POLICY INSTRUMENTS:**

Interventions to address urban heat will take many different forms: from “soft” policy instruments such as public awareness campaigns and incentives for residents, businesses, and public agencies, to “hard” legislative and regulatory mandates, such as changes to building codes.

The first regional report in this World Bank series on urban heat laid out a three-pronged approach to addressing urban heat: “Places, People, and Institutions.”³⁷⁶ As shown in Figure 5.1, this means a combination of strategies that address problems with urban design, land use, and infrastructure that exacerbate urban heat; measures to protect public health during heat emergencies, shield workers from dangerous heat, and help the most vulnerable people to cope and adapt; and institutional measures to mainstream heat resilience into city strategies, operations, and budgets.

FIGURE 5.1. A “PLACES, PEOPLE, AND INSTITUTIONS” FRAMEWORK FOR ADDRESSING URBAN HEAT



Source: Adapted from Roberts et al. (2023).³⁷⁷

Cities across Latin America and the Caribbean are already working to mitigate and adapt to rising urban heat. Many measures to date have focused on the “places” challenge, such as urban greening initiatives and structural interventions such as adding shaded shelters at bus stops. On the “people” side, governments have prioritized public health alerts during heat events and enhanced protections for workers, among others. Progress on the “institutions” side has been slower, but cities are increasingly creating the policies, plans, and institutional structures needed to mainstream heat resilience and enable effective, coordinated responses.

Sections 3 and 4 outlined key sector-specific interventions to make critical infrastructure systems and services more resilient to heat: from electricity supplies (section 3.3), to public transit and road networks (section 3.4), to schools (section 4.2).

Section 3.2 focused on improving housing and reducing indoor temperatures, with particular attention to the needs of low-income people. The report highlights the need for broad adoption of passive cooling strategies, which will require expanding the evidence base on effective solutions for hot and tropical climates, building capacity within the construction sector to implement these measures, and updating building codes to incorporate these approaches. In cases where passive measures alone are insufficient, expanding access to energy-efficient air conditioning and ventilation will be essential.

This section focuses on “big-picture” solutions: cooling cities through nature, shade, wind, and design (“places”), saving lives during heat events and protecting workers and the urban poor (“people”), and mainstreaming heat resilience into urban strategies, budgets, and operations (“institutions”). For additional guidance for planning at the city scale, as well as a summary of key urban heat solutions by sector, see Annex 1 and 2.

5.1 PLACES: COOL CITIES THROUGH DESIGN, SHADE, WIND, AND NATURE

Urban design and form play a crucial role in determining how hot or cool a city will be. As discussed in section 2.1, the UHI effect is a direct result of the built environment. Cities in Latin America and the Caribbean—as in much of the world—have large areas covered almost entirely in concrete, asphalt, and other heat-absorbing materials, with little or no vegetation.³⁷⁸ Many have also grown in sprawling, inefficient ways and have inadequate public transit, leading to high car dependency and severe traffic congestion.³⁷⁹

Some of these problems have existed for generations. Latin America and the Caribbean have been majority-urban, as a region, since the early 1960s,³⁸⁰ and many of the hot, densely built-up, often high-poverty neighborhoods discussed in section 2.3 are at least as old. Yet governments have also helped create new heat islands—often at the expense of cooling forests—by sponsoring or promoting, through policy, large-scale housing construction in urban peripheries.³⁸¹

5.1.1 PROMOTE LAND USE POLICIES AND DESIGN STRATEGIES FOR COOLER CITIES

Compact and connected urban forms, with strategic and efficient land use, have many benefits: from increased productivity, to lower greenhouse gas emissions.³⁸² Mixed-use development is a key element of this approach, as it makes it easier for people to access jobs, services, and amenities without having to drive. Well-planned, mixed-use density with good public transit and walking and cycling infrastructure can mitigate urban heat by reducing the number of vehicles on the streets—along with the heat and air pollution they produce.

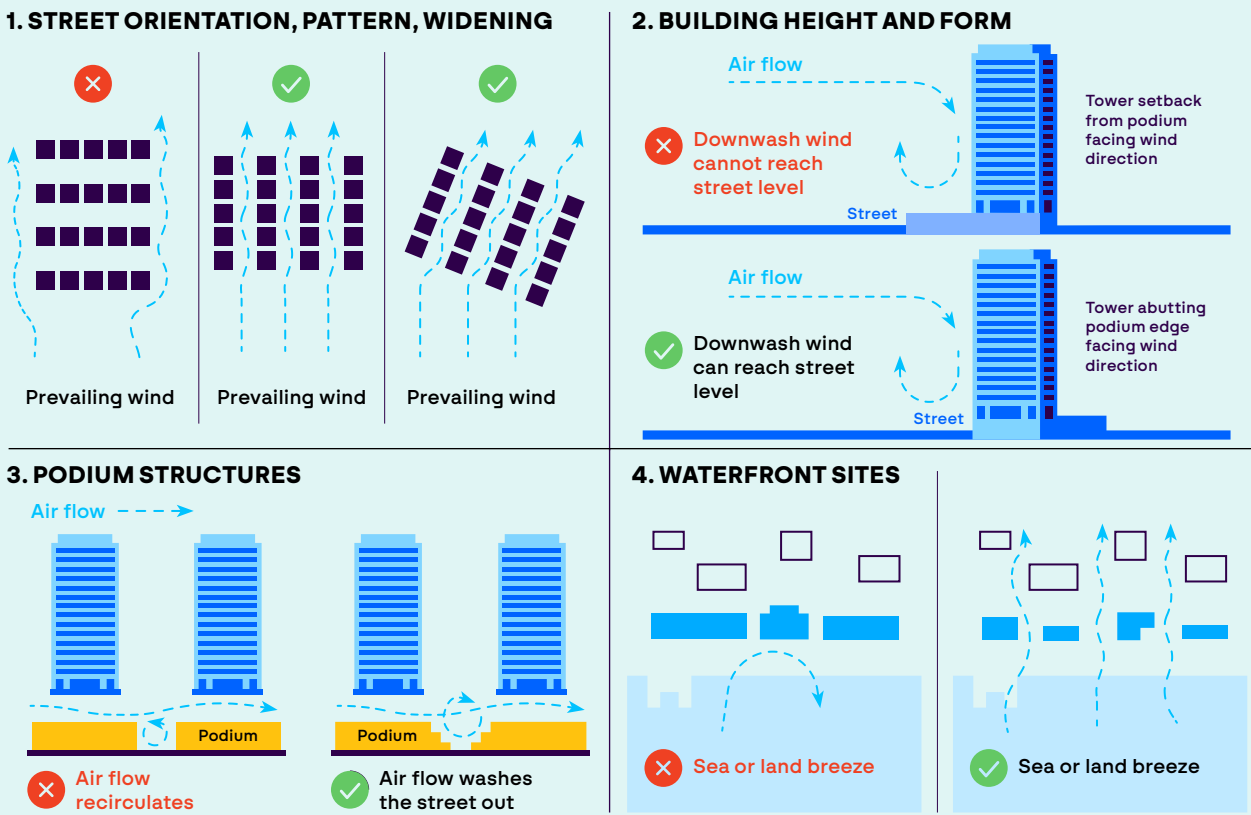
The notion of urban density as a solution to urban heat may seem counterintuitive, as there is evidence across the region and globally (see sections 2.1 and 2.2) that UHI effects are more severe in densely built-up urban areas. But cities have to grow somehow, and the alternative to compact development—within the existing urban footprint or on the margins—is sprawl. Studies around the world have found that while low-density growth results in less intense urban heat, it increases temperatures overall, as farmland, forests, and other green areas that provided cooling benefits are replaced by buildings and roads.³⁸³

Urban planners thus have to strike a delicate balance, and efficient land use is key. In Latin America and the Caribbean today, urban density often means low-rise buildings crowded together, with little or no green space. A more efficient approach is to build vertically to make the most of available space, while preserving or freeing up land for parks, tree-lined pedestrian corridors, and other green features.³⁸⁴ Strategically positioned tall buildings can also help cool cities through shading and ventilation (see Figure 5.2 below). To the extent that cities do grow outward, one way to mitigate the heating effects is to concentrate development along corridors with robust public transit, as Curitiba, Brazil, has done. This results in “star-shaped” cities with less traffic congestion and plenty of green space between corridors.³⁸⁵

Cities can also benefit from reclaiming space they had given up to cars. For example, Bogotá’s Vital Neighborhoods (*Barrios Vitales*) project is strategically reusing street space to make neighborhoods more dynamic, accessible, and pedestrian-friendly.³⁸⁶ By enhancing access to green space and integrating vegetation in the built environment, it is also making the targeted areas less likely to overheat. The program is supported by the city’s Climate Action Plan 2020–2050 and has engaged with communities to ensure successful implementation.³⁸⁷

Effective urban design strategies can significantly reduce urban heat, even in densely developed areas. These strategies include creating ventilation corridors by aligning major streets parallel to prevailing winds and using a “step-up configuration” where buildings become progressively taller downwind (Figure 5.2). Designing corridors for cool air to flow from nearby bodies of water is particularly beneficial for the region’s hot coastal cities. Considering the sun’s angles during the hottest hours is also crucial, to maximize shade.

