# Unlivable

## How Cities in Europe and Central Asia Can Survive – and Thrive – in a Hotter Future

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# Executive Summary

Urban areas across Europe and Central Asia are heating up—unevenly and with far-reaching effects. From Tirana to Tashkent, urban areas across this vast and varied region are experiencing a sharp rise in temperatures, an increase in heatwaves, and growing risks to public health, economic output, and infrastructure. This report explores the emerging challenge of extreme heat, explaining what is at stake, what cities are doing, and what needs to happen next.

## Why does heat deserve special attention?

Extreme heat is one of the most lethal, least visible, and most underestimated hazards we face. Unlike storms or floods, it leaves no debris behind. But the toll it exacts on people, infrastructure, and the economy is enormous. Tens of thousands of heat-related deaths have occurred in Europe alone in the past two decades, often coinciding with record-breaking heatwaves, which have brought unprecedented warm temperatures to cities across the region in recent years.

Extreme heat events don't just kill—they send thousands to emergency rooms, worsening chronic illness and overwhelming hospitals, especially for older adults and low-income communities. And when it gets too hot, the costs are immediate and widespread: workers slow down, hours are lost, and output drops. Jobs in construction, transport, tourism, and informal services are especially hard hit—threatening livelihoods just when they're most needed. The ripple effects touch every part of the urban economy, from health care to logistics to retail.

The threat is especially insidious because it's so quiet. Heat doesn't topple buildings, but it floods emergency rooms. It can short-circuit transport systems in a single event, but also wear them down faster over time. And while it may not dominate headlines, it acts as a threat multiplier, compounding and amplifying other crises.

Extreme heat intensifies droughts by accelerating evaporation and drying out soils, reducing water availability for agriculture, hydropower, and urban supply. It elevates wildfire risk by desiccating vegetation and extending fire seasons, which in turn can destroy infrastructure and displace communities. Air quality worsens as higher temperatures fuel ground-level ozone formation and trap pollutants closer to the ground—especially in congested urban areas. Power grids, already stretched by rising demand for cooling, become more vulnerable to outages just as they are most needed. In cities, these effects do not occur in isolation: when one system falters, others often follow, creating feedback loops that deepen disruption and increase the costs of recovery.

## Why cities matter in the fight against heat

Cities are the epicenter of this crisis. The urban heat island (UHI) effect can make cities several degrees hotter than their rural surroundings, especially at night. As temperatures rise, urban residents and economies will be disproportionately affected. In a region where more than 70 percent of people live in cities, and with jobs, capital, and services concentrated in urban areas, the impacts could be severe and widespread.

Cities have significant challenges to overcome. Densely built-up areas with poor airflow, little green space or vegetation, and large expanses of concrete, asphalt, and other heat-trapping materials get disproportionately hot during the day and stay hot even at night, when rural areas cool down.

This affects not only comfort, but also economic performance. Sectors that dominate urban economies—like services, construction, and transport—are especially sensitive to heat stress. When it's too hot to work, productivity drops, particularly for workers in outdoor and informal jobs. Small businesses are often least equipped to adapt, compounding economic inequality.

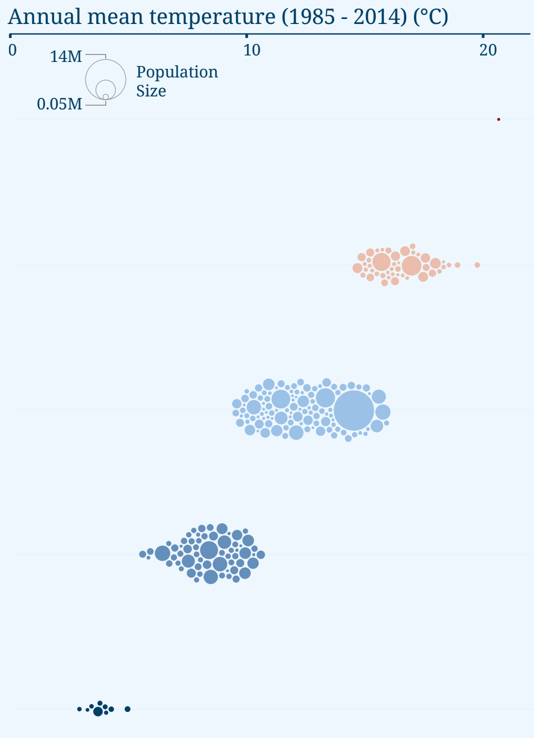
But cities are also where action can move fastest. Local governments have powerful tools to reduce heat exposure and protect the most vulnerable: from zoning and building codes, to public space management, to early warning systems. Urban heat adaptation delivers some of the highest returns for public investment, safeguarding health, productivity, and quality of life. For a region facing a hotter future, resilient cities will be key to resilient economies.

## Why this region?

Europe and Central Asia are home to some of the world's most diverse climates and urban forms: from Mediterranean coastal cities and temperate plains, to continental interiors and high-elevation hubs. Many of the region's cities were built for mild summers and long winters, not for frequent days above 40°C. This legacy of climate-tuned design means that even moderate increases in temperature can have outsize effects on daily life, public health, and infrastructure. And this is just the beginning. Extreme heat events are becoming more frequent, more intense, and longer-lasting—even in places that once considered themselves immune.

Europe is now the fastest-warming continent on Earth, with land areas heating at more than twice the global average. Cities across Europe and Central Asia are already seeing the effects of this trend, where the urban heat island effect amplifies warming and pushes aging infrastructure to its limits. The future isn't just warmer. For cities across ECA, it will be dangerously hotter—and sooner than expected.

**FIGURE ES-1** Projected Increase in Hot Days for Cities in Europe and Central Asia




| City group | | 2040 - 2059 Change in Tmax | 2040 - 2059 Change in #days > TX95t | 2080 - 2099 Change in Tmax | 2080 - 2099 Change in #days > TX95t |
|---|---|---|---|---|---|
| **Hot cities** | Number of cities: 1<br>Mean annual T (C): 20.5<br>Total population (million) : 0.1<br>95th percentile of Tmax (TX95t, C): 35.6 | +1.51°C | +57 days | +2.33°C | +74 days |
| **Warm cities** | Number of cities: 45<br>Mean annual T (C): 16.4<br>Total population (million) : 18.7<br>95th percentile of Tmax (TX95t, C): 35.8 | +1.97°C | +52 days | +3.04°C | +68 days |
| **Temperate cities** | Number of cities: 106<br>Mean annual T (C): 12.1<br>Total population (million) : 57.4<br>95th percentile of Tmax (TX95t, C): 31.6 | +2.13°C | +48 days | +3.17°C | +63 days |
| **Cool cities** | Number of cities: 61<br>Mean annual T (C): 8.3<br>Total population (million) : 32.3<br>95th percentile of Tmax (TX95t, C): 27.5 | +2.1°C | +48 days | +3.09°C | +63 days |
| **Cold cities** | Number of cities: 9<br>Mean annual T (C): 3.7<br>Total population (million) : 2.2<br>95th percentile of Tmax (TX95t, C): 28.9 | +2.2°C | +45 days | +3.41°C | +61 days |

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

Moreover, countries across the region are at a crucial development crossroads. Many face rapidly aging populations, economic transitions, and urban growth pressures, all of which makes them especially vulnerable to the cascading impacts of heat. At the same time, the region holds enormous potential for climate-smart innovation and interregional cooperation. Coordinated action on heat could serve as both a test case and a template for broader resilience strategies in the face of accelerating climate change.

## What this Report Covers

This report investigates how extreme heat is already reshaping cities across Europe and Central Asia and what that portends for the decades ahead. It offers:

- **An assessment of the current and projected impacts** of extreme heat on health, labor productivity, and urban economies;
- **A survey of existing responses,** from early warning systems to urban greening;
- **A roadmap for action,** focusing on cooling down cities, protecting vulnerable people, adapting infrastructure, and embedding heat action in planning and institutions.

This report zooms in on heat because of its rapid rise and wide-ranging, underestimated impacts. It focuses on adaptation and resilience, while recognizing that heat will be worse in a high-emissions scenario. It considers the many human impacts of extreme heat, and pays particular attention to its economic implications: slowing workers down, shrinking productive hours, and deepening economic divides between places, sectors, and firms.

## What the Analysis Found

This report presents new analysis of climate, infrastructure, and health data to better understand the drivers, the impacts, and the policy responses to extreme urban heat in the region. The findings point to the urgent need for timely and targeted action to build heat resilience in urban areas:

- **The number of hot days in major cities could more than triple by 2050.** Analysis carried out using state-of-the-art climate model projections for 222 cities indicate that all cities (except Gdansk and Bydgoszcz in Poland) will experience more than 40-70 additional hot days per year compared with historical baselines, especially in Southern Europe and Türkiye.
- **By 2100, extreme heatwaves will become the new normal for many cities across Europe and Central Asia.** Almost 70 percent of the region's urban centers are projected to face at least one severe heatwave a year. In one third of these cities - particularly in the Western Balkans, Eastern and Southern Europe, Türkiye, and Central Asia - extreme heatwaves are expected to strike annually, lasting up to two months and reaching peak temperatures 4°C higher than today.
- **Heat-related deaths could rise sharply without adaptation—doubling or tripling in many cities.** Under a moderate emissions scenario, cities such as Bucharest, Athens, and Istanbul could each experience more than 10,000 cumulative heat-related deaths by 2050—a death toll that places extreme heat on par with more widely acknowledged public health challenges such as road traffic accidents.

- **Economic losses from extreme heat could reach 2.5 percent of GDP by midcentury in parts of the region.** Heat undermines both present-day productivity and long-term human capital. When it gets hot, workers slow down or stop working entirely. Heat reduces physical and cognitive performance. Machines fail, energy systems strain, and supply chains stall. The productivity losses alone could cut GDP by up to 1.3 percent in countries such as Albania, North Macedonia, and Tajikistan, with urban centers hardest hit. The worst-hit countries—Cyprus, Greece, Bulgaria, and Türkiye—could see GDP losses of 2–6 percent in coming decades.

- **Cities are not yet ready.** While 87 percent of countries in the region have some form of heat alert system, only 28 percent have comprehensive heat health action plans. Less than a quarter of capital cities have integrated heat risks into urban climate strategies. Much of the region's infrastructure—particularly in Central Asia and parts of Eastern Europe—was built in the mid-20th century and is overdue for renewal. Building stock, transport infrastructure, and energy systems remain highly vulnerable to overheating.

- **But adaptation works—and pays off.** The report finds that timely investments in urban cooling, resilient infrastructure, and health preparedness can prevent up to 80 percent of projected heat-related deaths and halve productivity losses. For every euro invested in heat adaptation, the benefits range between €2 and €20, with several investments showing very high net benefits and BCRs reaching hundreds or even thousands, depending on location and measure.

## What Needs to Happen

This report lays out a practical agenda with 10 strategic actions built on four principles—making cities cooler, protecting lives, preparing infrastructure, and embedding heat resilience in governance. Together, these actions can help cities address the urgent need to prepare for extreme heat events while making medium- and long-term investments to adapt for a hotter future.

- **Make urban spaces cooler:** Cities must invest in large-scale urban greening, climate-sensitive design, and building retrofits to lower ambient and indoor temperatures. Strategic tree planting in underserved neighborhoods, protecting natural airflow corridors, and prioritizing shade and ventilation in public design are all essential. In dense areas with legacy infrastructure, adapting streetscapes and public spaces for thermal comfort can deliver high-impact, low-cost improvements.

- **Protect lives during extreme heat events:** Early warning systems and responsive public health services are central to reducing preventable deaths. Vulnerable populations—especially older adults, outdoor workers, and people living in low-quality housing—require targeted protection, including cooling centers, occupational safeguards, and access to information and services. Heat health preparedness must become a permanent fixture of national and municipal health systems.

- **Adapt infrastructure for a hotter future:** Infrastructure systems—energy, transport, buildings, schools, and digital networks—are directly affected by heat and must be urgently upgraded. Thermal stress degrades roads, railways and power grids, while overloading cooling demand threatens blackouts. Retrofitting schools, hospitals, and housing stock for passive cooling; using heat-tolerant materials; and integrating renewable, distributed energy systems can significantly boost resilience. Infrastructure planning should be forward-looking, factoring in future climate extremes and ensuring that public investment delivers long-term adaptive value.

- **Embed heat resilience across government:** Heat needs to be mainstreamed into national and local governance. This means incorporating heat risk into adaptation plans, urban development strategies, sectoral policies, and capital investment frameworks. Appointing clear institutional leads, such as chief heat officers or inter-agency task forces, can enhance coordination, ensure accountability, and elevate heat as a core urban policy issue.

Figure ES-2 provides an overview of this agenda with the simplified labels “Places, People, Infrastructure, and Institutions.”

**FIGURE ES-2** **Places, People, Infrastructure, and Institutions: 10 Strategic Actions for Heat Resilience in Europe and Central Asia**

**Places**
Make urban spaces cooler

1. Advance urban greening through strategic planning
2. Harness wind, shade and design
3. Upgrade building stock to tackle overheating risks

**People**
Protect the vulnerable during extreme heat

1. Save lives through heatwave early warning and response
2. Strengthen health system readiness
3. Protect heat-exposed workers and residents

**Infrastructure**
Adapt for a hotter future

1. Build resilience of energy systems
2. Integrate heat resilience into the transport sector
3. Prevent schools overheating

**Institutions**
Mainstream heat resilience into national and municipal strategies, operations and budgets

*Source:* World Bank elaboration

## Who should do it, and how?

Reducing urban heat exposure is a distributed challenge, but not a leaderless one. National governments must set the policy direction and unlock financing. Local governments are typically closest to implementation: they manage green space, housing permits, school infrastructure, and emergency response. But too often, mandates are misaligned with means. Fewer than a quarter of countries in Europe and Central Asia give subnational governments the financial autonomy to lead on adaptation, even though many of the most effective measures—such as retrofitting buildings, expanding tree cover, or installing shade structures—are inherently local.

This report maps the 10 strategic actions to the level of government best placed to lead and identifies other key stakeholders. Some actions are top-down: national governments must set standards, fund heat-resilient infrastructure, and protect labor rights. Others are hyperlocal: municipalities must design public spaces for shade, manage early warning systems, and retrofit schools and hospitals. Across the board, clarity of roles, alignment of incentives, and consistent financing are critical.

Emerging solutions show promise. Cities are piloting heat vulnerability indices and using them to direct funds to high-risk areas. Some are embedding heat into transport and housing strategies; others are using performance-based transfers to reward local action. Still, the financing gap remains wide—and without new mechanisms to close it, even the most ambitious plans risk stalling.

Ultimately, resilience is not just about what needs to happen. It's about how. Section 4 shows that success depends on enabling local action within a broader, well-coordinated system. That means assigning responsibilities clearly, building municipal capacity, and making heat resilience part of everyday governance: from zoning, to budgets, to public health planning.

## Final Word: Heat Is Here to Stay

Europe and Central Asia are heating faster than most regions of the world. Cities, where people, power, and productivity converge, are where the impacts are felt most acutely. But cities are also where solutions can scale fastest. If left unaddressed, extreme heat will act as a silent drag on urban economies—slowing workers, straining firms, and undermining competitiveness. This report shows that a livable future is still possible—but only if cities act now, act boldly, and act together.

# 1 A New Climate Reality for Europe and Central Asia

## 1.1 Mild Climates Shaped Civilizations in Europe and Central Asia

From the sun-soaked hills of western Turkey to the Danube basin and the high plains of Kazakhstan, Europe and Central Asia is a region shaped by striking climatic contrasts. These conditions have long influenced where people settled, how economies evolved, and the kinds of cities and infrastructure that emerged. The region spans a rich mosaic of landscapes and climate zones: from Mediterranean and humid continental climates in much of Southern and Eastern Europe, to alpine and subarctic conditions in mountain ranges such as the Carpathians, Caucasus, and Tien Shan. Further east, the steppes of Ukraine and Kazakhstan experience sharp seasonal swings, with hot summers and frigid winters.

The French historian Fernand Braudel wrote: “Geography is not an arena in which history unfolds—it is history.”[1] For centuries, Europe’s climate has been a quiet architect of civilizations. Mild temperatures, regular rainfall, and fertile soil enabled nations to flourish. The river valleys of the Rhine and Danube became early centers of agriculture and economic activity, supporting the growth of cities such as Vienna, Budapest, and Belgrade. Mild climates facilitated industrialization in regions like Silesia (spanning present-day Poland and Czechia) and Ukraine’s Donbas coal region, where temperatures could sustain

1. Braudel, F. (1972). *The Mediterranean and the Mediterranean World in the Age of Philip II* (Vol. 1, S. Reynolds, Trans.). Harper & Row. (Original work published 1949).