FIGURE 5.2. STREET DESIGN FOR IMPROVED VENTILATION, COOLER TEMPERATURES, AND REDUCED AIR POLLUTION



Source: Reproduced from Roberts et al. (2023), drawing on Hong Kong SAR (2015).³⁸⁸

Modeling tools can be used to evaluate the cooling effects of various configurations. Many of these approaches draw on principles similar to those used when designing buildings for hot climates (see section 3.2).³⁸⁹ Some of these strategies may not be feasible in areas that are already densely built up, but they can still be implemented in large redevelopment projects, new housing complexes in the urban periphery, and urban expansion projects. For instance, in the China-Singapore Guangzhou Knowledge City Pilot Project, the World Bank worked with the Guangzhou Municipal Planning and Natural Resources Bureau to pilot initiatives to shape the urban layout to create wind corridors.³⁹⁰

5.1.2 INTEGRATE NATURE-BASED SOLUTIONS IN THE BUILT ENVIRONMENT

Incorporating cool and permeable surfaces in urban landscapes has proven effective in reducing urban heat. Sections 3.4 and 3.2 covered two key examples: cool pavements—with coatings or additives that make them reflect sunlight—and cool roofs, painted white or given another kind of reflective coating. Research has shown that applied at scale, such approaches can significantly mitigate the urban heat island effect—though, as discussed in the respective sections, there can be trade-offs, such as hotter air temperatures for pedestrians at midday.³⁹¹

Another approach to cooling paved areas is to use permeable surfaces such as porous pavements, which allow water to infiltrate and evaporate, providing additional cooling through evaporative processes. In Mexico City, for example, the Vía Verde (Green Way) project³⁹² turned a major highway viaduct into a massive vertical garden, adding plantings on more than 1,000 pillars as well as green strips, with permeable pavements that absorb rainwater. The vegetation also helps improve air quality and creates a small carbon sink. The use of permeable pavements can also help cities with stormwater management, reducing runoff—an important benefit in areas prone to flooding.

Given that a key reason why urban areas overheat is that they lack trees and other vegetation (see section 2.1), it makes sense that NBS to mitigate urban heat often involve greening. Across the region, cities are adding, expanding, and restoring green spaces, connecting fragmented areas into green corridors, creating pedestrian zones lined with planters, and planting trees along sidewalks and roads. However, environmental conditions—such as climate zones—largely determine how much green space a city can naturally support.³⁹³ At the same time, the distribution and accessibility of green areas, particularly parks, are shaped by urban planning policies.

Plants are being added to rooftops and to the sides of buildings, creating green roofs and green walls, just as the Vía Verde in Mexico City created green viaduct pillars. And some urban renewal and new affordable-housing projects have deliberately integrated shade trees and native plants favored by wildlife. A 2021 study identified more than 150 projects using NBS across the region, in both urban and rural settings, but it also found many projects were still in early stages, and there was significant potential to scale up these approaches in the region.³⁹⁴

More than 30 Latin American cities have joined Cities4Forests, a global alliance of urban leaders working to conserve, restore, and sustainably manage forests within and around cities.³⁹⁵ Among the first were Mérida, Mexico, which is surrounded by federally protected forest, but also the heavily built-up São Paulo, which has created new nature conservation areas and invested in street tree planting on a large scale.³⁹⁶ In Costa Rica, where over 60 percent of the land is covered by a conservation strategy, “interurban biological corridors” are being used to engage communities in restoring natural landscapes, particularly along rivers in dense urban areas, and create connected ribbons of green space.³⁹⁷ Cali, Colombia, has carved out multiple “green corridors” throughout the city, including by reclaiming 22 km of disused rail lines.³⁹⁸

None of these projects focuses only on mitigating urban heat, though it is a key benefit. Other benefits include reducing flood risks, increasing carbon storage, enhancing biodiversity, providing new amenities for exercise and recreation, improved social cohesion, and economic benefits.³⁹⁹ An analysis of 323 Latin American cities found that greater levels of greenness may offer some protection against heat-related deaths, especially in arid climate zones.⁴⁰⁰ Many projects explicitly aim to address disparities such as those discussed in section 2.3. In general, for example, in Latin America, street trees are more abundant in wealthier neighborhoods than in poorer ones—or in ones with large concentrations of older adults or children.⁴⁰¹

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Planting trees across large areas can create a “park cool island” effect, where differential heating between green and built-up areas generates localized breezes that cool surrounding blocks.⁴⁰² How far those effects are felt, and how intense they are, depends on characteristics of the parks (e.g. the density of the tree cover) and of nearby areas (such as the air flow patterns created by the built environment, as discussed above), as well as the direction and speed of the prevailing winds. Even street trees can make a significant impact; a study in Curitiba, Brazil, for example, found an average 1.6°C difference between streets with and without trees.⁴⁰³

Planting trees in cities is a relatively low-cost intervention with high returns on investment. For example, a 2024 World Bank economic analysis focused on three Indian cities found benefit-cost ratios of 3:1 or higher, as increasing the cities’ tree canopy cover by 10–30 percent could reduce air temperatures by as much as 1.5°C on a localized basis.⁴⁰⁴ The study only quantified the benefits of avoided heat-related mortality and labor productivity losses, but the authors noted the additional benefits of providing cooling areas for laborers, street vendors, workers, and commuters during hot days, as well as separate physical and mental health benefits.

A 2016 study by The Nature Conservancy and C40 Cities examined the potential health benefits of planting trees in 245 cities worldwide, considering both heat mitigation and improved air quality.⁴⁰⁵ It found that, at a median cost of \$468 per 1°C of cooling achieved over a 100-square-meter area, tree-planting was most cost-effective than any strategy except for cool roofs—and with particular impacts near the ground, where people benefit most. In Mexico City, the study showed, investing just \$861,000 per year to increase tree cover in some areas could reduce temperatures by 1.5°C for 361,000 people, while also improving air quality. In Rio de Janeiro, investing \$2.4 million per year could achieve the same benefits for about 942,000 people. Targeting areas with particularly severe UHI problems can maximize the return on investment.

Even small increases in the urban tree canopy can make a difference, but large-scale efforts can be transformative. In 2016, Medellín launched a three-year, \$16.3 million greening initiative to create “Green Corridors” (Corredores Verdes), planting 8,800 trees, as well as palms and shrubs, along 18 urban roads and 12 waterways.⁴⁰⁶ The city prioritized sites with traffic and air pollution, and trained 75 people from disadvantaged backgrounds to care for the green spaces. The plantings reduced air temperatures by about 2°C, improved air quality, and have even brought wildlife back into the city, prompting further investments in greening since then.⁴⁰⁷ In Medellín, according to city officials, the cost of planting trees amounts to US\$38–140, including the supply, transport, and planting of trees (depending on size and species); maintenance costs around US\$10–20 per tree per year.

BOX 5.1

EXPLORING OPPORTUNITIES FOR NBS IN LATIN AMERICAN AND CARIBBEAN CITIES

The Global Program on Nature-Based Solutions for Climate Resilience (GPNBS) fosters knowledge, operations, and partnerships to identify, prepare, and implement investments in NBS. To support this work, the program created the Nature-Based Solutions Opportunity Scan, a tool to provide a rapid assessment of the potential for NBS to improve climate resilience in cities worldwide.⁴⁰⁸

To explore opportunities for NBS to reduce heat stress in cities in the region, the tool was applied to a sample of Latin American and Caribbean cities: Belém, Buenos Aires, Cali, Kingston, San Salvador, Santa Cruz, and Santo Domingo.

The share of built-up land in those cities ranges from 38 to 61 percent of total land area, with an average of 52 percent. Current tree cover ranges from 16 to 49 percent, with an average of 26 percent. That tree canopy is a critical source of protection from urban heat, among other benefits. Next, the analysis explored how much tree canopy cover could potentially be increased.

FIGURE 5.3. CURRENT TREE CANOPY COVER AND POTENTIAL FOR EXPANSION

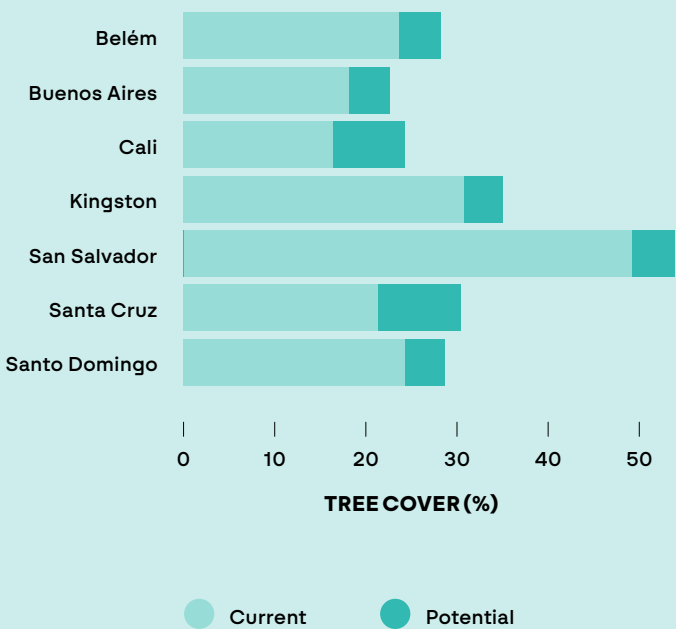


Figure 5.3 shows the current tree canopy cover in each city and the potential for expansion. On average, the analysis showed, urban greening initiatives—new parks, green corridors, street trees, etc.—could increase tree cover by 25 percent.

While the tool identifies all potential NBS creation opportunities within urban cores, the potential heat stress benefits vary. In general, NBS opportunities in densely populated areas will provide the highest cooling benefits. Across all cities, green corridors provide more heat reduction benefits than urban forests due to their potential to 1) provide cooling benefits in densely populated areas, and 2) their potential to reduce local urban heat islands by offsetting the warming effects of roads and paved surfaces. On average, the implementation of green corridors is estimated to reduce local UHI effects by 29 percent across the seven example cities.

5.2



PEOPLE: PROTECT HUMAN HEALTH AND WELL-BEING

The human impacts of extreme urban heat are profound: from disruption to children's schooling, to exhaustion and productivity loss for workers, and rising burden of heat-related illness and mortality (see Section 4). Actions to reduce heat exposure in the built environment are part of the solution, but they cannot fully protect people from excessive heat. When temperatures rise to dangerous levels, city and national authorities need to be ready. Early warning systems, clear guidance on heat-related risks and protective measures, and targeted policies can save lives and help people in cities across Latin America and the Caribbean to stay safe on hot days.

5.2.1 SAVE LIVES THROUGH EARLY WARNING SYSTEMS

To a great extent, heat-related deaths and illnesses are predictable. They are concentrated in the hottest months of the year, especially when temperatures exceed certain thresholds (see Box 1.1 and section 4.1), and mainly involve people who are particularly vulnerable due to their age or health status, and/or who are highly exposed to heat due to their jobs or other factors.

Most of these deaths and illnesses are also preventable. People can protect themselves to a great extent by staying out of the sun, drinking plenty of water, avoiding physical exertion, and, if needed, cooling their bodies through strategies such as applying cold water.⁴⁰⁹ They can also use fans and air conditioning to bring down indoor temperatures. Not everyone can do this—they may not have access to potable water when they need it, for instance, or they may be unable to leave a job site. However, for a large share of the population, a timely warning and guidance should go a long way towards staying safe.

This means a crucial part of the solution is to set up systems to warn the public and mobilize emergency responses as needed. That is the purpose of heat early warning systems (EWS): mechanisms that use weather forecasts to trigger the issuance of public health advisories, as well as key interventions by public agencies and other stakeholders, such as opening public cooling centers.

Global experience with heat EWS is still fairly recent. In the United States, cities such as Philadelphia pioneered them in the 1990s. European countries and Japan have implemented them since the 2000s, and middle-income countries such as India, Argentina, and Chile introduced them in the 2010s. Already, the evidence of their effectiveness is strong enough that the World Meteorological Organization (WMO) and World Health Organization (WHO) have estimated that scaling up heat health warning systems in just 57 countries could save over 98,000 lives per year.⁴¹⁰

Experience with heat EWS in Latin America and the Caribbean to date offers important lessons and examples for cities across the region. Argentina, for instance, uses a system of color-coded alerts (Box 5.2). The Regional Metropolitan Government of Santiago,

Chile, has established a comprehensive regional protocol for extreme heat management, in partnership with the Chilean Meteorological Service (DMC), the National Service for Disaster Prevention and Response (SENAPRED), and other stakeholders. The protocol implements a tiered alert system triggered when temperatures are forecast to reach 24°C or higher (see section 5.2.2).

Heat EWS have only modest implementation costs, but have been shown to deliver significant benefits in terms of deaths prevented and economic losses averted.⁴¹¹ A World Bank study focused on Indian cities found that heat EWS, which have been implemented in cities such as Ahmedabad, had a benefit-cost ratio of 50:1.⁴¹² The very high benefit-cost ratio reflects the fact that heat alert systems—particularly when paired with a targeted emergency management protocol—enable well-coordinated action to protect vulnerable people when the risk is highest.

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BOX 5.2

ARGENTINA'S EARLY WARNING SYSTEM FOR EXTREME TEMPERATURES

Argentina has seen a dramatic increase in extreme weather events over the past six decades, particularly in rising temperatures. The frequency of heatwaves has significantly increased, with the number of heatwaves occurring between 2010 and 2018 being twice as high as in the 1990s.

The extreme heatwaves of the summer of 2013–2014, which led to preventable fatalities, spurred further research into the health impacts of extreme heat.⁴¹³ Collaborative research by the Ministry of Health, the National Meteorological Service (SMN), and universities revealed a strong statistical link between extreme temperatures and increased mortality rates.⁴¹⁴ The analysis found that mortality risk during heatwaves rose significantly in 13 out of 18 provinces, while extreme cold temperatures were also associated with higher mortality rates in several cities. These findings highlighted the urgent need for an effective early warning system.

In response, the SMN, the Ministry of Health, and partners developed the Early Warning System for Heatwaves and Health and piloted it in two cities, Buenos Aires and Rosario. This system was designed to reduce heat-related mortality by providing targeted alerts and health guidance to the public, health care providers, and civil protection agencies. After further research, in 2017 the temperature thresholds were adjusted, and in 2021, the

system was expanded to 168 locations nationwide. It was also renamed as the Early Warning System for Extreme Temperatures – Heat (SAT-TE Calor), complemented by a similar system for extreme cold.