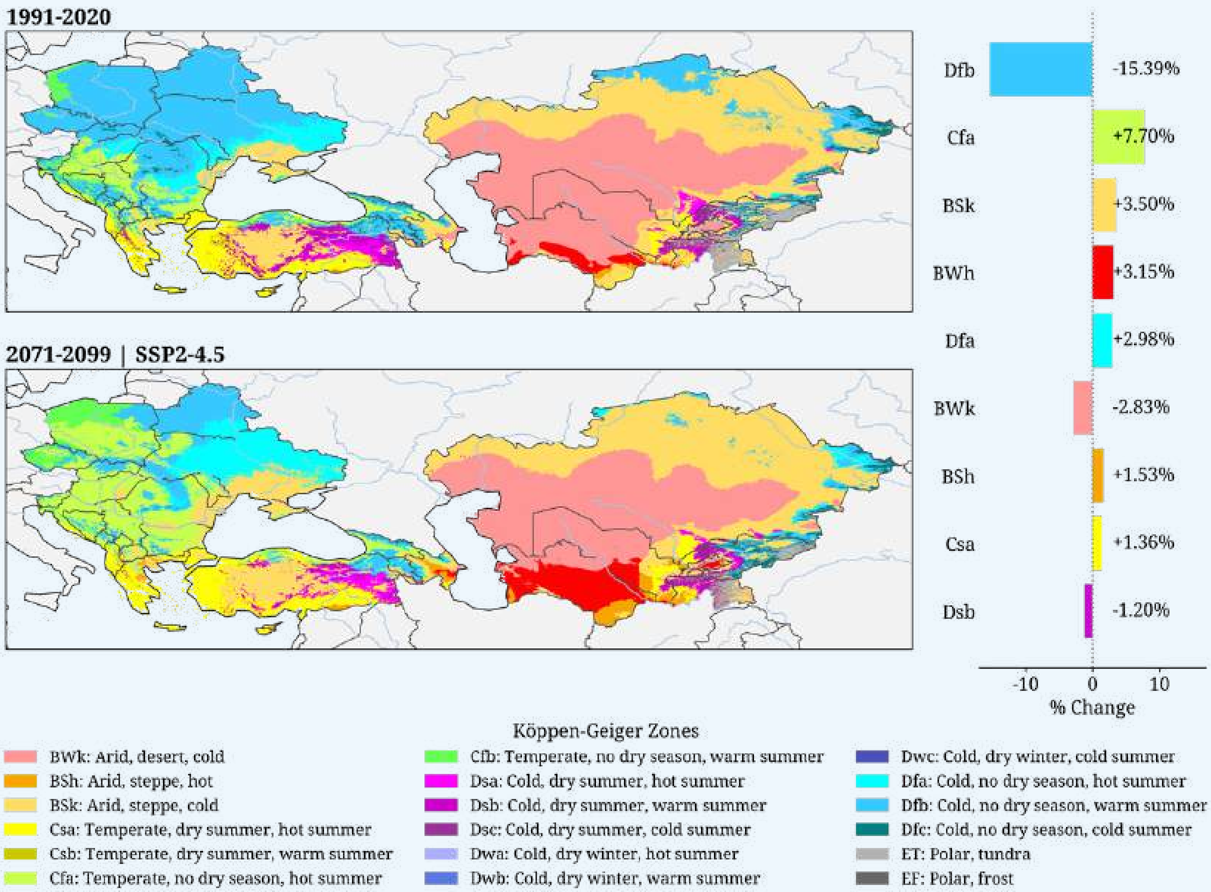
year-round labor and infrastructure development. In Central Asia, trade hubs along the Silk Road thrived in hospitable microclimates where water and temperate conditions enabled agriculture, caravan trade, and the rise of urban centers from Samarkand to Bukhara.

Temperatures have long shaped economies, infrastructure, and daily lives in the region's cities. In cities such as Astana (Kazakhstan) and Minsk (Belarus), extreme seasonal variation defines the urban experience, with winter temperatures often dropping below -25°C and summer highs exceeding 30°C. These wide temperature swings influence the nature of work, infrastructure demands, and energy use, requiring substantial heating in winter and cooling in summer. In contrast, cities like Tbilisi (Georgia) and Istanbul (Turkey) enjoy relatively mild winters and warm summers, with average summer peaks ranging between 25°C and 30°C, leading to different patterns of energy use and urban design.

Compared with other regions, a significant share of Europe and Central Asia's inhabited land lies within temperate climate zones with relatively mild climates. However, as shown in Figure 1.1, climate patterns are shifting due to global climate change, and hotter and more extreme conditions are becoming increasingly common. For countries across the region, those shifts, which are particularly noticeable in urban areas, present a growing challenge that could affect prosperity and security in the decades to come.

**FIGURE 1.1** Changing Climate Zones across Europe and Central Asia (1991–2020 vs. 2071–2099)

*Projected shifts in Köppen-Geiger climate classifications in SSP2-4.5 scenario*




*Source:* Beck et al. (2023)[2] with supplementary analysis by World Bank team.

*Notes:* This figure shows the historical (1991–2020) and projected (2071–2099) distribution of climate zones across Europe and Central Asia, based on the Köppen-Geiger classification system, which categorizes regions according to annual patterns of temperature and precipitation. The lower map shows future projections under the SSP2-4.5 emissions scenario, highlighting a marked expansion of arid and hot-summer climates and a significant contraction of cold or humid continental climate zones. The right-hand panel quantifies percentage changes in the land area of major climate types, showing that some temperate and cold climate zones are expected to decline sharply, while arid and subtropical climates expand across southeastern Europe, Türkiye, and Central Asia.

**2.** Beck, H. E., McVicar, T. R., Vergopolan, N., Berg, A., Lutsko, N. J., Dufour, A., Zeng, Z., Jiang, X., van Dijk, A. I. J. M., & Miralles, D. G. (2023). High-resolution (1 km) Köppen-Geiger maps for 1901–2099 based on constrained CMIP6 projections. Scientific Data, 10(1), 1–16. **https://doi.org/10.1038/s41597-023-02549-6.**

## BOX 1 How hot is too hot? Defining heat stress and heat waves

The question "how hot is too hot?" is more than just an academic one. Cities need clear definitions to know when to issue heat alerts, when to close schools, and when to introduce safety protocols in hospitals or workplaces. The answer depends on how heat affects the human body, how we measure it, and how extreme heat is defined.

**Heat stress—when the body can't keep up.** Human beings need to maintain a core body temperature of around 37°C to ensure proper functioning of essential physiological processes. When exposed to heat, it cools itself through sweating and blood circulation. But in hot, humid, or windless conditions, the body's controlling system struggles. If the body's core temperature rises above 40°C, heat stroke can set in – a potentially fatal condition. Heat stress is worse in environments with high humidity, low wind speed, or excessive radiation from the sun or hot surfaces.

**How is heat stress measured?** Measuring heat is easy; measuring its effect on people is harder. Air temperature is the simplest metric, but it doesn't account for humidity. Heat Index (or "feels like" temperature) adjusts for moisture in the air, making it more useful for public warnings. Wet-bulb globe temperature (WBGT) is the gold standard for occupational safety. It combines temperature, humidity, wind speed, and radiation—and is used in factories, mines, and sports events for crucial safety decisions.

**What is a 'hot day'? It depends on where you live.** A "hot day" in Stockholm is different from a hot day in Tashkent. People adapt to local climates through clothing, housing, and routines, so heat impacts vary by city. This study defines a hot day as one on which temperatures reach or exceed the 95th percentile of daily temperatures for that city during a historical baseline period.

**What is extreme heat?** Under sufficiently high combinations of air temperature and humidity, exposure for even short durations (about six hours) becomes lethal without air conditioning.[3] Extreme heat also affects work safety. This study defines an extreme heat day as one where WBGT exceeds 30.5°C, the threshold at which even light manual labor becomes unsafe without breaks.

**What is a heat wave?** A heat wave is a multi-day period of heat that is excessively high relative to the local climate. This study defines a heatwave as at least three consecutive days where temperatures exceed the 90th percentile of the historical distribution of temperatures for that location.

**How does humidity make heat more dangerous?** Sweating is one of the body's main ways to cool down—but it works only if sweat evaporates. When humidity is high, evaporation slows down, trapping heat inside the body. This means that dangerous heat stress happens at much lower temperatures. For example, at 30 percent relative humidity, the extreme heat threshold (30.5°C WBGT) isn't reached until air temperatures surpass 40°C in the shade. At 75 percent relative humidity, the threshold is already crossed at just 33°C. This study highlights these growing risks, particularly in cities where humidity levels are growing.

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**3.** Laboratory research shows that temperature and humidity combinations equivalent to a wet-bulb temperature of between 31°C and 35°C exceed what even fit and acclimatized young people can withstand. Survivability thresholds are rarely breached in dry environments, because extremely high air temperatures (exceeding 55°C) would be required. However, at high levels of humidity, air temperatures as low as 35°C result in theoretically unlivable heat. Hot regions of the world are projected to experience an increasing number of days or weeks per year of heat-humidity combinations that exceed survivability thresholds as the century progresses.

Vecellio, D.J., Wolf, S.T., Cottle, R.M. and Kenney, W.L., 2022. Evaluating the 35 C wet-bulb temperature adaptability threshold for young, healthy subjects (PSU HEAT Project). *Journal of Applied Physiology*.

## 1.2 Heat Extremes have Become More Frequent and Intense

Temperatures across Europe and Central Asia have already risen, leading to more frequent and intense episodes of extreme heat. The year 2024 set a new global temperature record. It marked the first year in which the average global temperature exceeded 1.5°C above average levels in the pre-industrial period.[4] The warming trend has been even more pronounced in Europe and Central Asia, where land temperatures in 2015–2024 were 2.2°C higher than in pre-industrial times. Some countries warmed much faster than others, with the temperature increase ranging from 1.4°C in Cyprus to 2.7°C in Belarus (see Figure 1.2).

**4.** Copernicus Climate Change Service (2025). *Global Climate Highlights 2024*. Available at: **https://climate.copernicus.eu/global-climate-highlights-2024**.

**FIGURE 1.2** Rising Temperatures across Europe and Central Asia (1850–2024)

*Annual temperature anomalies in degrees Celsius relative to the pre-industrial average (1850–1900)*


*Source:* World Bank analysis based on Berkeley Earth data.[5]

*Notes:* This figure visualizes the change in annual average air temperatures across 27 countries in Europe and Central Asia from 1850 to 2024, using temperature anomalies (in °C) relative to the pre-industrial baseline period of 1850–1900. Each column represents one year, and each row represents one country, grouped by subregion. Shades of red indicate years warmer than the pre-industrial average, while blue shades indicate cooler years. The deepening red hues in recent decades reflect the sharp acceleration in warming across the region.

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**5.** Rohde, R. A.; Hausfather, Z. The Berkeley Earth Land/Ocean Temperature Record. Earth System Science Data 2020, 12 (4), 3469–3479. **https://doi.org/10.5194/essd-12-3469-2020.**

Europe is now the fastest-warming continent on Earth, with land areas heating at more than twice the global average.[6] Moreover, the rate of warming has increased significantly in recent decades. On average, temperatures across Europe and Central Asia were 1.8°C higher in 2015–2024 than they were in the 1970s.

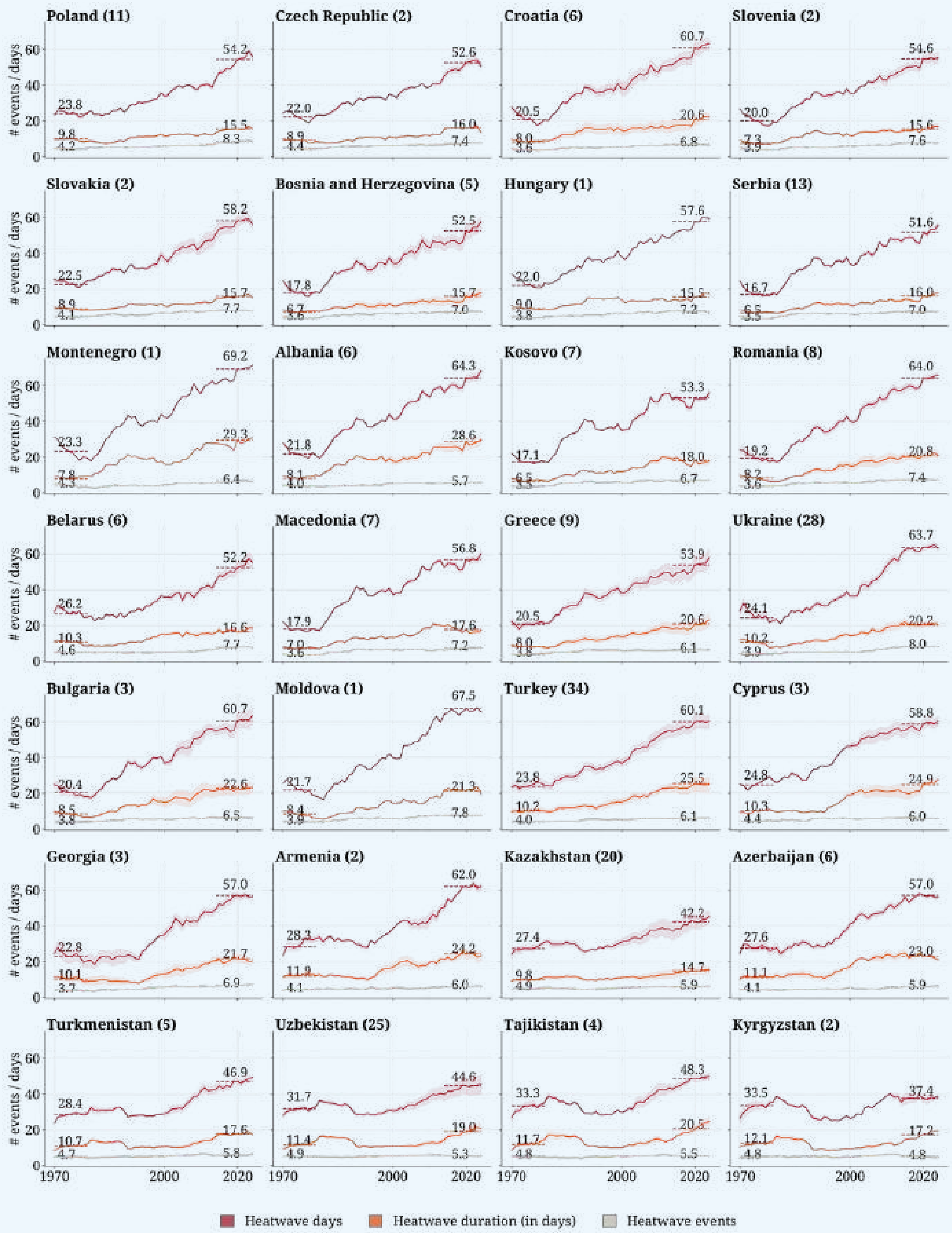
Accelerated warming has led to a marked increase in heatwaves across cities in the region. An analysis for this study examined climate reanalysis datasets together with daily readings from 20 local weather stations across the region. In every case, the readings revealed an upward trend in the frequency, intensity, and duration of heatwaves. Compared with 1970–1979, in the most recent decade (2015–2024) there have been, on average, 2.4 more heatwave events per year (5.8 vs. 3.4) and 30 additional heatwave days per year (51 vs. 21). The longest heatwave each year also became nine days longer, on average (16 vs. seven days). These trends are especially pronounced in Southeastern Europe, the Western Balkans, and Türkiye (see Figure 1.3). For instance, Bulgaria, Moldova, and Romania each saw 40 more heatwave days per year in 2015–2024 than in 1970–1979. In Montenegro, Albania, and Türkiye, the year's longest heatwave now lasts, on average, 15 days.

**6.** Bednar-Friedl, B., Biesbroek, R., Schmidt, D. N., Alexander, P., Børsheim, K. Y., Carnicer, J., Georgopoulou, E., Haasnoot, M., Cozannet, G. Le, Lionello, P., Lipka, O., Möllmann, C., Muccione, V., Mustonen, T., Piepenburg, D., & Whitmarsh, L. (2023). Europe. In Climate Change 2022 – Impacts, Adaptation and Vulnerability (pp. 1817–1928). Cambridge University Press. **https://doi.org/10.1017/9781009325844.015.**

Copernicus Climate Change Service (C3S) and World Meteorological Organization (WMO), 2025: European State of the Climate 2024, **climate.copernicus.eu/ESOTC/2024**, **doi.org/10.24381/14j9-s541.**

Dong, B., & Sutton, R. T. (2025). Drivers and mechanisms contributing to excess warming in Europe during recent decades. Npj Climate and Atmospheric Science, 8(1), 1–13. **https://doi.org/10.1038/s41612-025-00930-3.**

**FIGURE 1.3** Observed Changes in Heatwaves Frequency and Duration in Europe and Central Asia, 1970–2024




*Source:* World Bank analysis using ERA5-Land reanalysis data and national weather station data.

*Notes:* Number of cities per country are indicated in brackets. Country-level statistics are derived from the average of the available city time series. Shaded bands show ±1 standard deviation across a country's cities. Trends in heatwave metrics are calculated based on 10-year rolling means of the heatwave metric time series. Values shown reflect the first and last decade averages.

In recent decades, heatwaves have intensified in severity as well as frequency. Heatwaves can be classified on a scale from "moderate," through "severe," to "super-extreme," based on a metric called the Heat Wave Magnitude Index daily,[7] which captures both how long a heatwave lasts and how much temperatures deviate from local norms during this time. As a benchmark, examples of heatwaves where peak values reached "very extreme" and "super extreme" levels are those that affected Western and Central Europe in 2003 and southern Russia in 2010, respectively. In August 2003, temperatures reached 40°C in France and hit a peak of 47.5°C in southern Spain. In the most devastating episode of heat-related mortality experienced up until that time, an estimated 70,000 people died across France, Italy, Spain, and other countries,[8] with deaths concentrated among elderly people who lived alone and without air conditioning. In 2010, an estimated 11,000 people died because of the heatwave in Russia.[9]

Heatwaves of comparable severity have become increasingly common, an analysis of climate data for 222 cities in Europe and Central Asia for this study shows (see Figure 1.4). During the past two decades, almost half of cities across the region experienced "moderate" or "severe" heatwaves, and some experienced "very extreme" heatwaves. Between 2014 and 2024, on average 30 cities across the region experienced at least one heatwave per year classed as "severe" or worse. During the previous 20 years, that occurred only in two cities per year, on average.

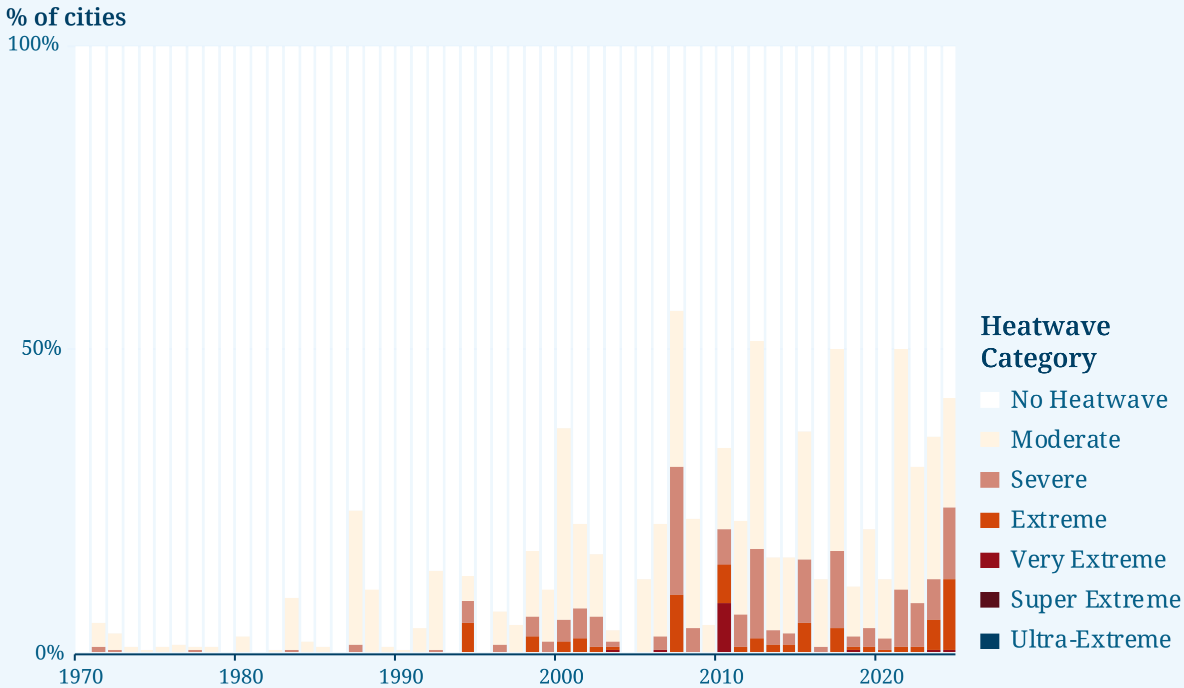
**7.** Russo, S., Sillmann, J., & Fischer, E. M. (2015). Top ten European heatwaves since 1950 and their occurrence in the coming decades. Environmental Research Letters, 10(12), 124003. **https://doi.org/10.1088/1748-9326/10/12/124003.**
Zittis, G., Hadjinicolaou, P., Almazroui, M., Bucchignani, E., Driouech, F., El Rhaz, K., Kurnaz, L., Nikulin, G., Ntoumos, A., Ozturk, T., Proestos, Y., Stenchikov, G., Zaaboul, R., & Lelieveld, J. (2021). Business-as-usual will lead to super and ultra-extreme heatwaves in the Middle East and North Africa. Npj Climate and Atmospheric Science, 4(1). **https://doi.org/10.1038/s41612-021-00178-7.**

**8.** Robine, J.-M., Cheung, S. L. K., Le Roy, S., Van Oyen, H., Griffiths, C., Michel, J.-P., & Herrmann, F. R. (2007). Death toll exceeded 70,000 in Europe during the summer of 2003. Comptes Rendus. Biologies, 331(2), 171–178. **https://doi.org/10.1016/j.crvi.2007.12.001.**

**9.** Shaposhnikov, D., Revich, B., Bellander, T., Bedada, G. B., Bottai, M., Kharkova, T., Kvasha, E., Lezina, E., Lind, T., Semutnikova, E., & Pershagen, G. (2014). Mortality related to air pollution with the Moscow heat wave and wildfire of 2010. Epidemiology, 25(3), 359–364. **https://doi.org/10.1097/EDE.0000000000000090.**

**FIGURE 1.4** Observed Rise in Heatwave Intensity across European and Central Asian Cities (1970–2024)

*Percentage of cities experiencing heatwaves by severity category, based on reanalysis data*

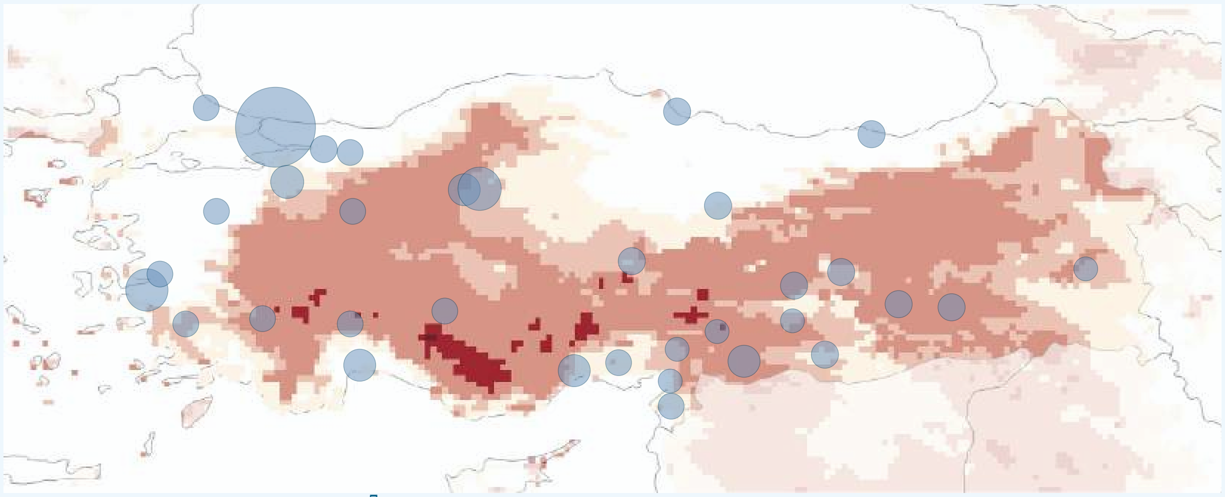



*Source:* World Bank analysis using ERA5-Land reanalysis data.

## BOX 1.1 The Mediterranean on Fire: Mapping Türkiye's July 2023 Heatwave

In July 2023, Türkiye experienced one of the most severe heatwaves in its recorded history, with temperatures in the southeast reportedly nearing 50°C. Using high-resolution climate reanalysis data, the map below illustrates the intensity and spatial extent of the heatwave, which reached "extreme" to "very extreme" levels across large parts of central, southern, and eastern Türkiye.

Media reports at the time highlighted the event's severe and far-reaching consequences, including threats to public health, pressure on critical infrastructure, destructive wildfires, and deepening water shortages, particularly in major population centers such as Istanbul and Izmir.



Population (Millions)

5

0.2

Heatwave Category

No Heatwave | Moderate | Very Extreme

Severe | Super Extreme

Extreme

**Türkiye witnesses record heat wave, temps in SE may reach 50°C**

Professor Sermin Taşlı, lead of the Geography Department at Bakırçay University in western Izmir, told Anadolu Agency (AA) that global average temperatures since the beginning of July have risen to an unprecedented level that has never been documented in human history.

"The greatest threat will be to human, plant and animal health as heat waves will disproportionately harm the elderly, newborns, outdoor laborers and those suffering from chronic ailments," she said.

© Daily Sabah, Jul 16, 2023 – 11:56 am GMT+3

**'Like a blowtorch': Mediterranean on fire as blazes spread across nine countries**

In Turkey, a hospital and a dozen homes were evacuated as a precaution in the tourist town of Kemer, where firefighters for the third day battled a blaze raging through a woodland.

At least 10 planes, 22 helicopters and hundreds of firefighters were dispatched to the affected area as meteorologists warned temperatures could rise several degrees above seasonal averages.

© The Guardian, Wed 26 Jul 2023 17.56 CEST

**Turkey: Istanbul residents urged to save water amid 'catastrophic drought'**

Residents of Turkey's largest city, Istanbul, have been asked to reduce their water consumption as major cities across the country grapple with a drought crisis and high temperatures.

On Wednesday, Istanbul Mayor Ekrem İmamoğlu urged the city's 16 million residents to save "every precious water drop flowing from the tap".

His call came days after the Istanbul Water and Sewerage Administration (İSKİ) published data showing that the city's dams were only around 33 percent full as of mid-August, the lowest rate in nine years. Water supplies are also falling rapidly in dams serving Ankara and Izmir.

© Middle East Eye, 17 August 2023 14:37 BST

*Source:* World Bank analysis of ERA5-Land reanalysis data; media reports.

## 1.3 Urban Form Amplifies Heat Risks

Europe and Central Asia have long been heavily urbanized, and from 1970 to 2020, the region's urbanization rate rose from about 60 to over 70 percent, as the urban population grew from about 450 million to over 670 million.[10] Cities such as Istanbul, Warsaw, and Kyiv, for example, expanded rapidly due to industrialization, economic transformation, and rural-to-urban migration.

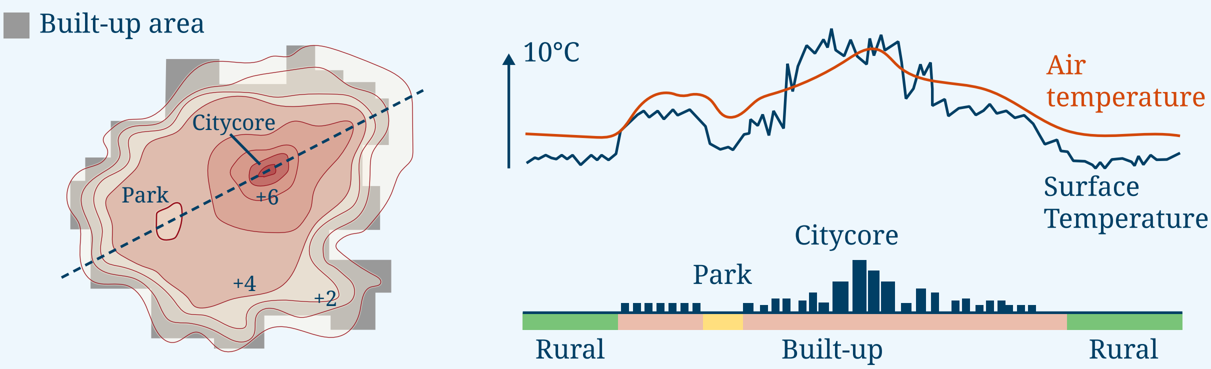
Urbanization has many advantages, but it has also been accompanied by a loss of forests and farmland, leveling of hills and valleys, and within cities, sealing of ground surfaces

**10.** Source: World Bank staff estimates based on the United Nations, Department of Economic and Social Affairs, Population Division (2019). World Urbanization Prospects: The 2018 Revision. New York: United Nations.

and a high concentration of heat-trapping materials and mechanical processes that emit heat, such as motor vehicles and air conditioning.[11] Vegetation cools the environment through evapotranspiration—the process by which water on plant surfaces and in the leaves is turned to vapor, using thermal energy. But in urban landscapes, vegetation can be sparse, and instead the ground is mainly made up of asphalt, concrete, or packed earth. As a result, most of incoming solar energy is either absorbed by those materials, retaining heat, or warms the surrounding air.

As shown in Figure 1.5, on thermal maps, cities can show up as islands of heat, with temperatures as much as 10°C higher than in surrounding rural areas under some conditions.[12] That difference is called the urban heat island (UHI) effect. It is most pronounced at night, as human-made surfaces retain heat longer and cool more slowly than natural landscapes. Weather conditions play a key role: UHI intensity peaks on clear, calm nights after a hot, sunny day without enough wind flow to dissipate the heat. The denser the urban development, the higher the temperatures generally are.

**FIGURE 1.5 The Urban Heat Island Effect: How Built Form and Vegetation Influence Temperature Patterns**




(a) Temperatyre difference at night due to Urban Heat Island effect.

(b) Areas with dense buildings and little vegetation are hotter - affecting people, economies and infrastucture

*Source:* Adapted from WMO (2013).

*Notes:* These diagrams illustrate the urban heat island (UHI) effect, where temperatures rise sharply in built-up areas compared to nearby rural zones—especially at night. Panel (a) shows how temperatures increase toward the city core, with differences of up to 10°C, while panel (b) depicts how dense development and limited vegetation drive both air and surface temperatures higher. Parks and green spaces provide localized cooling. The UHI effect is most pronounced on clear, calm nights, when urban materials retain heat and the absence of wind slows cooling, intensifying risks to health, infrastructure, and energy systems.

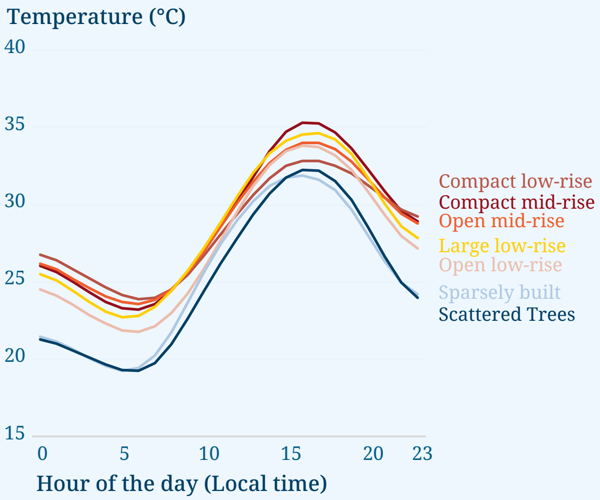
**11.** Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). Urban Climates. In Urban Climates. Cambridge University Press. **https://doi.org/10.1017/9781139016476.**

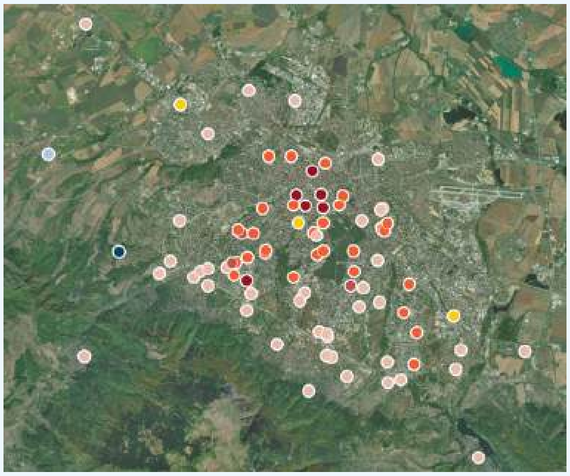
**12.** Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). Urban Climates. In Urban Climates. Cambridge University Press. **https://doi.org/10.1017/9781139016476.**

The UHI effect plays out in real time, reshaping everyday thermal conditions. Thanks to citizen science weather stations, the impact can be studied firsthand. In Sofia, Bulgaria, a network of privately owned weather stations—installed outside homes by individuals—captures hour-by-hour temperature variations across the city. During the July–August 2021 heatwave, which lasted 25 days, these stations recorded stark differences. Temperatures in the city's dense neighborhoods of mid-rise buildings peaked at over 35°C, while greener zones with scattered trees stayed several degrees cooler during peak afternoon hours and were up to 5°C cooler at night (see Figure 1.6).