BOX 5.2 (CONTINUATION)

ARGENTINA’S EARLY WARNING SYSTEM FOR EXTREME TEMPERATURES

SAT-TE Calor issues color-coded alerts (yellow, orange, and red), starting when a location is forecast to surpass the 90th percentile of temperatures for that place. Yellow alerts signal caution, while orange and red alerts, issued at progressively higher temperatures, indicate the need for stronger protective measures.⁴¹⁵

SAT-TE Calor leverages existing weather monitoring infrastructure, including data from automatic weather stations, to generate forecasts and issue alerts. The SMN issues the weather alerts, and the Ministry of Health provides health advice. From October 2021 to March 2022, for example, 987 daily alerts were issued nationwide (615 yellow, 205 orange, and 167 red). Alerts are disseminated through social media, the news media, and other channels to ensure timely preventive actions. The system also helps the health system to prepare for and manage the increased demand on hot days. The same color coding is used for other hazards (always with clear labels showing what the hazard of concern is), and a website provides detailed guidance.

Establishing heat EWS requires important groundwork by city or national governments, including engaging with public health agencies and epidemiologists to identify temperature thresholds at which action is needed. However, cities may not need dedicated EWS just for heat. If they have existing EWS for other hazards, such as floods, storms, or wildfires—or need to set them up—heat can be integrated into a multi-hazard early warning system (MHEWS).

MHEWS are indispensable tools for managing complex and interconnected risks and responding to cascading hazards. For example, a severe heatwave may increase wildfire risks, deplete water resources, and intensify drought conditions, while heavy rainfall may trigger flooding in already parched areas. MHEWS enable authorities to issue coordinated alerts ensuring communities and emergency teams are prepared for these overlapping hazards.

Another key issue to consider in designing a heat EWS—stand-alone or as part of a MHEWS—is the kind of warnings that should be issued. Traditionally, warnings have focused on the hazard that is forecast, not necessarily the expected impacts on people, infrastructure, and livelihoods. However, there is a growing shift toward impact-based forecasting and warnings.

Impact-based forecasting considers vulnerabilities in each context to predict the likely consequences of extreme events. For example, during a heatwave, such systems may forecast not only the expected temperature, but also specific health risks, with dedicated alerts for older adults, outdoor workers, or other groups of concern. They may also warn about risks to infrastructure systems and services, such as water shortages, power outages, or crowded emergency rooms. Table 5.1 provides some examples of how impact-based warnings would differ from conventional extreme-weather forecasts.

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TABLE 5.1. METEOROLOGICAL WARNINGS VS. IMPACT-BASED WARNINGS

METEOROLOGICAL WARNING	IMPACT-BASED WARNING
 “Temperatures are expected to reach 40°C over the next three days, with high humidity.”	“Extreme heat will persist over the next three days. High temperatures and humidity increase the risk of heat exhaustion and heat stroke, especially for older adults, children, and people with chronic health conditions. Take steps to stay cool and hydrated, and check on vulnerable neighbors and family members.”
 “The heatwave is expected to last from Tuesday to Friday, with temperatures consistently above 35°C.”	“An extended heatwave from Tuesday to Friday will place a heavy demand on the power grid, increasing the risk of outages. Public transit systems may experience delays. Avoid non-essential outdoor activities, plan for possible power interruptions, and go to one of the city’s five cooling centers if you cannot stay cool at home.”
 “A heat advisory is in effect, as temperatures are expected to exceed seasonal norms by 5°C.”	“A heat advisory is in effect: Outdoor work and physical activities should be limited. Schools and camps are advised to adjust outdoor schedules to avoid peak afternoon heat. Cooling centers will be open, and residents are encouraged to seek indoor spaces if they don’t have air conditioning at home.”

Integrating impact-based forecasting into MHEWS provides significant benefits for addressing heat and other interconnected risks, providing a wealth of valuable information:

- **Timing and location of expected impacts**, detailing when and where impacts will occur, which may differ from the hazard’s origin or peak;
- **Severity and likelihood of impacts**, helping prioritize response actions based on the risk levels of each potential consequence;
- **Impact types**, identifying specific sectors or populations at risk, from vulnerable communities to critical infrastructure;
- **Actionable advice**, such as practical steps to mitigate risks, ensuring that response actions are clear and timely.

Such approaches not only help save lives, but also maximize the efficiency of resource allocation. However, many countries in the region face significant challenges in implementing them, due to limited technical and financial resources, insufficient data collection, and inadequate interagency coordination. To overcome these barriers, improvements in data-sharing, community education, and regional agreements on forecasting are crucial.

Expanding the use of global forecasting models, such as the European Centre for Medium-Range Weather Forecasts (ECMWF) and Copernicus Climate Change Service, can help increase forecast accuracy and extend lead times for extreme heat events. The current two- to five-day lead time for extreme heat events that is typical in the region should be extended to seven to 10 days to enable proactive, life-saving measures. It is also important to increase the density of observation networks—especially in urban areas—to collect high-resolution data.

5.2.2 PROTECT URBAN WORKERS FROM THE HEAT

Governments can develop a range of regulations to protect workers from the adverse effects of excessive heat. These measures often include mandatory rest breaks, provision of shaded rest areas, and restrictions on outdoor work during peak heat hours. The ILO “Code of Practice on Ambient Factors in the Workplace” provides detailed recommendations that can inform policies and guide employers who know their workers may face high levels of heat and/or humidity.⁴¹⁶

The ILO calls for assessing whether conditions could lead to heat stress, given the ambient temperature, workers’ exposure to radiant heat, the arduousness of the work, and other factors.⁴¹⁷ Efforts are to be made to eliminate the need to work in hot conditions, or at least to reduce the thermal load, such as through improved ventilation and water sprays. Employers are also urged to arrange a work–rest cycle for exposed workers, and provide water and/or suitable cold drinks. Workers should also be supervised, so they can be removed if they start to show symptoms of heat stress, and first-aid facilities should be available.

There are many examples that policy makers in Latin America and the Caribbean can learn from and emulate—across the world and within the region. For example, in a collaboration that the ILO has highlighted as a model, Greece’s labor ministry worked with labor and employers’ organizations, doctors, scientists, the national meteorological service, and other experts to develop an integrated framework to protect workers from heat stress.⁴¹⁸ The measures included changes to work schedules and to protective gear, considerations for vulnerable workers, including those who are not acclimatized, and thresholds, based on wet bulb globe temperature (WBGT), when work must stop: 32.5°C for low-intensity work, 31.5°C for moderate-intensity work, 30.5°C for high-intensity work, and 30°C for very high-intensity work. The meteorological service developed 48-hour WBGT forecasts for the entire country, which are available on a smartphone app. A pilot phase allowed for real-world testing of the new rules.

Qatar worked with scientists and the ILO in 2019 to study workers’ exposure to excessive heat and update the country’s existing worker protections.⁴¹⁹ In 2021, Ministerial Decision No. 17 banned outdoor work from 10 a.m. to 3:30 p.m. from June 1 to September 15, expanding a previous ban. In addition, if at any time, the WBGT rises above 32.1°C in a particular work site, all work must stop. Employers must also provide workers with annual health checks and educate them about heat stress, with specialized training for those at greatest risk. Data collected by the Qatar Red Crescent found that in the first summer after the new rules were adopted, hospitalizations associated with workplace heat stress dropped by more than half.

Brazil has also set thresholds for when employers must adopt measures to protect workers from heat: If WBGT exceeds 31.7°C for very low-intensity work (100 W), or 20.7°C for very high-intensity work (602 W),⁴²⁰ employers must provide fresh drinking water, try to reschedule high-intensity work, and provide heat-protective clothing if appropriate.⁴²¹ If WBGT exceeds 33.7°C for very low-intensity work (100 W), and 24.7°C for very

high-intensity work (606 W), employers must take measures to reduce the temperature, such as adapting work processes, alternating low- and high-exposure tasks, and providing a cooler space for workers to take breaks.

Mexico's Federal Regulation of Occupational Health and Safety, adopted in 2014, outlines measures for employers to protect workers from heat stress.⁴²² They must identify areas with hazardous heat conditions, for example, and adopt risk reduction strategies such as placing safety signs to limit access to areas with thermal hazards, taking action to reduce heat as needed, and providing workers with personal protective equipment. Employers must also educate workers about heat stress, and are forbidden from assigning pregnant workers to tasks that would expose them to extreme heat (see Box 5.3 for Costa Rica).