**FIGURE 1.6** Intra-Urban Heat Variation in Sofia during the July–August 2021 Heatwave

*Hourly temperatures across urban forms based on citizen weather station data*



*Source:* World Bank analysis using hourly Netatmo data provided by Ruhr-University Bochum.[13]

*Notes:* This figure illustrates the hourly temperature cycle recorded across different urban zones in Sofia, Bulgaria, during the 25-day heatwave from July 25 to August 18, 2021. Data were collected via a network of 85 citizen-operated weather stations (Netatmo), which provided hourly temperature observations across the city. Urban areas are classified using the Local Climate Zone (LCZ) framework,[14] which reflects differences in building form, density, and land cover.

**13.** The dataset and the quality-control procedures applied to it are described in more detail in Kittner, J., Fenner, D., Demuzere, M., Bechtel, B.: Crowd-Database — Data Description, 2025, **https://ruhr-uni-bochum.sciebo.de/s/G7FdLFA6NzkPsQG#pdfviewer**, and Fenner, D., Bechtel, B., Demuzere, M., Kittner, J., & Meier, F. (2021). CrowdQC+ - A quality-control for crowdsourced air-temperature observations enabling world-wide urban climate applications. Frontiers in Environmental Science. **https://doi.org/10.3389/fenvs.2021.720747.**

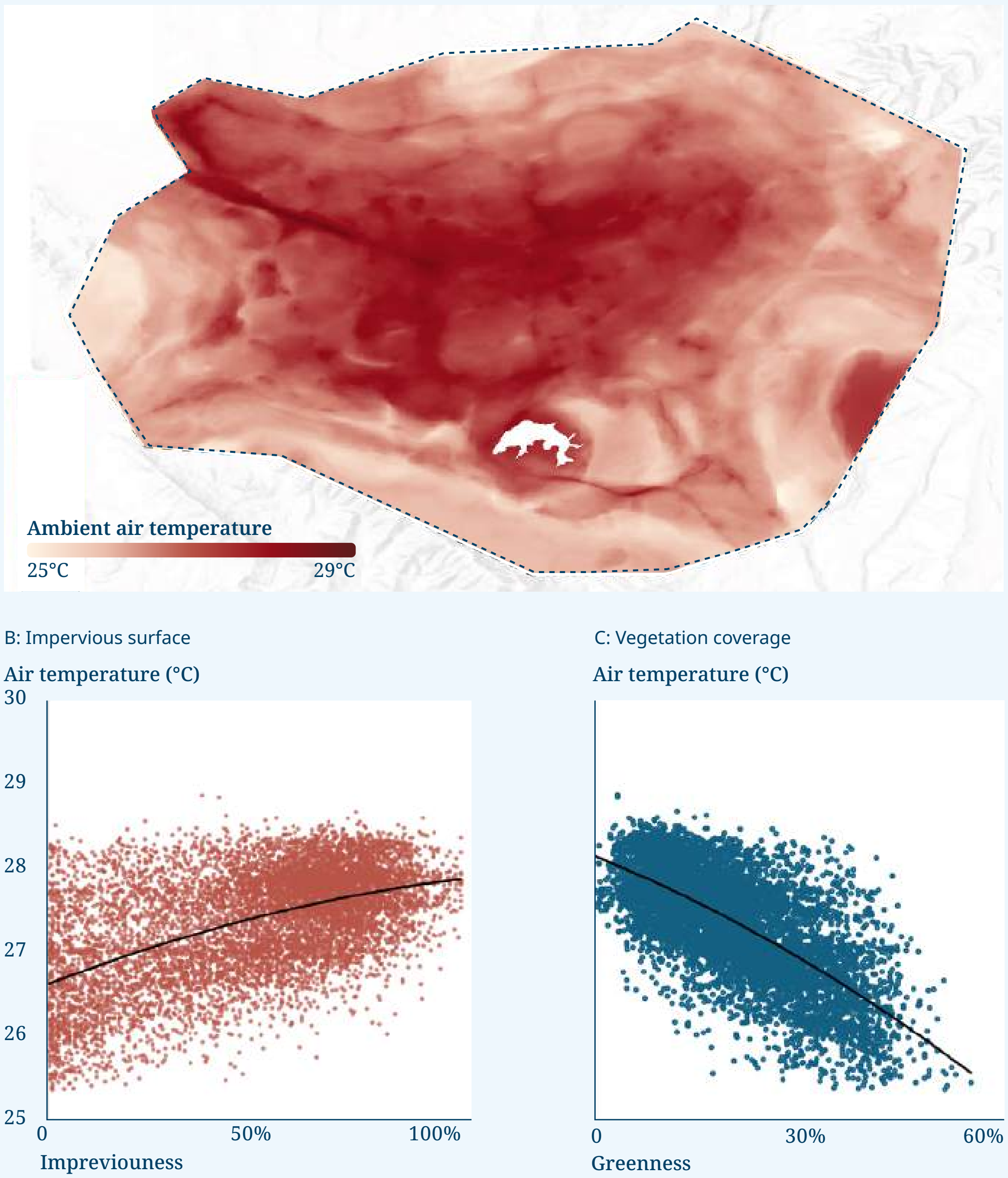
**14.** Stewart, I. D., & Oke, T. R. (2012). Local Climate Zones for Urban Temperature Studies. Bulletin of the American Meteorological Society, 93(12), 1879–1900. **https://doi.org/10.1175/BAMS-D-11-00019.1.**
14. Demuzere, M., Kittner, J., Martilli, A., Mills, G., Moede, C., Stewart, I. D., van Vliet, J., & Bechtel, B. (2022). A global map of local climate zones to support earth system modeling and urban-scale environmental science. Earth System Science Data, 14(8), 3835–3873. **https://doi.org/10.5194/essd-14-3835-2022.**

The role of land cover and urban form in shaping thermal conditions is underscored by a measurement campaign undertaken in Tirana, Albania, during the summer of 2023. A team of 10 volunteers recruited by the University of New York, Tirana, fitted temperature sensors to car windows and drove pre-planned routes across the city. Tens of thousands of near-ground temperature measurements were acquired during three separate vehicle traverses (conducted at 6–7am, 3–4pm, and 7–8pm). By relating the heat measurements to ground cover characteristics using a machine learning model, a high-resolution temperature map for the entire city was created (Figure 1.7, panel A). It shows strong spatial variations in heat exposure across Tirana at the time of the campaign, with a 6.4°C difference between the hottest and coolest neighborhood.

Areas with a higher proportion of sealed, impervious surfaces—such as roads, parking lots, and buildings—show higher temperatures, whereas areas with more tree and grass cover were consistently cooler (Figure 1.7, panels B and C). Hotter areas overlapped, at least partly, with lower-income communities: Neighborhoods composed of single-family dwellings were substantially cooler, while mid-rise areas with apartment blocks and low tree cover were hotter.

## FIGURE 1.7 Relationship between Air Temperatures and Ground Cover Characteristics in Tirana, Albania

A: Ambient air temperature in Tirana, Albania on August 14, 2023




*Source:* World Bank analysis using data from a citizen science mapping campaign (Heat Watch Albania) conducted by CAPA Strategies and the University of New York, Tirana; World Settlement Footprint (WSF);[15] and Sentinel-2 satellite imagery.

*Notes:* The air temperature map represents a hot day (August 14, 2023) in Tirana. The map was created through local air temperature measurements taken by citizen science volunteers using vehicle-mounted sensors. Imperviousness is obtained by resampling the binary 10m WSF built-up layer to a 100m imperviousness map. Median greenness is calculated using the Normalized Difference Vegetation Index metric applied to satellite imagery.

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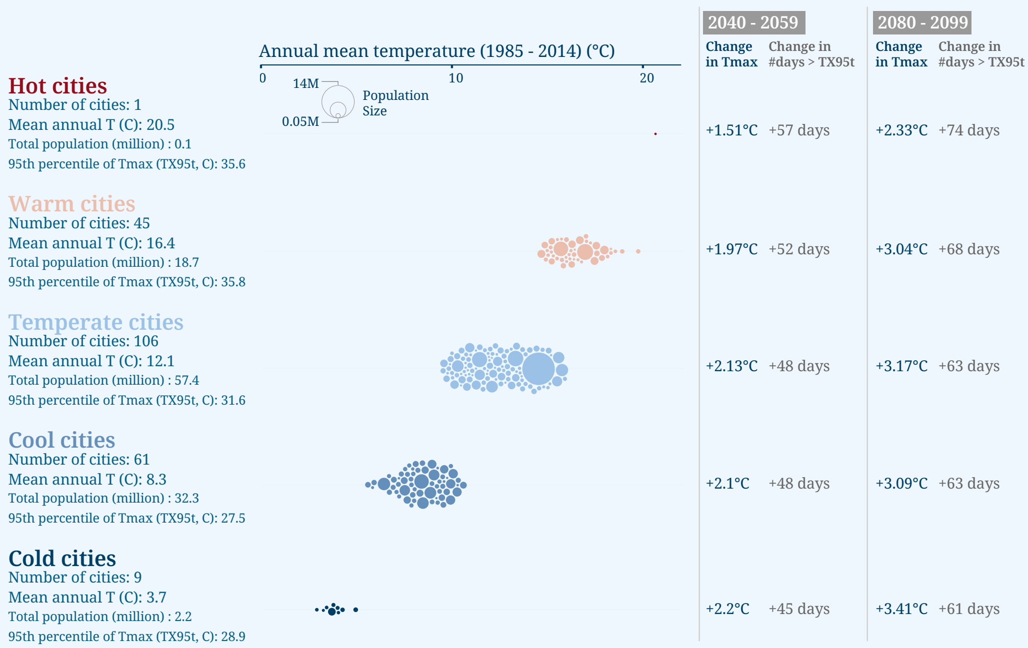
**15.** Marconcini, Mattia; Metz-Marconcini, Annekatrin; Üreyen, Soner; Palacios-Lopez, Daniela; Hanke, Wiebke; Bachofer, Felix; et al. (2020): World Settlement Footprint (WSF) 2015. figshare. Dataset. **https://doi.org/10.6084/m9.figshare.10048412.v1.**

Through hyperlocal measurements of the atmospheric layer that human beings experience daily (that is, ambient air temperatures at near-ground level), the heat mapping campaign provides a more accurate description of spatial variation in heat than is possible through satellite observations or local weather stations.[16] Heat disparities in cities such as Tirana are large enough to influence the health and quality of life of residents.

As shown in Figure 1.8, cities across Europe and Central Asia – whether currently hot, warm, temperate or cold – are projected to experience significant increases in the number of hot days by the end of the century. Localized urban heat island effects can compound and amplify these risks, particularly in neighborhoods that lack access to green space or cooling infrastructure.

## FIGURE 1.8 Projected Increase in Hot Days for Cities in Europe and Central Asia




*Source:* World Bank staff analysis using data from ERA5-Land Reanalysis[17], NEX-GDDP-CMIP6[18], and the Urban Centre Database.[19]

*Notes:* Analysis includes 222 cities available grouped by present day (1985-2014) annual mean temperature category: hot (20–25°C), warm (15–20°C), temperate (10–15 °C), cool (5–10°C), and cold (< 5°C). A hot day is defined as a day with a daily maximum temperature exceeding the 95th percentile of daily maximum temperatures for that city in the reference period. Projected changes in annual average daily maximum temperatures and number of hot days per year are computed as the median based on 22 CMIP6 models from NEX-GDDP-CMIP6.

**16.** Shandas, V., Voelkel, J., Williams, J. and Hoffman, J., 2019. Integrating satellite and ground measurements for predicting locations of extreme urban heat. *Climate*, 7(1), p.5.

**17.** Muñoz-Sabater, J., Dutra, E., Agustí-Panareda, A., Albergel, C., Arduini, G., Balsamo, G., Boussetta, S., Choulga, M., Harrigan, S., Hersbach, H., Martens, B., Miralles, D. G., Piles, M., Rodríguez-Fernández, N. J., Zsoter, E., Buontempo, C., & Thépaut, J. N. (2021). ERA5-Land: A state-of-the-art global reanalysis dataset for land applications. Earth System Science Data, 13(9), 4349–4383. **https://doi.org/10.5194/essd-13-4349-2021.**

**18.** Thrasher, B., Wang, W., Michaelis, A., Melton, F., Lee, T., & Nemani, R. (2022). NASA Global Daily Downscaled Projections, CMIP6. Scientific Data, 9(1), 1–6. **https://doi.org/10.1038/s41597-022-01393-4.**

**19.** Florczyk, A., Melchiorri, M., Corban, C., Schiavina, M., Maffenini, L., Pesaresi, M., Politis, P., Sabo, F., Carneiro Freire, S., Ehrlich, D., Kemper, T., Tommasi, P., Airaghi, D., & Zanchetta, L. (2019). Description of the GHS Urban Centre Database 2015. KJ-02-19-103-EN-N (online). **https://doi.org/10.2760/037310** (online).

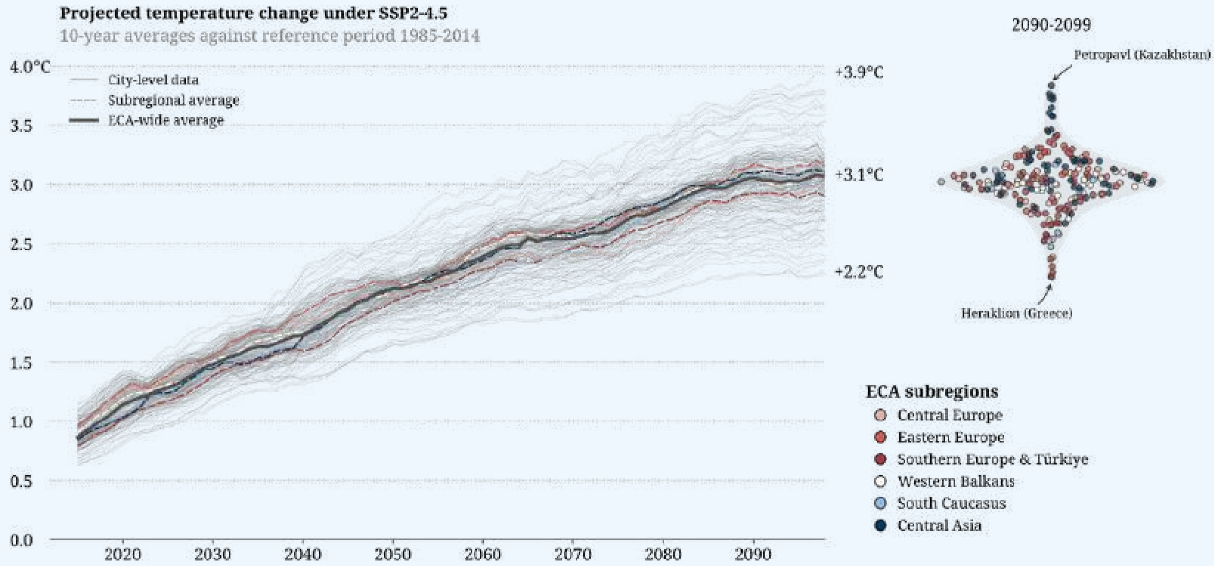
## 1.4 Cities across the Region Will Get Much Hotter

Climate researchers have developed large-scale simulations of the earth's climate system, known as global climate models, which are used to project how air temperature and other variables may change under different greenhouse gas emission scenarios. Based on a "middle-of-the-road" climate scenario (SSP2-4.5) in which economic trends and environmental policies remain largely unchanged, global average year-round temperatures are projected to rise 1.2°C by 2030, 1.9°C by 2050, and 3°C by 2090 compared with the average in 1985–2014.[20]

For cities in Europe and Central Asia, climate projections suggest temperature rises of a comparable magnitude on average, but with significant variation. Models suggest that Heraklion in Greece may experience slightly more than 2°C of warming by the end of the century, while Petropavl, Kazakhstan, could experience closer to 4°C (see Figure 1.9). These higher average temperatures will translate into a larger number of days each year when it is too hot to safely work outdoors, walk to or from work or school without health risks.

**20.** The SSP2-4.5 scenario represents a trajectory aligned with current global policy trends and moderate climate change mitigation efforts. Under this scenario, global mean temperatures are projected to rise by approximately 3°C above pre-industrial levels by 2100, assuming neither a significant acceleration of mitigation efforts, nor complete failure. See Hausfather, Z. and G.P. Peters. 2020. "Emissions – the 'Business as Usual' Story Is Misleading." *Nature* 577 (7792): 618–20. **doi:10.1038/d41586-020-00177-3.**

## FIGURE 1.9 Projected End-of-Century Warming for Cities in Europe and Central Asia (SSP2-4.5)




*Source:* World Bank analysis using NEX-GDDP-CMIP6 data

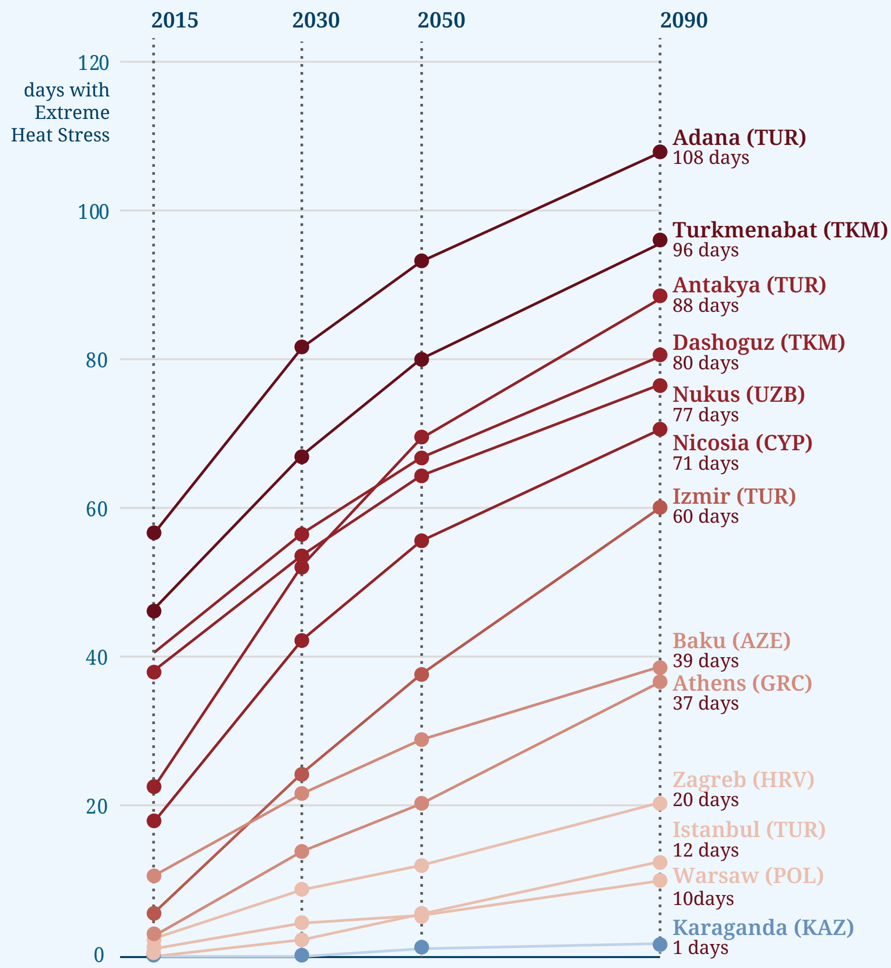
*Notes:* Temperature projections are based on the NEX-GDDP-CMIP6 SSP2-4.5 scenario, a "middle-of-the-road" emissions pathway. The left panel shows projected annual mean temperature change (relative to a 1985–2014 baseline) for 222 cities, with the black line representing the mean for all cities. The right panel displays end-of-century (2090–2099) temperature changes for individual cities across Europe and Central Asia, highlighting the range of warming expected under this scenario.

When gauging heat stress risks, public health and occupational health experts often use a metric called wet-bulb globe temperature (WBGT), which accounts for air temperature, humidity, air flow, and thermal radiation from the sun or other sources. WBGT more closely reflects how the human body will experience thermal conditions than the air temperature given on weather reports. In the shade, with a breeze and low humidity, WBGT may be much lower than the air temperature. In full sun, on a humid and windless day, it may be much higher. As discussed further in Section 2, individual physiology, acclimatization, and physical exertion also affect how heat is perceived. Still, the International Organization for Standardization (ISO) considers WBGT values above 30.5°C to pose a health risk even for light work such as desk jobs, teachers, or security guards.[21]

**21.** Flouris, A., Azzi, M., Graczyk, H., Nafradi, B., and Scott, N., eds. 2024. Heat at Work: Implications for Safety and Health. A Global Review of the Science, Policy and Practice. ILO.

Cities across the region are projected to see an increase in days above 30.5°C. For instance, in Adana, Turkey, the number of such extremely hot days is projected to more than double, from 57 per year today, to 108 by 2090. Cities with mild climates will face conditions like those in places that are much hotter today. For example, by 2090, Warsaw is expected to experience as many extremely hot days as Zagreb does today (see Figure 1.10).

**FIGURE 1.10** **Projected Increase in Days with Extreme Heat Stress in European and Central Asian Cities (Present – 2090)**




*Source:* World Bank analysis using a dataset produced by CarbonPlan for this study.[22]

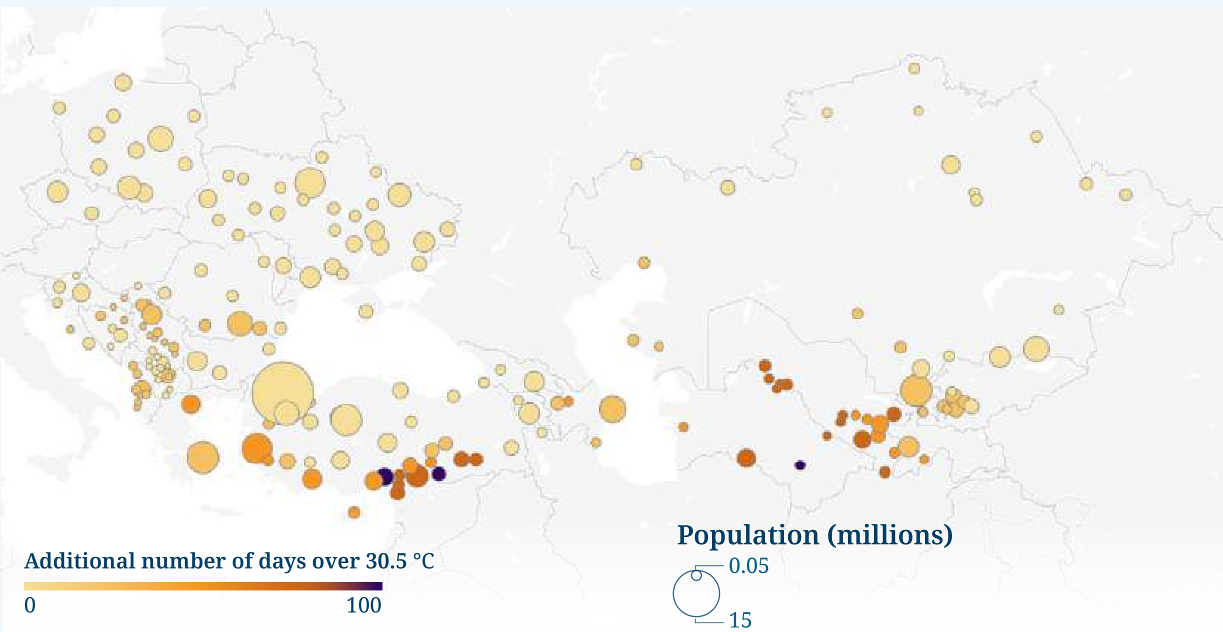
*Notes:* This figure shows the projected number of days per year when wet-bulb globe temperature (WBGT) exceeds 30.5°C—a threshold associated with high heat stress for outdoor activity. Values reflect conditions for individuals standing outdoors in the sun. Projections are shown for present-day, 2030, 2050, and 2090 under the SSP2-4.5 emission scenario. The analysis covers selected cities across Europe and Central Asia highlighting regional disparities in future heat exposure.

**22.** Chegwidden, O. and J. Freeman. 2023. "Modeling Extreme Heat in a Changing Climate." San Francisco, CA, US: CarbonPlan. **https://carbonplan.org/research/extreme-heat-explainer.**

Currently, about 40 percent of the region's cities experience, on average, zero days of extreme heat per year, but by 2030, that share is projected to drop to about 12 percent; by 2050, to 6 percent; and by 2090, to less than 1 percent. Of all the cities included in modeling for this study, only Brasov, Romania, and Van, Türkiye, remain in that category by 2090.

The largest increase in extreme heat days per year is projected to be seen in southern Türkiye, as the eight cities experiencing the largest increase in extreme heat days are all located there. Antakya and İskenderun are the cities with the largest projected increase in extreme heat days by 2090, with 67 and 66 additional such days respectively (see Figure 1.11).

**FIGURE 1.11 Additional Days of Extreme Heat Exposure across European and Central Asian Cities by 2090**




*Source:* World Bank analysis using a dataset produced by CarbonPlan for this study

*Notes:* This map shows the projected increase in the number of annual days with extreme heat stress—defined as wet-bulb globe temperature (WBGT) above 30.5°C in full sun—across cities in Europe and Central Asia by 2090 under the SSP2-4.5 emissions scenario. Color intensity represents the additional number of extreme heat days per year relative to present-day conditions. Circle size corresponds to city population, highlighting areas where large numbers of people may be affected. Cities in Türkiye, southern Central Asia, and the Western Balkans are projected to face the sharpest increases, with some locations seeing more than 75 additional extreme heat days per year.

## 1.5 Life-Threatening Heatwaves will Shift from Rare to Routine

As temperatures continue to climb, heatwaves across Europe and Central Asia are expected to become more frequent and severe, posing escalating threats to human health, economic productivity, and vital infrastructure. Within cities, neighborhoods that are already hotter due to localized factors will disproportionately face the brunt of rising global temperatures.

For example, in Skopje, North Macedonia, modeling conducted for this study shows that nighttime temperatures in the urban core exceed those in the nearby countryside by 4.7°C. High nighttime temperatures contribute to health risks by preventing people from sleeping and cooling off their body. Central regions of Skopje already experience around two weeks per year of hot nights—defined as those when temperatures do not fall below 25°C. This is twice as many as greener neighborhoods, and climate modeling suggests that the number of hot nights could nearly double by 2050 (see Table 1.1). Similarly, detailed climate modeling confirms that central neighborhoods already experience heatwave conditions more frequently. By 2050, the number of heatwave days per year could rise by 60 percent, to more than 40 per year (see Table 1.1 and Figure 1.12).

**TABLE 1.1 Projected Heatwave Days, Hot Nights, and Cooling Energy Needs in Central Skopje, North Macedonia**

| Metric | Present | 2050 |
|---|---|---|
| Heatwave days (per year)[a] | 25 | 40 (60% increase) |
| Hot nights (per year)[b] | 16 | 31 (94% increase) |
| Potential energy needs for cooling[c] | 7,100°C | 10,970°C (52% increase) |

*Source:* Analysis conducted by VITO using the UrbClim model for this study.

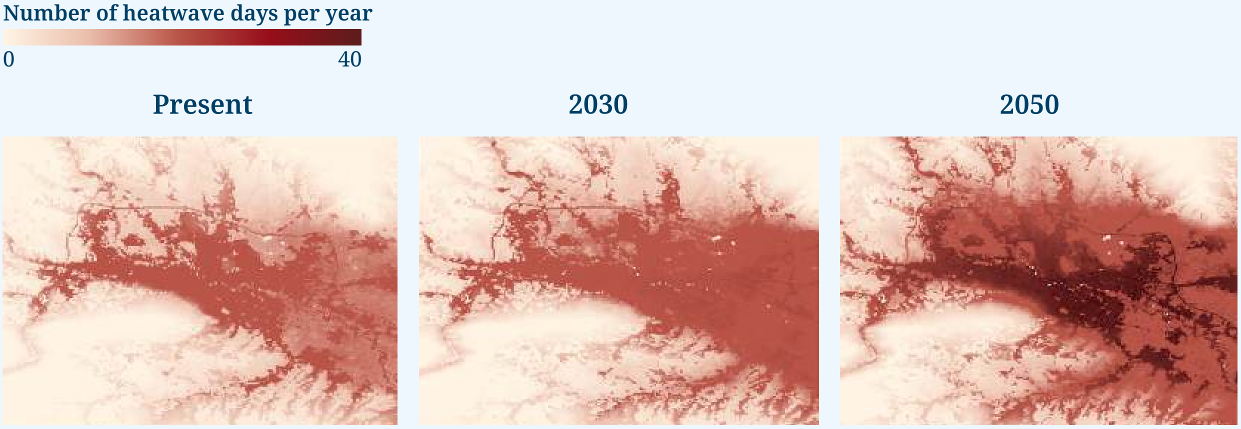
*Notes:* The modeling assumes a moderate-to-high climate change scenario (SSP3-7.0). The metrics are defined as follows:

a. Heatwave days: the annual number of days where temperatures exceed the 95th percentile temperature of a historical reference period (2001–20) for at least three consecutive days.

b. Hot nights: the annual number of nights where temperature remains above 25°C (also known as 'tropical nights').

c. Measured as cooling degree hours. Cooling needs are calculated by comparing outdoor temperatures with a reference point representing indoor thermal comfort. The cooling requirement for each period is multiplied by the length of the period. This metric captures projected energy demand driven by temperature effects, ignoring the growth driven by increased adoption of air conditioning.

**FIGURE 1.12** Projected Number of Heatwave Days per year in Skopje, North Macedonia




*Source:* Analysis conducted by VITO using the UrbClim model for this study.

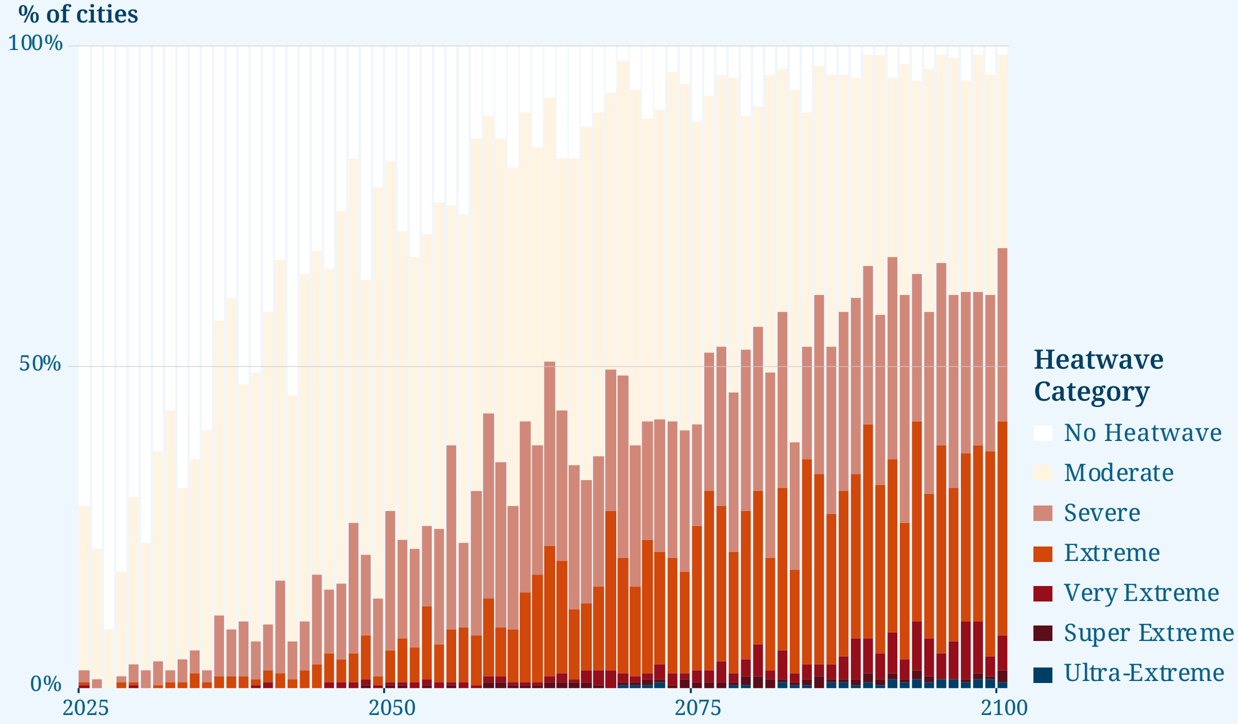
*Notes:* A heatwave is defined as a period of at least three consecutive days in which temperatures exceed the 90th percentile of a historical reference period (in this case 2001–2020).

Across the region, the frequency and intensity of heatwaves appears set to rise substantially as the century progresses. Climate modeling conducted for this study based on the Heatwave Magnitude Index daily metric shows that nearly all cities in the region are likely, by the end of the century, to experience as least one moderate heatwave per year. Two-thirds will experience at least one severe heatwave per year; around 40 percent, an extreme heatwave; 10 percent, a very extreme event; and 2.5 percent, a super extreme heatwave (Figure 1.13). This all far exceeds historical norms.

Three cities - Limassol (Cyprus), Chania (Greece) and Heraklion (Greece), are projected to experience an ultra-extreme heatwave—surpassing the peak severity of the 2010 Russian heatwave, recognized as one of the most extreme heatwaves in recent history. In this new climate reality, exceptionally severe heatwaves—once considered rare, once-in-a-generation disasters—may become regular occurrences in many cities across the region.