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BOX 5.3

PROTECTING OUTDOOR WORKERS FROM HEAT STRESS IN COSTA RICA

In 2015, in response to studies showing high rates of chronic kidney disease among Central American farmworkers, Costa Rica adopted a new regulation aimed at protecting all outdoor workers.⁴²³ Inspired by approaches taken in the United States, it includes a range of measures:

1. **Elimination and control of heat sources:** Efforts should be made to eliminate unnecessary heat and water vapor sources, shield radiant emissions, and use ventilation systems to draw in cooler air.
2. **Cooling measures:** Install spot coolers, blowers, fans, or air conditioning to relieve humidity and move the air. Dehumidifiers and other humidity reduction methods should also be used.
3. **Hydration and breaks:** Workers should be provided with clean, fresh water and allowed frequent short water breaks at regular intervals during their shifts. A recommended practice is to drink a cup of water (250 ml) every 15–20 minutes.
4. **Respite areas:** Provide cool rooms or heat refuges where workers can take breaks and recover from the heat.
5. **Education and acclimatization:** Workers should be educated about the signs and symptoms of excessive heat exposure and heat stroke, as well as about the acclimatization process. Workers should be given time to reacclimatize after being away from the hot environment.
6. **Buddy system:** Implement a system in which worker look after one another to ensure safety and quick response in case of heat stress symptoms.
7. **Protective equipment:** Ensure that workers have suitable personal protective equipment (PPE) that does not contribute to heat stress.
8. **Work scheduling:** Pace work to suit the conditions and schedule physically demanding tasks during cooler parts of the day.

The regulation's implementation has led to significant improvements in worker safety, particularly in reducing the incidence of health impacts such as heat stroke and heat exhaustion. The requirements for providing shaded areas, rehydrating drinks, and acclimatization periods have been effective in creating safer working conditions.

However, some shortcomings have been noted, including inconsistent enforcement and limited resources for smaller employers to fully comply with the regulation. In addition, while an accompanying health surveillance program has been beneficial, there are challenges in maintaining comprehensive monitoring and follow-up due to logistical and financial constraints. These issues highlight the need for ongoing support and resources for effective implementation.

While national governments have typically taken the lead in protecting workers from extreme heat, cities can also take action. Worker protection is a key priority as part of the “Code Red” heat action protocol in Santiago, Chile, which includes educational initiatives for employers about heat-related dangers and the implementation of protective practices. Figure 5.4 shows an educational sign from the initiative.

FIGURE 5.4. A PUBLIC AWARENESS SIGN TARGETING WORKERS AS PART OF SANTIAGO’S “CODE RED” INITIATIVE



Developing and implementing worker protection measures can present challenges, however. One is ensuring compliance, especially in sectors with a high proportion of informal or unregulated work, such as construction. In Brazil, for example, informality has been a challenge in enforcing heat protection regulations. There may also be resistance from employers due to concerns about productivity and financial costs associated with implementing heat protection measures. It is crucial to have robust enforcement mechanisms and public awareness campaigns to educate both employers and workers about the health risks of heat exposure and the benefits of compliance. Integrating these regulations into broader occupational health and safety frameworks can help ensure their sustainability and effectiveness.

Ensuring that worker protection strategies are inclusive and equitable is also critical. Gender norms and occupational segregation often shape who is most exposed to heat. Women, for example, are frequently overrepresented in caregiving roles and informal sectors like street vending or domestic work, where protections are limited or absent. Disaggregating heat exposure and health impact data by gender can uncover these patterns and inform more responsive regulations. Embedding gender sensitivity into occupational health and safety frameworks—through targeted policies like mandated rest breaks, shaded areas, hydration stations, and flexible hours—can help ensure that protections reach those most at risk, while also supporting productivity and well-being.

5.2.3 SUPPORT THE URBAN POOR THROUGH SOCIAL PROTECTION AND MICRO-INSURANCE

Given the large implications of extreme heat for workers' livelihoods, governments in Latin America and the Caribbean may also find it beneficial to enhance social protection—and/or innovative micro-insurance instruments—to provide targeted support to individuals and communities affected by extreme heat events. Appropriate programs may include direct cash transfers, subsidies, and insurance schemes that activate payouts when certain temperature thresholds are met.

Many countries in Latin America and the Caribbean already have strong social protection systems and have even used adaptive social protection (ASP) systems to quickly deliver assistance after disasters and, most notably, during the Covid-19 pandemic.⁴²⁴ For example, after catastrophic floods in Rio Grande do Sul in May 2024, Brazil provided prompt support to affected households through its Bolsa Familia program, including 21,700 newly enrolled families.⁴²⁵ It also quickly delivered targeted aid for reconstruction.

Governments in the region recognize ASP as a key tool to shield the urban poor from climate shocks and other emergencies. Yet despite advances in recent years, significant gaps remain—both in the underlying systems, and in the financing, data and information systems, and institutional arrangements needed to successfully deploy ASP.⁴²⁶ Moreover, although ASP has been used across the region to respond to hurricanes, major floods, and other disasters, there are few examples of applications in the context of extreme heat. Integrating these programs with broader climate adaptation and disaster risk management strategies is essential but complex, requiring collaboration across various sectors and levels of government.

Micro-insurance provides another, potentially more feasible option for governments with limited resources. For example, in India, a micro-insurance scheme for extreme heat was implemented for 50,000 self-employed female workers, providing automatic payouts when temperatures exceed a specific threshold for three consecutive days.⁴²⁷ When temperatures in Rajasthan, Gujarat, and Maharashtra reached 40°C Celsius in May 2024, each woman received US\$5.

Similarly, in Bangladesh, the Early Action Protocol (EAP) for extreme heat offers multi-purpose cash transfers to vulnerable populations, including outdoor workers, to help mitigate the heat's effects.⁴²⁸ While accurate data, financial resources, and institutional capacity are still essential, promising models such as those piloted in India and Bangladesh offer innovative, scalable solutions. These programs directly support vulnerable urban populations, enabling them to pause work during extreme heat and address health needs, with particular benefits for women, who often face heightened risks.

Incorporating gender considerations into ASP frameworks can further enhance the effectiveness of these programs. Gender-informed strategies—such as targeted cash assistance, micro-insurance, or caregiver support—can help mitigate the socio-economic impacts of extreme heat, particularly for those most vulnerable to heat stress. These measures ensure that resilience-building efforts are not just reactive, but responsive to the lived realities of historically marginalized groups who are often excluded from formal protection systems.

These models could be adapted for Latin American and Caribbean countries. Integrating heat micro-insurance into adaptive social protection frameworks, with subsidies targeting the urban poor and women workers, could overcome potential barriers like limited willingness to pay. With financing support from initiatives such as the Global Facility for Disaster Reduction and Recovery (GFDRR) and the Global Shield, these innovative pilots could be transformative in building resilience to extreme heat across the region.

5.3 INSTITUTIONS: MAINSTREAM HEAT INTO STRATEGIES, BUDGETS, AND OPERATIONS

Governments in Latin America and the Caribbean increasingly recognize that extreme heat is a serious threat that requires comprehensive, systemic responses. As highlighted by the wide range of strategies discussed in this section alone, it is time to mainstream heat resilience into city strategies, operations, and budgets—and into the national systems that support them.

For cities, the first step is to take stock: to assess what they know about heat in their community; its impacts on people, infrastructure, and the economy; which institutions and stakeholders have a role to play in building heat resilience, and what is already being done (see Annex 1).⁴²⁹ Based on what they learn, they may choose to develop a stand-alone heat action plan, or integrate heat management into a larger climate action, disaster risk reduction, or sustainable development plan. They may partner with neighboring cities to develop a regional plan, and/or work closely with national or state or province-level government agencies. The key is to create an overarching strategy to proactively address urban heat and prepare for heat-related emergencies, with sustained coordination and stakeholder engagement.

Few cities have such plans today, even if they have been proactive in addressing climate change. A 2023 World Bank analysis of the climate action plans of 30 cities in eight countries in Latin America and the Caribbean found that out of 622 adaptation actions described in the plans, only 41—less than 7 percent—addressed extreme heat.⁴³⁰ The measures mainly involved nature-based solutions. This means that there is significant potential to better integrate heat resilience into cities' climate plans, incorporating strategies beyond NBS.