## FIGURE 1.13 Projected Increase in Heatwave Severity across European and Central Asian Cities (2025-2100)

*Percentage of cities experiencing moderate to ultra-severe heatwaves under the SSP2-4.5 scenario*




*Source:* World Bank analysis using NEX-GDDP-CMIP6 climate projections

*Notes:* This chart shows the projected number of cities in Europe and Central Asia expected to experience heatwaves of varying severity each year between 2025 and 2100, based on NEX-GDDP-CMIP6 climate model projections under the SSP2-4.5 emissions scenario. Heatwaves are categorized into six severity levels: moderate, severe, extreme, very extreme, super extreme, and ultra-extreme, based on intensity, duration, and deviation from historical norms. For reference, the Western European heatwave of 2003 was categorized as very extreme and the Russian heatwave of 2010 was categorized as super-extreme. The analysis covers 222 cities across the region and uses standardized thresholds derived from each city's historical climate conditions.

# 2 The Toll of Extreme Heat on People, Jobs, and Infrastructure

## 2.1 Heat Causes Death and Illness among Vulnerable Groups

Public health researchers have long tried to assess the impact of temperatures on mortality rates,[23] from the global to the local level, and even in smaller statistical units.[24] Epidemiological models can estimate the temperature threshold below or above which the risk of death (from heat or cold, respectively) is at its lowest. This is known as the Minimum Mortality Temperature (MMT). The relative risk of mortality increases as temperatures move farther from the threshold.[25] Some analyses calculate the increase in mortality risk for specific age categories or by gender.

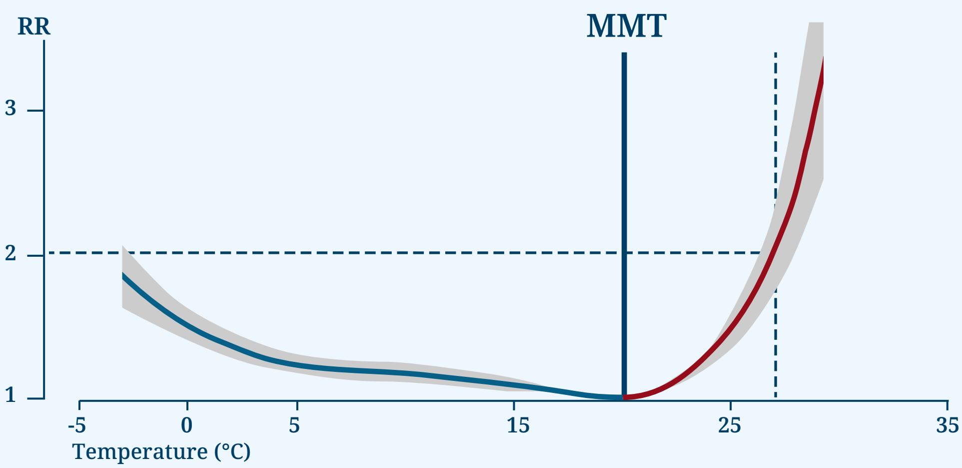
**23.** Such epidemiological models typically utilize daily counts of mortality from all causes recorded by regional health authorities. These are then matched with near-surface daily mean air temperature (Tmean) measured by weather stations at similar geographical scales. Along with a set of other socio-economic and demographic indicators (e.g., GDP) that are usually available at regional or national level, the time series data of the two variables (mortality and Tmean) are then combined in the epidemiological model to examine the location-specific risk of mortality from both cold and heat.

**24.** Gasparrini, A. et al., 2015: Mortality risk attributable to high and low ambient temperature: a multicountry observational study. Lancet 386, 369–375 **https://doi.org/10.1016/S0140-6736(14)62114-0** ; Gasparrini, A. et al., 2022: Small-area assessment of temperature-related mortality risks in England and Wales: a case time series analysis. The Lancet Planetary Health, Vol 6 (7), E557-E564 **https://doi.org/10.1016/S2542-5196(22)00138-3**

**25.** Put differently, the optimal temperature; also referred to as the temperature at which the associated mortality risk is the lowest, or more commonly as the Minimum Mortality Temperature (MMT), facilitates easier interpretation of the relative risk (RR) of mortality for each unit increase (heat) or decrease (cold) in temperature away from the MMT (Gasparrini, A. et al., 2015).

Figure 2.1 illustrates the increases in mortality risk from cold (depicted by the blue line) and heat (depicted by the red line) relative to Istanbul's optimal temperature (depicted by the vertical MMT line). The shading depicts the confidence intervals, showing that the uncertainty in the estimated risks is larger at both ends of the curve. When the number of days of exposure to extreme temperatures is low, it is even more difficult to estimate mortality risks precisely.

**FIGURE 2.1** How Temperature Affects Mortality Risk in Istanbul, Türkiye




*Source:* World Bank elaboration based on the modeling methodology described in Vicedo-Cabrera et al., 2019.[26]

What is clear from the figure is that the mortality risks generally increase far more sharply with rising heat than with deeper cold—a pattern found in many other assessments in the public health literature.[27] The MMT line in the figure is estimated at 20.5°C—the point where the risk of death is lowest, set at 1.0. Across most studies, temperature–mortality relationships take on either a U or J shape, capturing both the nonlinear nature of the

**26.** Vicedo-Cabrera, A. M., Sera, F. & Gasparrini, A., 2019: Hands-on Tutorial on a Modeling Framework for Projections of Climate Change Impacts on Health. Epidemiology 30, 321–329 **https://doi.org/10.1097/EDE.0000000000000982.**

**27.** For a majority of the cities across the globe where the historical temperature-related mortality associations have been previously estimated in literature, the heat part of the risk curve generally increases far more sharply compared with the cold part. However, the estimated relative risk levels at the extreme cold and heat range of temperatures in some cities can be near similar in magnitude, or at times, even higher for cold compared to heat. A similar pattern emerges for cities in Europe and Central Asia. See Gasparrini, A. et al., 2017: Projections of temperature-related excess mortality under climate change scenarios. Lancet Planet. Heal. 1, e360–e367 **https://doi.org/10.1016/S2542-5196(17)30156-0**; Mistry, M.N. et al. 2022: Comparison of weather station and climate reanalysis data for modeling temperature-related mortality. Sci Rep 12, 5178 **https://doi.org/10.1038/s41598-022-09049-4**; Masselot P. et al., 2023: Excess mortality attributed to heat and cold: a health impact assessment study in 854 cities in Europe. Lancet Planet Health. 2023 Apr;7(4):e271-e281. **https://doi.org/10.1016/S2542-5196(23)00023-2.**

effect and the delayed impact of extreme temperatures.[28] The dashed lines in the figure serve as guides: at around 27°C, the mortality risk surpasses 2.0—meaning the risk of death has doubled relative to the MMT.

The health effects of heat extend well beyond mortality,[29] contributing to a wide range of illnesses and problems. Exposure to high temperatures during pregnancy has been associated with a greater risk of preterm birth, which can continue to affect children as they grow up. In some settings, extreme heat has been linked to increased rates of still-birth and lower birth weight.[30] High temperatures can also put serious strain on the body, especially for people with health conditions such as heart or kidney disease. Heat makes the heart work harder to keep the body cool, which can trigger heart attacks or worsen existing cardiovascular problems. At the same time, dehydration from heat can reduce blood flow to the kidneys, increasing the risk of kidney injury or failure—this is especially risky for outdoor workers or older adults.[31]

High temperatures also contribute to both premature death (years of life lost) and disability, a combined impact typically measured in disability-adjusted life years (DALYs).[32] Heat exposure and the severe dehydration it can often cause have been shown to exacerbate cardiovascular disease, respiratory conditions, and diabetes, and cause kidney damage. It also increases the risk of adverse pregnancy outcomes, including preterm birth and low birth weight. Emerging evidence also suggests heat affects sexual and reproductive health, influencing fertility and increasing menstrual pain[33] Heat can also limit people's cognitive abilities, increasing the risk of accidents and resulting injuries, including in workplaces. And it can take an emotional toll, worsening common mental health conditions such as depression and anxiety.

Heat doesn't just strain individuals—it puts pressure on healthcare systems. Hospitalizations rise, particularly among those with cardiovascular and respiratory conditions, as their bodies struggle to regulate temperature. At the same time, healthcare workers themselves are affected, as heat inside facilities can increase workplace stress and potentially reduce the quality of care.[34]

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**28.** See Gasparrini et al. (2015) and Vicedo-Cabrera et al. (2019), both previously cited.

**29.** In several parts of the world including some of the countries examined in this study; such as in South Caucasus and Central Asia, city-level daily mortality counts from all causes are often not recorded systematically or publicly available over an extended period. Even more difficult to access are the records of specific health outcomes, making it difficult for public health researchers to assess the burden of heat on morbidity. Given these data constraints and while acknowledging the various ways in which heat can affect human health, the assessment of heat on health in this report has been restricted to mortality.

**30.** Roos et al., 2021: Maternal and newborn health risks of climate change: A call for awareness and global action. Acta Obstet Gynecol Scand. 2021 Apr;100(4):566-570. **https://doi.org/10.1111/aogs.14124**.

**31.** Ebi et al., 2021: Hot weather and heat extremes: health risks, The Lancet; 398:698-708, **https://doi.org/10.1016/S0140-6736(21)01208-3.**

**32.** Song et al., 2021: Ambient high temperature exposure and global disease burden during 1990–2019: An analysis of the Global Burden of Disease Study 2019. Science of The Total Environment 787 (147540), **https://doi.org/10.1016/j.scitotenv.2021.147540.**

**33.** Baker FC et al., 2020:. Temperature regulation in women: Effects of the menstrual cycle. Temperature (Austin), 7(3):226-262. **http://doi.org/10.1080/23328940.2020.1735927.**

**34.** Martins FP, et al., 2024: The Double Burden: Climate Change Challenges for Health Systems. Environmental Health Insights, 18. **https://doi.org/10.1177/11786302241298789.**

## BOX 2.1 Heat and the Human Body

Temperature regulation is intrinsic to how humans— like all other warm-blooded animals—maintain life and health. Regardless of how hot or cold it is outside, the body works to keep internal organs within a narrow temperature range, around 37°C for humans. Under heat stress, the body's ability to maintain the right internal temperature can be compromised.

### How do our bodies respond to rising heat?

When the body heats up, two key mechanisms kick in to cool it down and keep internal organs safe: vasodilation and perspiration. Blood vessels near the skin dilate, allowing heat to be shed more easily. Sweat released onto the skin cools the body through evaporation. Hydration is essential for this process, as fluid loss must be replaced to maintain cooling and blood pressure. Deliberate actions—such as seeking shade, adjusting clothing, and using water or fans—also support cooling.

### What makes heat dangerous?

Air temperature is central to heat stress, but other environmental factors also matter: lack of air movement, direct sunlight, high humidity (which reduces the effectiveness of sweating), and radiative heat from surfaces all raise risk. Our bodies also generate heat internally, especially during physical exertion. As the level of exertion increases during physical labor or sports, so does internal heat load that can vary by age, gender or pre-existing health conditions. Critically, high nighttime temperatures limit the body's ability to recover, leading to cumulative heat strain over successive days.

### How does heat cause illness or death?

Heat causes illness and death both directly and indirectly. Heat stroke—a life-threatening condition occurring when core body temperature exceeds 40°C—can cause organ and brain damage. However, most heat-related deaths result from the worsening of underlying conditions such as cardiovascular, respiratory, and kidney disease. For example, older adults with heart conditions may face serious risk when the heart must pump harder to dissipate heat, leading to an increase in heart attacks during hot weather. Importantly, heat combined with elevated levels of air pollution has a far greater impact on health. Studies examining the concurrent exposure of individuals to fine particulate matter (PM2.5 or PM10) and heat reveal a higher risk of mortality, especially for those suffering from asthma and cardiopulmonary diseases.[35]

### Who is most at risk?

Older adults are more vulnerable due to lower aerobic fitness, different body composition, and higher prevalence of chronic illness. Children and infants also face higher risks, as their thermoregulation is underdeveloped, and they depend on caregivers to alert them to heat risks. Certain medications—including diuretics, antipsychotics, and beta-blockers—can impair the body's ability to regulate temperature. Other risk factors include social isolation, alcohol or drug use, and living in overheated dwellings such as poorly insulated top-floor apartments.

Outdoor workers in construction, agriculture, or delivery services face prolonged heat exposure, often with limited access to shade, rest breaks, or water. A review of studies found the factors most strongly associated with death during heatwaves were being confined to bed, having a psychiatric illness, and not leaving the home daily, which raised the risk of death by 6.4, 3.6, 3.4 times, respectively.[36]

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**35.** Stafoggia et al., 2023: Joint effect of heat and air pollution on mortality in 620 cities of 36 countries, Environment International, Vol 8 (108258) **https://doi.org/10.1016/j.envint.2023.108258**.

**36.** Bouchama, A., Dehbi, M., Mohamed, G., Matthies, F., Shoukri, M., & Menne, B. (2007). Prognostic factors in heat wave–related deaths: a meta-analysis. *Archives of Internal Medicine*, 167(20), 2170–2176. **https://doi.org/10.1001/archinte.167.20.ira70009.**

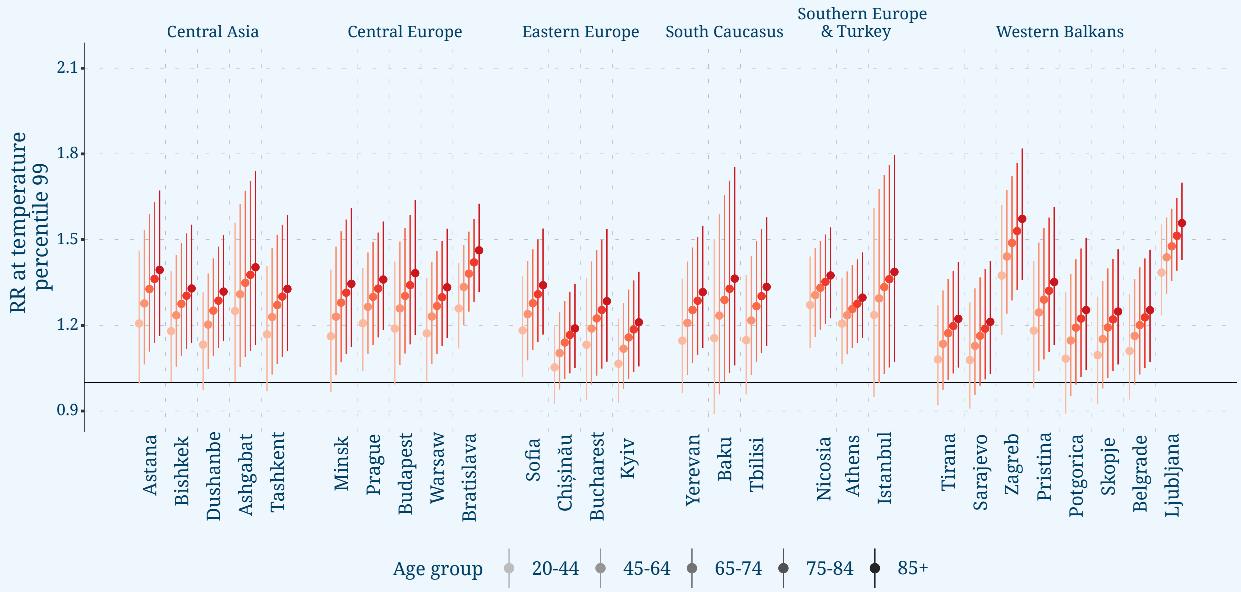
Recent studies show a markedly higher risk of heat-related mortality among people over the age of 65 than among younger adults. However, much of this research has focused on countries in Europe where public health authorities maintain comprehensive historical health records.[37] Importantly, the risk of heat-related death—both among older adults and other age groups—is not evenly distributed across the region. This variation reflects a combination of factors, including demographic structure, the quality of public health services, and especially differences in heat exposure—measured by the average number of hot days per year. The cities in Europe and Central Asia examined for this report here show similar patterns, with the highest burden of heat-related mortality, particularly among older adults, concentrated in Cyprus, Greece, and Turkey.

Figure 2.2 shows the relative risk of heat-related mortality for adults in selected cities across the region, by age group, on days when the temperature reaches the 99th percentile of each city's daily mean temperature. There is a clear and consistent pattern of the risk of mortality rising with age throughout Europe and Central Asia. However, there are also stark differences across cities in the relative risk of mortality. A few cities, such as Zagreb and Ljubljana in the Western Balkans, clearly stand out.[38]

**37.** Masselot et al., 2023; Ballester et al., 2023: Heat-related mortality in Europe during the summer of 2022, Nature Medicine 29, 1857-1866, **https://doi.org/10.1038/s41591-023-02419-z**; García-León et al., 2024: Temperature-related mortality burden and projected change in 1368 European regions: a modeling study, The Lancet Public Health, Vol 9(9) e644 - e653, **http://doi.org/10.1016/S2468-2667(24)00179-8**. An exception is the comprehensive global study examining the temperature-mortality associations by age and cause over 532 cities across 33 countries, Scovronick et al., 2024: Temperature-mortality associations by age and cause: a multi-country multi-city study. Environmental Epidemiology 8(5):p e336, DOI: 10.1097/EE9.0000000000000336.