Whichever approach they take to heat action planning, cities need to recognize that building heat resilience requires both effective leadership and strong collaboration. They will need to bring together multiple agencies and diverse stakeholders, and build political will and public support. A systematic approach is also crucial for maximizing co-benefits and for budgeting and securing external finance as needed.⁴³¹

In contrast with established policy priorities such as transportation, housing, or health, no single government agency is typically vested with the authority and resources to lead on heat resilience. The actions needed tend to be fragmented among multiple agencies, and city or national governments often lack a clear focal point for leadership on this agenda.

In recent years, cities in Latin America and the Caribbean and in other regions have started creating new institutional mandates on heat resilience, ranging from committees of enquiry, to city task forces, to a dedicated Chief Heat Officer. The very first Chief Heat Officer in the world was appointed in Miami-Dade County, Florida, in the United States in May 2021, after local stakeholders identified extreme heat as their top concern around climate change.⁴³² Since then, Santiago, Chile; Monterrey, Mexico, and more than a dozen cities or regions globally have introduced dedicated positions to lead on this agenda.

Reflections by Chief Heat Officers highlight the importance of gradually building momentum through a sequence of activities.⁴³³ This approach helps establish a robust evidence base, engage key stakeholders, and encourage public agencies to integrate heat resilience targets into their budgets and operations.

5.3.1 GUIDE EFFECTIVE RESPONSES THROUGH HEAT ACTION PLANNING

Many cities that have developed heat resilience strategies share a particular experience: heat resilience work started out as an effort of a very small number of individuals, with limited access to funding and management attention, but gained momentum as the activities progressed. In a growing number of cases, cities or regions have seen the benefits of developing a heat action plan or similar strategy aimed at mitigating the adverse impacts of extreme heat.⁴³⁴

Inclusive approaches can help ensure heat action plans meet the needs of the most vulnerable and have buy-in from stakeholders who will play key roles in managing heat

risks. After appointing its first Chief Heat Officer in 2022, the city of Santiago, Chile, followed a consultative process before introducing the “Code Red” extreme heat response protocol.

For cities that are at an early stage in addressing the extreme heat challenge, it is wise to begin by appointing a task force to review evidence on extreme heat impacts, consult affected groups, and recommend actions. In Miami, for example, a key insight from research and workshops organized to inform the county’s new heat action plan was that everyday summer conditions, not just rare heatwaves, increased heat-related mortality risks.⁴³⁵ The work also showed that the places with the highest rates of severe heat-related illness had more intense UHI effects and/or higher proportions of vulnerable people including outdoor workers, Indigenous populations, people living in poverty or mobile homes, or households with children.

Broad-based consultations—and innovative approaches such as “citizen science” heat mapping campaigns—can support the effort by building a strong evidence base while bringing community voices into the debate. Building a partnership (a “cool city coalition”) with stakeholders inside and outside government can also advance heat resilience actions.

For example, in Buenos Aires, the city has established a Climate Shelter Network in partnership with public and private organizations. This initiative transforms spaces such as libraries and banks into cooling centers, offering residents a place to cool off and find temporary relief during hot days.⁴³⁶ By bringing evidence to the table and strengthening partnerships, urban and national leaders can act decisively to reduce heat exposure increase heat resilience.

While heat action planning is still a fairly new concept for most cities, there are many resources available to support municipal leaders, with examples and lessons from around the world.⁴³⁷ Heat action plans have proven to significantly reduce heat-related illnesses and fatalities, protect vulnerable populations, and maintain the continuity of essential services.⁴³⁸

A well-crafted plan should incorporate both near-term actions, such as the implementing EWS, and long-term strategies, such as urban greening and infrastructure improvements. For clarity and accountability, it may be helpful to formulate “SMART” objectives—that is: specific, measurable, achievable, relevant, and timebound.⁴³⁹ This might mean, for example, “launch a Cool Roof Program for elementary schools to achieve 20 percent coverage by 2030,” or “by 2035, reduce heat-related mortality among people over the age of 65 in the city through targeted health risk awareness campaigns.”

Another feature of effective heat action plans is special attention to vulnerable populations, including children, older adults, people who lack adequate housing (such as residents of informal settlements), and others who are at particularly high risk, with targeted measures to support them. For example, integrating gender-responsive

strategies into heat action plans—by engaging diverse gender groups in planning and decision-making—can help ensure that solutions reflect the varied experiences of daily life, particularly for those from marginalized communities. Ensuring that these plans are inclusive requires close coordination among stakeholders, including government agencies, community organizations, and private sector partners, which is crucial for streamlined implementation and support.

It is also essential to secure adequate funding and resources to sustain these initiatives and achieve meaningful outcomes. Recent analysis by the World Bank has highlighted the need to tap into a wide range of financing sources to support urban climate resilience and low-carbon growth.⁴⁴⁰ Along with climate-specific financing, such as green bonds or adaptation finance, national and local budgets, development finance institutions, public-private partnerships, loans, bonds, and private investment may all play a role, depending on the actions to be funded. Many efficiency measures will pay for themselves—for instance, through reduced energy costs—but may still require significant upfront investments.

Annex 1 and 2 provide additional guidance and an overview of urban heat solutions by sector. For city leaders across Latin America and the Caribbean, the key takeaway is that urban heat can be managed—and efforts to address it could have numerous benefits: from cost savings, to cleaner air, to healthier and more livable communities.

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ANNEX 1: FROM STOCKTAKING TO ACTION ON URBAN HEAT

As discussed in Section 5.3, mainstreaming heat resilience into a city's institutions and strategies requires a systematic approach, tailored to the context: from the city's size and available resources, to the local climate, to the severity of extreme heat risks.

Table A1, adapted from the East Asia counterpart to this report, lays out key steps that a task force on urban heat can take to assess local needs, identify appropriate solutions, and take action, including by mainstreaming heat resilience into existing institutions and strategies. Annex 2 complements this table with a sector-by-sector catalogue of urban heat solutions.

It is important to stress that while Table A1 frames the process from a single city's perspective, in practice, the work will almost certainly involve institutions at the state/province and national levels as well, as many of the required actions fall under their mandates. In large metropolitan areas, there is also a need to coordinate among municipalities. Cities may also choose to band together to make the most of limited resources and tackle shared challenges.⁴⁴¹

TABLE A1. KEY QUESTIONS AND ACTIONS FOR AN URBAN HEAT TASK FORCE

PHASE	1.	→ 2.	→ 3.	→ 4.
	TAKE STOCK	BUILD THE EVIDENCE BASE	BUILD A "COOL CITY COALITION"	IDENTIFY AND IMPLEMENT SOLUTIONS
 Activities	› Review knowledge, strategies, and actions relating to urban heat	› Strengthen understanding of heat hazards, vulnerability, and impacts	› Identify and engage key institutional actors and stakeholders	› Identify priority policy actions and investments, integrate into budgets and plans, and take action
 Places				
 Key questions	› Have urban heat island studies been carried out already? › What are the City and other stakeholders already doing to cool urban spaces? Are the interventions working? › How could heat mitigation fit into existing strategies, plans, and commitments?	› Which areas of the city have the most intense urban heat island effects? › Are there discernible reasons for differences in heat, e.g. types of building materials or green space? › How does heat affect key public facilities, including schools, hospitals, public transit, and sidewalks?	› Which government departments and other stakeholders have authority over these spaces and budgets that could support cooling? › Which public and private sector actors could be effective champions for cooler city spaces? › Could residents' associations, professional bodies, employers, trade unions or botanical gardens support design and upkeep of green assets and cool buildings?	› Which place-based cooling interventions offer the biggest near-term benefits? Which would make the greatest long-term impact? › Should City agencies' design and procurement standards or operational handbooks be revised to integrate cooling considerations? › What opportunities exist to increase green cover, make buildings cooler, integrate shade and water into urban design, and improve wind flow?

PHASE	1.	→ 2.	→ 3.	→ 4.
	TAKE STOCK	BUILD THE EVIDENCE BASE	BUILD A “COOL CITY COALITION”	IDENTIFY AND IMPLEMENT SOLUTIONS
 Supporting measures	› Map urban greening stakeholders › Map cool building stakeholders › Conduct desk review on policies and strategies for cool city places	› Conduct urban heat island studies using remote sensing, on-site measurements, and/or climate models › Pilot cooling interventions (such as cool roofs on schools or public housing) to evaluate potential investment options › Study impacts of buildings on wind to identify options for improved ventilation › Conduct a baseline assessment of urban forestry, including tree health, green cover disparities, and species suitability for future climate	› Engage citizens through participatory heat mapping, focus groups, and surveys › Consult forestry stakeholders on options to preserve and increase green cover › Engage building owners and construction industry on indoor heat reduction options	› Short-list investment options for cooler and greener city spaces › Identify options to integrate passive cooling measures into building codes and zoning regulations › Identify options to strengthen markets for cool building designs and materials through public procurement › Identify opportunities to mainstream heat mitigation into existing city department strategies › Initiate prefeasibility study for prioritized investment options



People

 Key questions	› Does the City monitor heat-related deaths each year and adjust hot-season planning based on the trends? › Do residents currently receive information about upcoming extreme heat? › How do doctors and hospital workers prepare for the hot season? › Does the national meteorological agency provide anticipatory heat stress forecasts for the city? › What existing resources can the City draw on to identify best practices and model policies?	› How do deaths and hospital admissions vary with heat? › Which socioeconomic groups have a higher rate of death, illness, or hospital admission during extreme heat? › Do current weather forecasting products meet the city's needs for protecting residents' lives during heat waves? › What health and economic losses could be suffered in the future if workers are not protected?	› Which groups of workers are most at risk of heat stress? › Which stakeholders need to disseminate information for vulnerable groups to reduce heat exposure and receive needed support? › Who is best positioned to alert vulnerable groups to heat risks and provide the needed support? › How can employers, labor groups, and civil society organizations best be engaged in tackling urban heat risks?	› What actions to protect vulnerable people would prevent deaths and illnesses at the lowest cost? › At what heat stress threshold should alerts be issued?
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PHASE	1.	→ 2.	→ 3.	→ 4.
	TAKE STOCK	BUILD THE EVIDENCE BASE	BUILD A “COOL CITY COALITION”	IDENTIFY AND IMPLEMENT SOLUTIONS
 Supporting measures	› Map public health and early warning system stakeholders › Conduct desk review of policies and strategies to protect lives during heat waves	› Conduct a study of how daily all-cause mortality varies with heat stress › Identify heat stress thresholds associated with increased mortality and morbidity › Assess the impact of current and future heat stress for workers and school children	› Consult vulnerable groups on how they receive climate and health information › Engage doctors to raise awareness of heat-related illnesses and prioritize response actions › Consult heat-exposed workers on their safety needs	› Design and implement an impact-based heat early warning system (see Table 4.1) › Identify response actions to accompany heat alerts in the health sector, in schools, and in heat-exposed workplaces › Plan public information actions with input from health professionals and affected groups
	Cross-cutting actions			
→ Establish leadership: Designate a city official with accountability for delivering heat mitigation outcomes. → Plan: Establish a multiyear plan with a vision, goals, and targets (integrate into existing strategies or develop a dedicated heat action plan). → Coordinate: Convene city departments to coordinate short-run actions (responsibilities during heat emergencies) and long-run actions (investments for a cooler city). → Communicate: Drive behavior change through communication ahead of every hot season.				

Source: Adapted from Annex 4A in Roberts et al. (2023).⁴⁴²

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ANNEX 2: URBAN HEAT SOLUTIONS BY SECTOR

Table A1 provided an overview for urban heat action planning and implementation led by a city-level task force. Such an approach is crucial for mainstreaming heat resilience across all relevant strategies, budgets, and operations. Yet most individual solutions will involve specific sectors—and a key part of building a “cool city coalition” is to understand how different actors fit in. Table A2 thus presents a simplified catalog of solutions organized by sector, drawn mainly from the topical discussions in Sections 2–4, with some additional insights from the World Bank’s new Handbook on Urban Heat Management.⁴⁴³

As with Table A1, many of the measures presented in Table A2 are likely to involve not just municipalities, but also (or only) agencies and institutions at the state/province or national level.

TABLE A2. A SIMPLIFIED CATALOG OF URBAN HEAT SOLUTIONS, BY SECTOR

	FOCUS			HEAT TYPE	
	 People	 Places	 Institutions	 Acute heat episodes	 Chronic heat exposure
URBAN DESIGN AND LAND USE					
Promote compact, vertical, mixed-use development that uses land efficiently, reduces car dependency, and preserves green space (section 5.1.1)					
Design urban spaces to maximize shade and create ventilation corridors (section 5.1.1)					
Choose nature-based solutions (NBS) when feasible, to achieve multiple benefits (e.g., cooling, clean air, biodiversity, flood protection, health, recreation) (section 5.1.2)					
Seize opportunities to reclaim road space for urban greening and enhanced walking and cycling infrastructure (section 5.1.1)					

	FOCUS			HEAT TYPE	
	People 	Places 	Institutions 	Acute heat episodes 	Chronic heat exposure 
HOUSING AND OTHER BUILDINGS					
Adopt heat-resilient, energy-efficient design guidelines and regulations (e.g., on construction materials) (section 3.2.3)	✓				✓
Raise public awareness of passive cooling techniques and resulting energy savings, prioritizing low-cost, easy-to-implement options (section 3.2.1, Box 3.1)	✓				✓
Promote cool roofs and green roofs (section 3.2.1)	✓				✓
Incentivize or require high-performance building envelopes (section 3.2.1)	✓		✓		✓
Integrate external shading elements, greenery, and/or water features (section 3.2.1)	✓				✓
If mechanical cooling is needed, promote the use of highly energy-efficient equipment (section 3.2.2)	✓				✓
Consider district cooling systems to achieve economies of scale and avoid the release of heat into the environment from distributed systems (section 3.2.4)	✓			✓	✓
PUBLIC HEALTH AND EMERGENCY MANAGEMENT					
Create early warning systems (stand-alone or as part of a multi-hazard EWS) with specific, actionable advice for different at-risk groups, including the most vulnerable (section 5.2.1)		✓		✓	
Raise public awareness of heat risks through educational campaigns (section 5.2.1)		✓		✓	
Train health care personnel to diagnose and treat heat-related issues (section 4.1.5)		✓		✓	✓
Upgrade health care facilities to ensure heat resilience (section 4.1.5)	✓	✓		✓	✓
Set up public cooling centers and work with community organizations to reach out to vulnerable groups (section 4.1.5)		✓		✓	
Distribute free cold drinking water ⁴⁴⁴		✓		✓	

	FOCUS			HEAT TYPE	
	People 	Places 	Institutions 	Acute heat episodes 	Chronic heat exposure 
ROAD INFRASTRUCTURE AND PUBLIC TRANSIT					
Increase shade in pedestrian areas and at bus stops through awnings, covered shelters, and location-appropriate street trees (section 3.4.4)	✓			✓	✓
Ensure roads and bridges are heat-resilient by using asphalt binders with higher heat ratings and allowing for greater thermal expansion of steel (section 3.4.4)	✓			✓	
Adopt cool pavements and reflective coatings (section 3.4.4)	✓			✓	✓
Maintain and, as needed, upgrade buses, trains, catenary lines, and tracks to ensure they can function well in extreme heat (section 3.4.4)	✓			✓	
Ensure good ventilation on buses and trains and in stations, and install air conditioning if needed (section 3.4.4)	✓			✓	✓
PARKS AND OTHER PUBLIC SPACES					
Maximize green space, including through linear parks (“green corridors”) and small parks in densely built-up areas, with ample vegetation and minimal paved areas (section 5.1.2)	✓			✓	✓
Facilitate access to existing bodies of water (e.g., riverbanks, seashore) and add blue infrastructure (e.g., ponds within parks) (section 5.1.1) ⁴⁴⁵	✓			✓	✓
Incorporate water features in public spaces, as well as drinking fountains (section 3.4.4) ⁴⁴⁶	✓	✓		✓	✓
Integrate greenery in existing infrastructure (e.g., green walls and roofs) (section 5.1.2)	✓				✓
ENERGY SYSTEMS					
Increase energy efficiency through mandatory minimum energy performance standards (MEPS), public outreach, and incentives (section 3.3.2)	✓		✓	✓	✓
Upgrade infrastructure to increase heat resilience, and maintain regularly (section 3.3.2)	✓			✓	
Diversify electricity generation to avoid overreliance on hydropower (section 3.3.2)	✓			✓	