**38.** The RR99 in these two cities clearly stand tall compared to the cities both in the Western Balkans and other regions. The mortality risk for the three elderly age groups: 65-74, 75-84 and 85+, ranges between 1.5-1.6, or 50-60 percent higher than the corresponding risk at the age-specific MMT, thereby providing more compelling evidence that the local population in Zagreb and Ljubljana are more vulnerable to extreme heat.

## FIGURE 2.2 Relative Risk of Mortality on the Hottest Days in Selected Cities in Europe and Central Asia

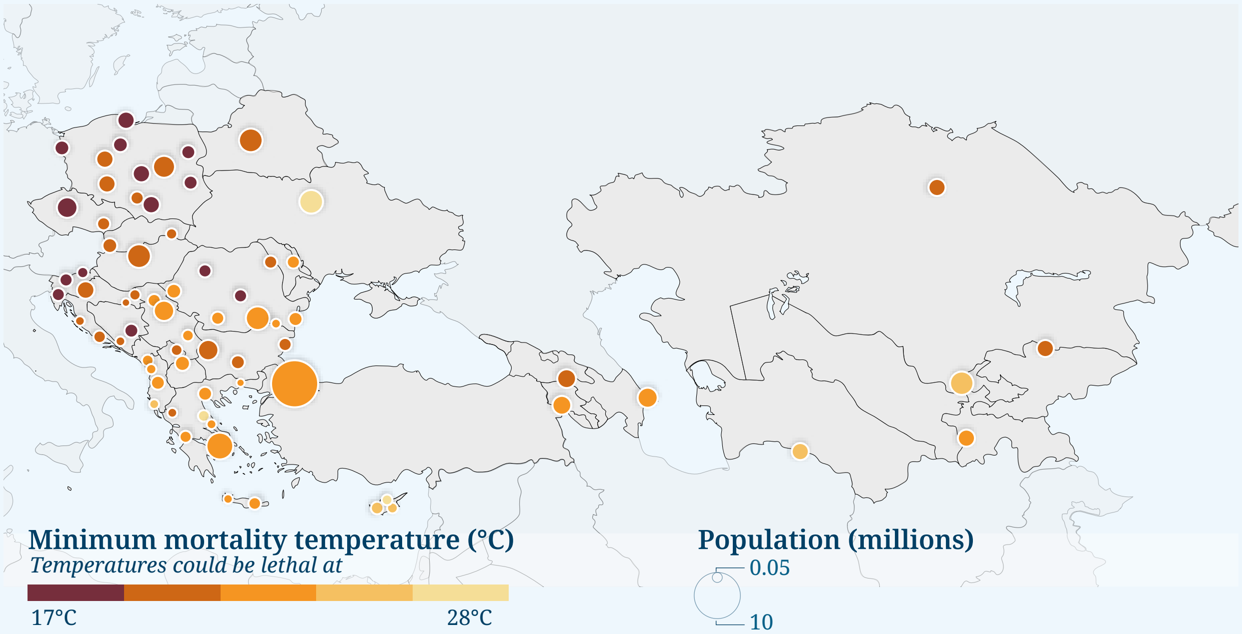



*Source:* World Bank elaboration based on the modeling methodology described in Masselot et al., 2023.

*Notes:* The 99th percentile temperature means that on average, that threshold would only be exceeded on 1 percent of days within a reference time period (here, the years 2000–2020). This approach offers a degree of standardization across locations while reflecting differences in the local climate to which people are adapted (as illustrated in Figure 2.3). In contrast, setting an absolute threshold—say, 30°C—would likely understate extreme heat mortality risks in hotter cities and overstate them in cooler cities. The dots and vertical lines represent the point estimates and confidence range, respectively. The contrast in colors reflect the associated RR99 across the different age groups, with the darker shades representing the RR for the older age groups.

Comparing MMTs across cities shows highlights large differences in the temperatures to which people are acclimatized, with a clear north–south (Figure 2.3). Southern cities such as Larnaka and Nicosia, in Cyprus, and Ashgabat, in Turkmenistan, exhibit higher optimal temperatures, around 27°C, across all age groups. In contrast, northern cities such as Minsk (Belarus), Warsaw (Poland), and Astana (Kazakhstan) show lower MMTs, estimated to range between 18.0°C and 19°C.

**FIGURE 2.3** Minimum Mortality Temperature (MMT), in °C, for 70 Cities in Europe and Central Asia




*Source:* World Bank elaboration based on the modeling methodology described in Masselot et al., 2023.

*Notes:* The MMT here is estimated across all age categories for each location and is commonly referred to as the overall MMT. The size of the bubbles is scaled in proportion to the estimated population in millions (reference year 2020). The analysis spanning 2000–2020 covers selected cities across Europe and Central Asia, highlighting regional disparities in present-day optimum exposure to temperature, driven largely by local-scale acclimatization and adaptation to both cold and heat.

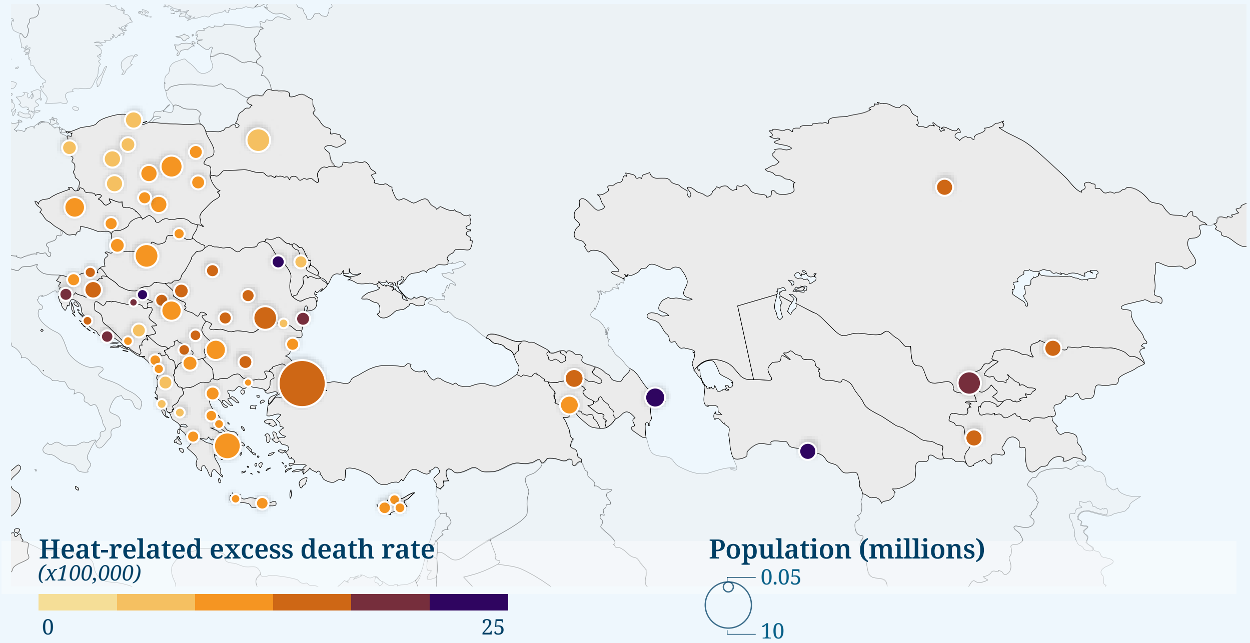
## 2.2 Heat-Related Mortality Will Rise in Europe and Central Asia

Figure 2.4 presents heat-related excess death rates for all age groups across 70 cities in Europe and Central Asia.[39] A familiar spatial pattern reemerges, with higher historical rates, in the general range of 25–27.5 per 100,000, estimated in cities with hotter climates, such as Lași (Romania), Ashgabat (Turkmenistan), Baku (Azerbaijan), and Osijek (Croatia).

**39.** The MMT and relative risk play a crucial role in translating temperature-related mortality into more intuitive health impact metrics. These include so-called "excess" deaths attributable to heat or cold—deaths that would not have occurred in the absence of exposure to non-optimal temperatures. The non-optimum temperatures here refer to the location-specific MMT. The deaths attributable to heat or cold therefore refer to deaths that occur from exposure to daily mean temperature falling outside the MMT where the risk of temperature-related death is the lowest (Gasparrini and Leone, 2014: Attributable risk from distributed lag models. BMC Med Res Methodol., 14(1):55. **https://doi.org/10.1186/1471-2288-14-55**). By combining these measures with location-specific population data and historical daily all-cause mortality, analysts can estimate temperature-related excess death rates, commonly expressed per 100,000 inhabitants.

However, some Central Asian cities with historically milder climates—including Astana (Kazakhstan), Bishkek (Kyrgyz Republic), and Tashkent (Uzbekistan)—also have high heat-related mortality rates, in the range of 18.5–20.5 per 100,000. This suggests that recent increases in heat exposure may have outpaced local adaptation and underscores a broader vulnerability: In many low- and middle-income parts of the region, limited access to heat-health early warning systems and preparedness measures—such as cooling centers and green spaces—may exacerbate the health burden of rising temperatures. When combined with aging populations, these critical shortcomings pose a serious threat of overwhelming local health systems, particularly during prolonged or extreme heat-waves, when demand for care can skyrocket, and resilience is most needed.

**FIGURE 2.4** **Heat-Related Mortality Rates in Cities across Europe and Central Asia, 2000–2020**




*Source:* Modeling by World Bank team based on the methodology described in Masselot et al., 2023.

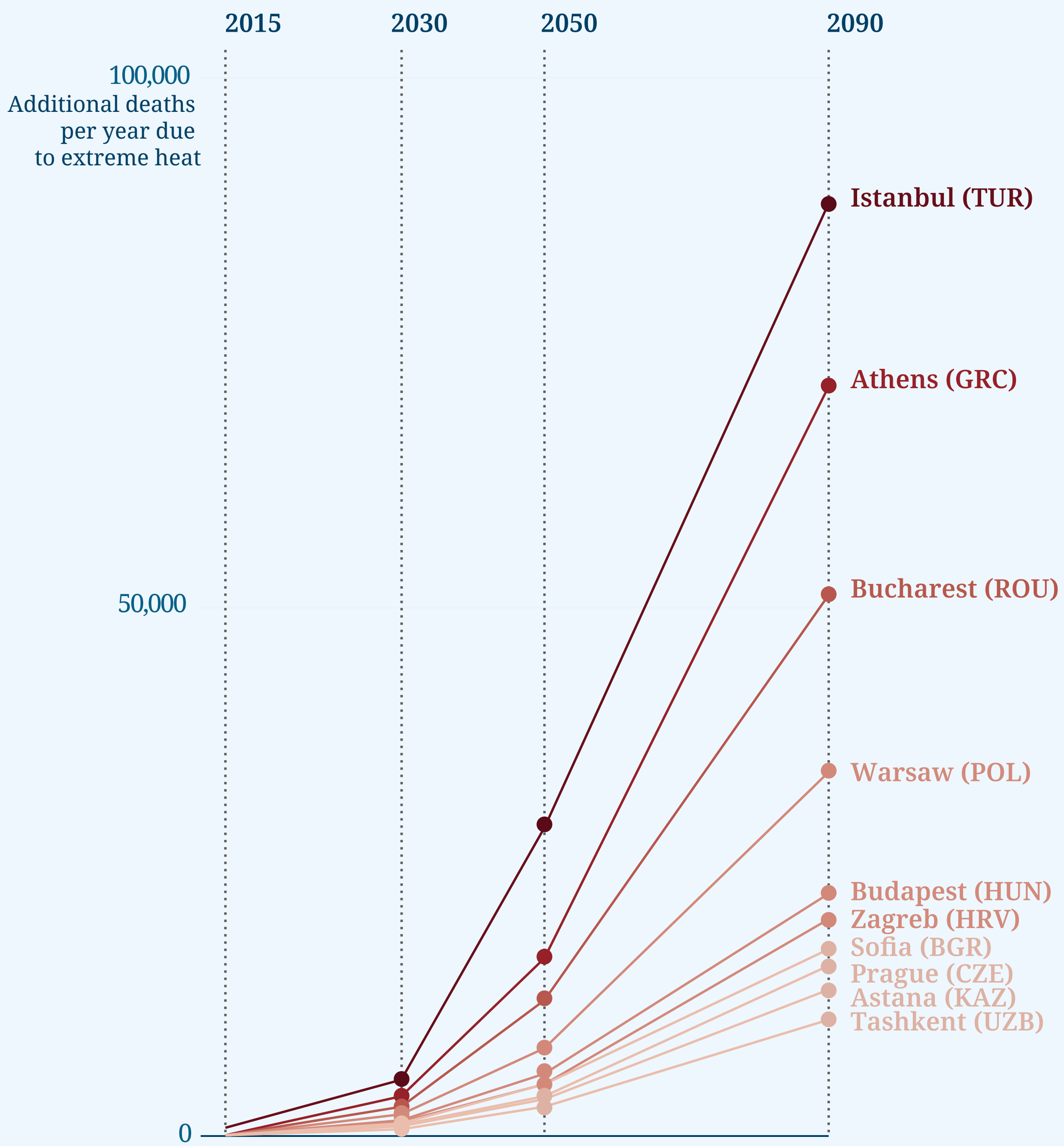
*Note:* The size of the bubbles is scaled in proportion to the estimated population in millions (reference year 2020), highlighting regional disparities in historical death rates across low and high populated areas.

Results from recent modeling studies indicate that across the European Union, the risk of heat-related deaths among older adults will likely continue to rise in the coming decades. This means it is crucial not only to invest in adaptation to heat, but in mitigation measures to reduce emissions and the subsequent rise in heat exposure.[40] However, how the future heat-related mortality burden will likely evolve in the larger Europe and Central Asia region has yet to be explored in depth.

A modeling exercise of the future heat-related mortality under the moderate warming SSP2-4.5 scenario highlights the rapidly evolving preventable health burden across the selected cities in the region. As shown in Figure 2.5, by 2090, the cumulative death toll from heat could reach 88,000 in Istanbul, 71,000 in Athens, 51,200 in Bucharest, and 34,500 in Warsaw, for instance.

**40.** The modeling framework also allows estimation of temperature-related burden on mortality in a future climate under a myriad of modeling scenarios accounting for different global warming levels, socio-economic pathways, demographic shifts, and last but not the least, hypothetical adaptation scenarios (Gasparrini, A. *et al.*, 2017; Vicedo-Cabrera, A. M., Sera, F. & Gasparrini, A., 2019; Masselot et al., 2025 Estimating future heat-related and cold-related mortality under climate change, demographic and adaptation scenarios in 854 European cities. Nat Med. **https://doi.org/10.1038/s41591-024-03452-2**). The projections of health impacts generated by this flexible framework form the basis for public-health experts and policy makers to understand the additional evolving heat-related health burden (García-León et al., 2024). For EU and EEA countries, see García-León et al., 2024 and Masselot et al., 2025.

**FIGURE 2.5** The 10 Cities in Europe and Central Asia with the Most Projected Heat-related Excess Deaths




*Source:* World Bank elaboration based on the modeling methodology described in Masselot et al., 2023; 2025.

*Notes:* This figure represents the projected heat-related mortality in three different periods in the SSP2-4.5 scenario, holding demographic patterns and adaptation to heat to 2020 levels. The dots in the different time periods represent the cumulative excess deaths—that is, excess deaths across all age groups projected to accumulate by the end of 2030, 2050, and 2090. The 10 cities shown had the highest cumulative heat-related excess deaths by 2090 in the modeling results.

Almost all cities across Europe and Central Asia will need to take action to avoid a rise in heat-related mortality. Even some cities on the lower end of the spectrum of the historical heat-related excess death rates, such as Prague, Warsaw, and Sofia, are projected to see those rates double or triple by midcentury: from 11.2 to 20.9 per 100,000; from 10.6 to 31.0; and from 13.2 to 39.0, respectively.[41] The projected surge in heat-related deaths underscores that heat-related deaths are growing fast, and could soon rival or exceed widely accepted public health concerns. By way of comparison, the projected additional number of heat-related deaths by mid-century significantly exceeds the number of people who were recorded as dying in road traffic accidents in 2019—5.9 per 100,000 in the Czech Republic, 9.4 in Poland, and 9.2 in Bulgaria.[42]

Moreover, and as evident by the steep gradient between the years 2050 and 2090 compared with the present day to 2050 (Figure 2.5), the cumulative death toll is projected to grow ever faster. This suggests that preventive actions to protect the local population, especially those who are most vulnerable to heat, would need to keep pace with the fast-evolving risks on health from heat.