	FOCUS			HEAT TYPE	
	People 	Places 	Institutions 	Acute heat episodes 	Chronic heat exposure 
Plan and design systems for increasingly extreme weather conditions (section 3.3.2)	✓			✓	
Incorporate rooftop solar, storage, and microgrids for extra resilience (section 3.3.2)	✓			✓	
OCCUPATIONAL HEALTH AND SAFETY					
Adjust work schedules to avoid arduous tasks during the hottest hours (section 5.2.2)		✓		✓	✓
Reduce thermal load through ventilation and minimize radiant heat (section 5.2.2)		✓			✓
Provide regular breaks to cool off and water to rehydrate (section 5.2.2)		✓			✓
Monitor temperatures and set thresholds for levels of physical exertion (section 5.2.2)		✓			✓
Train workers and supervisors on heat safety and emergency responses (section 5.2.2)		✓			✓
SUPPORT FOR THE URBAN POOR					
Use adaptive social protection or micro-insurance schemes to assist workers (including in the informal economy) whose livelihoods are disrupted by extreme heat (section 5.2.3)		✓		✓	
Enhance coping and adaptive capacity through targeted assistance for upgrades to informally built housing, purchase of energy-efficient fans, provision of shade and ventilation at public markets, and other measures (section 3.2 and box 2.2)	✓	✓		✓	✓
EDUCATION					
Monitor temperatures within school facilities to protect student health (section 4.2.3)		✓		✓	✓
Strengthen risk management through early warning systems (sections 4.2.3 and 5.2.1)		✓	✓	✓	✓
Educate teachers, students, and parents about heat risks and engage them in school-level responses (section 4.2.3)		✓			✓

	FOCUS			HEAT TYPE	
	People 	Places 	Institutions 	Acute heat episodes 	Chronic heat exposure 
Upgrade school infrastructure for heat resilience (see above) and ensure basic needs are met (e.g., safe drinking water) (section 4.2.3)	✓	✓			✓
Ensure learning continuity through schedule adjustments, remote classes, and support to make up for lost time (section 4.2.3)		✓			✓
CROSS-SECTORAL					
Create a heat action plan (stand-alone or as part of climate action plan) (section 5.3.1)			✓	✓	✓
Create an institutional mechanism for effective coordination and collaboration on heat issues (e.g. a Chief Heat Officer or a multi-agency task force) (section 5.3)			✓	✓	✓

ENDNOTES

SECTION 1

1 Historical data are for the state of Zulia, of which Maracaibo is the capital. See official government data at <http://inameh.gob.ve/web/climogra.php>.

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3 Godínez, S. 2024. "¡CDMX alcanza nuevo récord histórico de temperatura! El termómetro llegó a los 34.7°C." *El Universal*, May 25. <https://www.eluniversal.com.mx/metropoli/cdmx-alcanza-nuevo-record-historico-de-temperatura-el-termometro-llego-a-los-347c/>.

4 SMN. 2024. "Récords en Argentina: concluyó la primera ola de calor de la temporada." Servicio Meteorológico Nacional press release. February 15. <https://www.smn.gob.ar/noticias/r%C3%A9cords-en-argentina-concluy%C3%B3-la-primera-ola-de-calor-de-la-temporada>. Santiago del Estero was one of 15 communities that set new temperature records above 40°C during the heatwave, according to the National Meteorological Service. Buenos Aires exceeded 35°C multiple times and was at least 5°C hotter than the 1991–2020 average for several days. See <https://www.smn.gob.ar/clima/vigilancia>.

5 As of 2024, the UN estimates, 82.2 percent of people in Latin America and the Caribbean lived in urban areas, compared with 83.4 percent in North America, 75.8 percent in Europe, 52.2 percent in Southeast Asia, and 38.6 percent in South Asia. Custom data acquired via website from: UN DESA. 2018. "World Urbanization Prospects 2018." New York: United Nations Department of Economic and Social Affairs, Population Division. <http://esa.un.org/unpd/wup/>.

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7 ILO. 2024. "Ensuring Safety and Health at Work in a Changing Climate." Geneva: International Labour Organization. <https://www.ilo.org/publications/ensuring-safety-and-health-work-changing-climate>. See also Santos, D.M. dos et al. 2024. "Twenty-First-Century Demographic and Social Inequalities of Heat-Related Deaths in Brazilian Urban Areas." *PLOS ONE* 19 (1): e0295766. doi:10.1371/journal.pone.0295766.

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8 ECLAC. 2024. "Social Panorama of Latin America and the Caribbean, 2024: The Challenges of Non-Contributory Social Protection in Advancing towards Inclusive Social Development." LC/PUB.2024/21-P. Washington, DC: Economic Commission for Latin America and the Caribbean. <https://www.cepal.org/en/publications/80859-social-panorama-latin-america-and-caribbean-2024-challenges-non-contributory>.

The weighted average poverty rate for the 18 countries tracked by ECLAC was 27.3 percent, and the extreme poverty rate, 10.6 percent. There are large differences across countries, however: Honduras had the highest poverty rate, 56.0 percent, in 2023, followed by Colombia, at 32.7 percent, and Uruguay had the lowest, 4.5 percent. The data exclude some countries known to have a high prevalence of poverty, such as Haiti and Bolivia.

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<https://statistics.cepal.org/portal/cepalstat/dashboard.html?theme=1&lang=en>.
- 10 ILO. 2023. "2022 Labour Overview of Latin America and the Caribbean." Lima: International Labour Organization. <https://www.ilo.org/publications/2022-labour-overview-latin-america-and-caribbean>.
- 11 The Gini index ranges from 0 to 1, with 0 indicating perfect equality, and 1 indicating that all income goes to a single person. For comparison, the Gini index for the United States in 2022 was 0.41, and the indices for all but four European Union members in 2021 were in the 0.25–0.35 range. See World Bank data: <https://data.worldbank.org/indicator/SI.POV.GINI>.
- 12 The WBGT is the most widely accepted measure of heat for determining whether people are at risk of heat stress. The level of physical activity is also a factor, as exercise generates heat (see sections 4.4.1 and 5.2.2). For a simple explanation of how WBGT is measured, see: <https://nicholasinstitute.duke.edu/project/heat-policy-innovation-hub/what-is-wet-bulb-globe-temperature-wbgt>. For an explanation of how historical data and climate projections can be used to assemble WBGT, by the authors of the dataset used in section 1.4, see: Chegwiddden, O. and J. Freeman. 2023. "Modeling Extreme Heat in a Changing Climate." San Francisco, CA, US: CarbonPlan. <https://carbonplan.org/research/extreme-heat-explainer>.
- It is important to note that, while WBGT provides the most realistic representation of thermal environments and their effects on the human body, it is more difficult to measure and less intuitive than air temperature. For example, if humidity is low (e.g., 30 percent, as it might be in Guadalajara, Mexico, in March), there is a breeze, and the sun is not directly overhead, the 30.5°C WBGT threshold might not be exceeded until air temperatures reach as high as 40°C. With 75 percent humidity, however (about the norm in Guadalajara from July to September), and either stronger sunshine or less wind, the threshold could be exceeded at just 30°C. See the interactive modeling tool in Chegwiddden and Freeman, 2023.
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- 16 Masson-Delmotte, V. et al., eds. 2021. "Summary for Policymakers." In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, 3–32. Cambridge, UK, and New York: Cambridge University Press. doi:10.1017/9781009157896.001.
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SECTION 4

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SECTION 5

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ANNEXES

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For more detailed, step-by-step guidance, including advice on how to tailor actions to each city's context, see: World Bank, forthcoming, "Handbook on Urban Heat Management."

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UNLIVABLE

CONFRONTING EXTREME URBAN HEAT IN
LATIN AMERICA AND THE CARIBBEAN



WORLD BANK GROUP



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