Another notable pattern is that the cumulative heat-related mortality burden for several major cities in Western Balkan (Zagreb), Central Europe (Prague), Eastern Europe (Budapest and Sofia) and Central Asia (Astana and Tashkent), appears to be clustered between 10,000 and 23,000 deaths by 2090. While this may not appear to be a significant burden relative to the deaths occurring from other causes, one needs to consider these deaths as avoidable with appropriate interventions. Even accounting for their smaller present-day populations compared to Istanbul—where an estimated 88,000 cumulative heat-related deaths are projected by 2090 for a population of around 15 million—the projected mortality burden in these cities remains deeply concerning, underscoring the urgent need for targeted adaptation and preparedness measures across the region.

## 2.3 Heat Affects Workers, at a Cost to the Economy

Extreme heat is not just a health threat—it's an economic one. Wealthier economies have more options to adapt: from cooling infrastructure to policy interventions. Conversely, poorer economies face compounding vulnerabilities. When disasters strike, those with the fewest resources suffer the most and recover the slowest.[43]

**41.** This holds true irrespective of the metric or the time period chosen to estimate the change in future heat-related mortality in the analysis. Both: (a) the future excess death rates, and (b) the cumulative excess deaths due to heat, in each of the three future time periods, reveal similar rampant rise in heat-related health burden across most of the selected cities in the Europe and Central Asia region. Across the 10 cities shown in Figure 2.5, the heat-related excess death rates are projected to reach between 20-80 deaths per 100,000 people by 2050 under the SSP2-4.5 scenario.

**42.** Death rate data per 100,000 sourced from Ourworldindata: **https://ourworldindata.org/grapher/death-rate-road-traffic-injuries**.

**43.** Hallegatte, S., Vogt-Schilb, A., Bangalore, M. and Rozenberg, J., 2016. Unbreakable: building the resilience of the poor in the face of natural disasters. Washington D.C.: World Bank.

Cities sit at the center of both risk and opportunity. They concentrate economic activity and people, generating agglomeration economies that drive growth. Urbanization has lifted millions out of poverty around the globe and continues to fuel economic growth. In many countries, the largest urban area represents an outsized share of the economy.

Cities drive economic growth, but their density makes them uniquely vulnerable to extreme heat. When heatwaves hit, the economic fallout is far greater, with disruptions rippling across the entire economy. Urban areas are also hotter than their surroundings due to the urban heat island effect—buildings, roads, and concrete trap heat, making cities more exposed. Hence, it is important to understand how extreme heat impacts cities' and countries' economic performance. To do so, this section first discusses the different heat-productivity channels; then it presents the existing empirical evidence in Europe and Central Asia; lastly, it estimates heat-induced labor productivity losses for 62 cities in the region.

## How does heat affect productivity?

Extreme heat drags down economic output in multiple ways. Many studies have established that temperature fluctuations negatively impact economic growth, and the effect is stronger for poorer countries.[44] The mechanisms are complex, but one thing is clear: heat makes people less productive.

The most significant effect of heat on productivity is that workers do less work and a worse job when it is hot. Why is this the case? First, heat stress affects people's ability to perform their jobs, both from a physiological and cognitive perspective. Physically, it causes fatigue, weakness, cramps, and other symptoms, slowing workers down or making it necessary to take breaks or stop work entirely to avoid serious harm.[45] Cognitively, heat can impair decision-making, slow reaction times, and reduce focus.[46] Such impacts have been documented in different studies (see Figure 2.6). High-stakes tasks (such as those performed by executives, medical professionals, pilots) are particularly at risk.[47]

**44.** Dell, M., Jones, B.F. and Olken, B.A., 2012. Temperature shocks and economic growth: Evidence from the last half century. *American Economic Journal: Macroeconomics, 4*(3), pp.66-95. Burke, M., Hsiang, S.M. and Miguel, E., 2015. Global non-linear effect of temperature on economic production. *Nature, 527*(7577), pp.235-239.

**45.** Flouris, A., Graczyk, H., Nafradi, B., Scott, N. and Azzi, M., 2024. Heat at Work: Implications for Safety and Health. A Global Review of the Science, Policy and Practice. *Geneva: International Labour Organization.* Available at: **https://www.ilo.org/publications/heat-work-implications-safety-and-health**.

**46.** Graff Zivin, J., Hsiang, S.M. and Neidell, M., 2018. Temperature and human capital in the short and long run. *Journal of the Association of Environmental and Resource Economists, 5*(1), pp.77-105.

**47.** However, there is some evidence that the productivity loss in high-stake tasks is lower than in less crucial ones for the same category of workers (see Figure 2.8).

All occupations require a mix of physical and cognitive skills. Obviously, some are more affected, such as construction jobs that are performed outdoors and require high physical exertion. Overall, on hot days, workers tend to put in shorter hours and accomplish less.[48] The inevitable effect is a fall in labor productivity, which leads to lower economic output.[49]

An International Labour Organization (ILO) analysis found that heat starts affecting workers' productivity at 26°C WBGT, and the effects accelerate at 33–34°C WBGT, when 50 percent of productivity is lost in medium-intensity physical activities. No task can be safely performed above 38°C WBGT in the absence of adaptation measures, and workers' health is severely at risk.[50]

Heat not only slows down work today—it also undermines the foundations of future productivity by diminishing human capital through its effects on health and learning. Beyond immediate reductions in worker performance, elevated temperatures contribute to long-term declines in physical and cognitive ability. As discussed above, heat increases the incidence of illness and the risk of mortality, leading to both a shrinking labor supply—as workers reduce hours or exit the workforce—and lower productivity due to compromised health. In a self-reinforcing cycle, rising temperatures also correlate with the onset or worsening of chronic conditions (for example diabetes[51]) which further amplify the physiological toll of heat stress.[52] Compounding these effects, workplace heat exposure contributes to a higher number of injuries—including those unrelated to heat itself—resulting in an estimated 20,000 additional injuries each year.[53]

**48.** Graff Zivin and Neidell (2014), Behrer and Park (2017), Somanathan et al. (2021). Graff Zivin, J. and Neidell, M., 2014. Temperature and the allocation of time: Implications for climate change. *Journal of Labor Economics, 32*(1), pp.1-26.

**49.** Kjellström, T., Maître, N., Saget, C., Otto, M. and Karimova, T., 2019. *Working on a warmer planet: The effect of heat stress on productivity and decent work*. Geneva, Switzerland: International Labour Organization; Orlov, A., Sillmann, J., Aunan, K., Kjellstrom, T. and Aaheim, A., 2020. Economic costs of heat-induced reductions in worker productivity due to global warming. *Global Environmental Change, 63,* p.102087.

**50.** See Appendix I in Kjellstrom et al. (2019) for a detailed discussion. Some more recent literature argues that for some sectors work capacity loss starts well below 26°C, with an optimal point at 16°C WBGT. Ioannou, L.G., Tsoutsoubi, L., Mantzios, K., Gkikas, G., Agaliotis, G., Koutedakis, Y., García-León, D., Havenith, G., Liang, J., Arkolakis, C. and Glaser, J., 2023. The impact of workplace heat and cold on work time loss. *Journal of Occupational and Environmental Medicine*, pp.10-1097.

**51.** There is a positive relationship between incidence of type-2 diabetes and increased temperatures. Blauw, L.L., Aziz, N.A., Tannemaat, M.R., Blauw, C.A., de Craen, A.J., Pijl, H. and Rensen, P.C., 2017. Diabetes incidence and glucose intolerance prevalence increase with higher outdoor temperature. *BMJ Open Diabetes Research and Care*, 5(1), p.e000317.

**52.** See Flouris et al. (2024) for a comprehensive list of pathologies increasing the risk of heat-related severe illnesses for workers.

**53.** Based on an analysis of Californian workers injury claims. The authors estimate a total of 360,000 excess injuries between 2001 and 2018 compared to an optimal temperature benchmark. See: Park, J., Pankratz, N. and Behrer, A.P., 2021. Temperature, workplace safety, and labor market inequality. Journal of Public Economics, 198, p.104429. Available at: **https://doi.org/10.1016/j.jpubeco.2021.104429**.

**FIGURE 2.6** How Does Heat Affect Labor Productivity?

**Only 1 extra day above 35°C in a year leads to a .04% fall in payroll per capita in US counties.**

For the median county **25+ days above 25°C** in a year equal a **4.56% fall** in payroll per capita for the most exposed sectors.

Indian manufacturing firms see a **2.1%** decrease in annual output value for a **1°C higher** average daily temperature.

DHS* interviewers complete **13.6% less** interviews on a hot day, and the resulting output is of **poorer quality.**

Trials conducted in an office setting show that at 30°C performance (measured using objective indicators) falls by 8.9%.

For professional tennis players, a **10°C** increase in temperature, decreases service made rate by **1.1** and **0.6 percentage points** respectively for first and second serve.[$]

**Even students aren't spared.**

In New York taking an exam on a **32°C-day** reduces scores by **13% of a standard deviation** compared to a cooler 24°C-day, lowering the probability of passing a class by **10%.**[^]

Between 1998 and 2011, **90,000 students** would have **failed over 500,000 tests** if teachers had not boosted their grades on hot days.

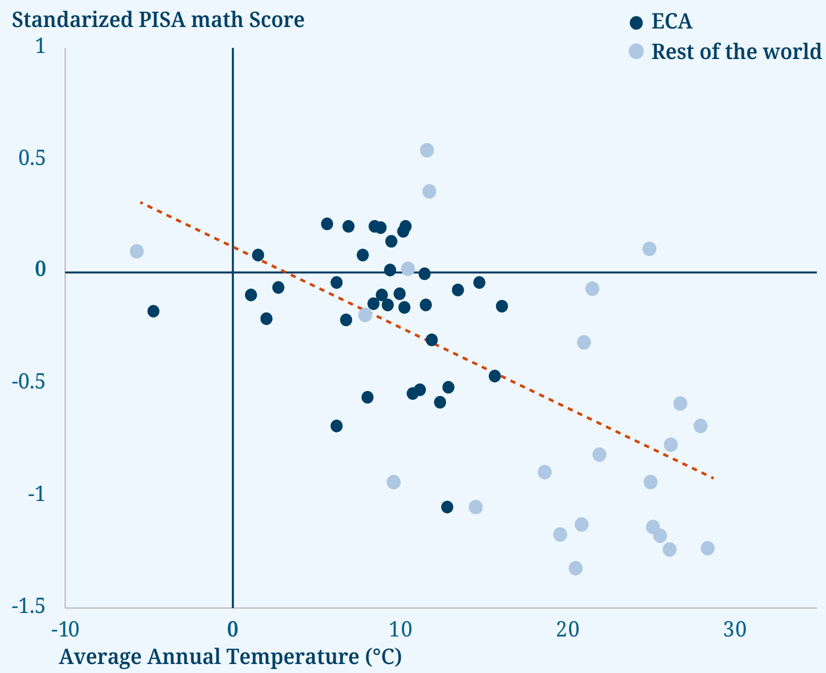
Notes
* Demographic and Health Surveys.
$ When the stakes are higher, in the second serve, the heat-induced productivity loss is lower.
^ The effect is large enough to decrease the overall probability of graduation.

References
Behrer, A.P. and Park, J., 2017. Will we adapt? temperature, labor and adaptation to climate change. Harvard Project on Climate Agreements Working Paper, pp.16-81.
Somanathan, E., Somanathan, R., Sudarshan, A. and Tewari, M., 2021. The impact of temperature on productivity and labor supply: Evidence from Indian manufacturing. Journal of Political Economy, 129(6), pp.1797-1827.
LoPalo, M., 2023. Temperature, worker productivity, and adaptation: evidence from survey data production. American Economic Journal: Applied Economics, 15(1), pp.192-229.
Seppanen, O., Fisk, W.J. and Lei, Q.H., 2006. Effect of temperature on task performance in office environment.
Picchio, M. and Van Ours, J.C., 2024. The impact of high temperatures on performance in work-related activities. Labour Economics, 87, p.102509.
Park, R.J., 2022. Hot temperature and high-stakes performance. Journal of Human Resources, 57(2), pp.400-434.

Workers' knowledge may be affected by prolonged exposure to higher temperatures. This is different than the established short-term impact on cognitive ability associated with performing activities on a hot day. Instead, constant exposure to heat may hinder learning and have longer-term impacts on human capital. In other words, the heat stress makes it more difficult to build knowledge and valuable skills. This has been well documented in schools. A recent U.S.-focused study looking at standardized test scores found that cumulative exposure to higher temperatures in a year reduced learning outcomes. Despite high levels of income and adaptation (air conditioning) in schools, a persistent temperature increase of 2°C was found to reduce students' performance by about 7 percent of a year's worth of learning.[54]

**54.** The study controls for test-day temperature. Crucially, the aim is to identify how much learning is affected by heat, rather than the ability to perform on a hot day. Park, R.J., Goodman, J., Hurwitz, M. and Smith, J., 2020. Heat and learning. American Economic Journal: Economic Policy, 12(2), pp.306-39.

**FIGURE 2.7** Higher Average Temperatures Are Associated with Lower Math Test Scores




*Source:* World Bank elaboration of Park et al. (2020) Figure 1, Panel A.

*Notes:* The figure displays a scatterplot of mean 2012 PISA math scores and average annual temperature by country measured over the period 1980–2011. The slope coefficient results from a bivariate regression of scores on temperatures with robust standard errors.

Capital also suffers from equipment efficiency losses due to extreme heat.[55] Many machines need to dissipate heat to run, and this process starts to fail at hotter temperatures. Lithium-ion batteries (powering a large share of essential capital nowadays, including but not limited to mobile phones, computers, and data centers) shut down and degrade faster at higher temperatures. Many materials deform or change consistency as they heat up, leading to higher degradation or risk of machine failures.[56] As machines perform less efficiently, they also draw more electricity, risking systems overloads and subsequent blackouts.

In June 2024, large areas of Albania, Bosnia and Herzegovina, Croatia, and almost the entirety of Montenegro were affected on the same day.[57] A 2017 study estimates of the

**55.** Hicks, M. and Narayanan, S., 2023. Machines can't always take the heat: Two engineers explain the physics behind how heat waves threaten everything from cars to computers. The Conversation. Available at: **https://theconversation.com/machines-cant-always-take-the-heat-two-engineers-explain-the-physics-behind-how-heat-waves-threaten-everything-from-cars-to-computers-210591**.

**56.** For example, this is the case of engine oils thinning and air expanding within car tyres (Hicks and Narayan, 2023), previously cited.

**57.** Balkans hit by blackouts as heatwave persists. BBC News, 21 June. Available at: **https://www.bbc.com/news/articles/c4nn140qp4do**. Major power outage hits Balkan region as countries swelter through early heatwave. *Euronews,* 21 June. Available at: **https://www.euronews.com/2024/06/21/major-power-outage-hits-balkan-region-as-countries-swelter-through-early-heatwave**.

monetary cost of the urban heat island effects in terms of reduced longevity (excess repair cost) and lower efficiency (excess operation cost) of air conditioning units as 0.04 percent of city GDP in London, 0.03 percent in Paris, and 0.15 percent in Athens.[58]

The potential effects of heat on productivity can go beyond the ones listed above. For example, extreme heat can also reduce mobility within cities, as seen in Indonesia, India, and Mexico.[59] Conversely, a mild climate is an amenity people are willing to pay for.[60] Cities facing larger temperature increases may lose out as they become less attractive to higher-skilled and more productive workers, who will prefer moving to cooler locations. Both mechanisms will lead to larger skill misallocation (more workers are not matched to the best job for them) and consequently lower productivity.

## 2.4 Smaller Firms, Weaker Economies: Heat Stress Deepens Economic Divides

The ILO projected in 2019 that by 2023, over 87,000 full-time-equivalent jobs would be lost due to increasing temperatures in Europe and Central Asia. Of these, 22,200 were in Uzbekistan,17,800 in Azerbaijan, and 16,100 in Türkiye. Azerbaijan appears the most affected country overall, with 0.38 percent of all working hours lost. In terms of urban sectors, Azerbaijan was projected to witness a 0.76 percent reduction in construction, 0.36 percent in industry, and 0.8 percent in Services. Turkmenistan, Tajikistan, Uzbekistan, and Cyprus also displayed significant expected working hour losses in the construction sector. All these countries (with Georgia, Albania, Türkiye and Spain) are among those with the highest expected GDP losses in the region.

Richer models for EU countries relying on the larger availability of employment data tell a similar story. Effects vary across countries, with southern countries, and those with a higher proportion of high-intensity jobs, facing higher losses. The latter is especially true for Romania, which is witnessing average labor productivity losses of 0.32 percent, up to over 0.9 percent under the worst-case scenario, larger than, for example, Italy or Spain, facing relatively higher increases in exposure to heat hazard.[61] For Romania, this translates into a GDP loss of up to 0.9 percent in the worst-case scenario.

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**58.** These effects may seem small but they only refer to one type of machine (AC units) and only based on assumption on the devices' longevity and thermodynamic cycle efficiency, discarding all other costs associated with the UHI effect. Miner, M.J., Taylor, R.A., Jones, C. and Phelan, P.E., 2017. Efficiency, economics, and the urban heat island. Environment and Urbanization, 29(1), pp.183-194.

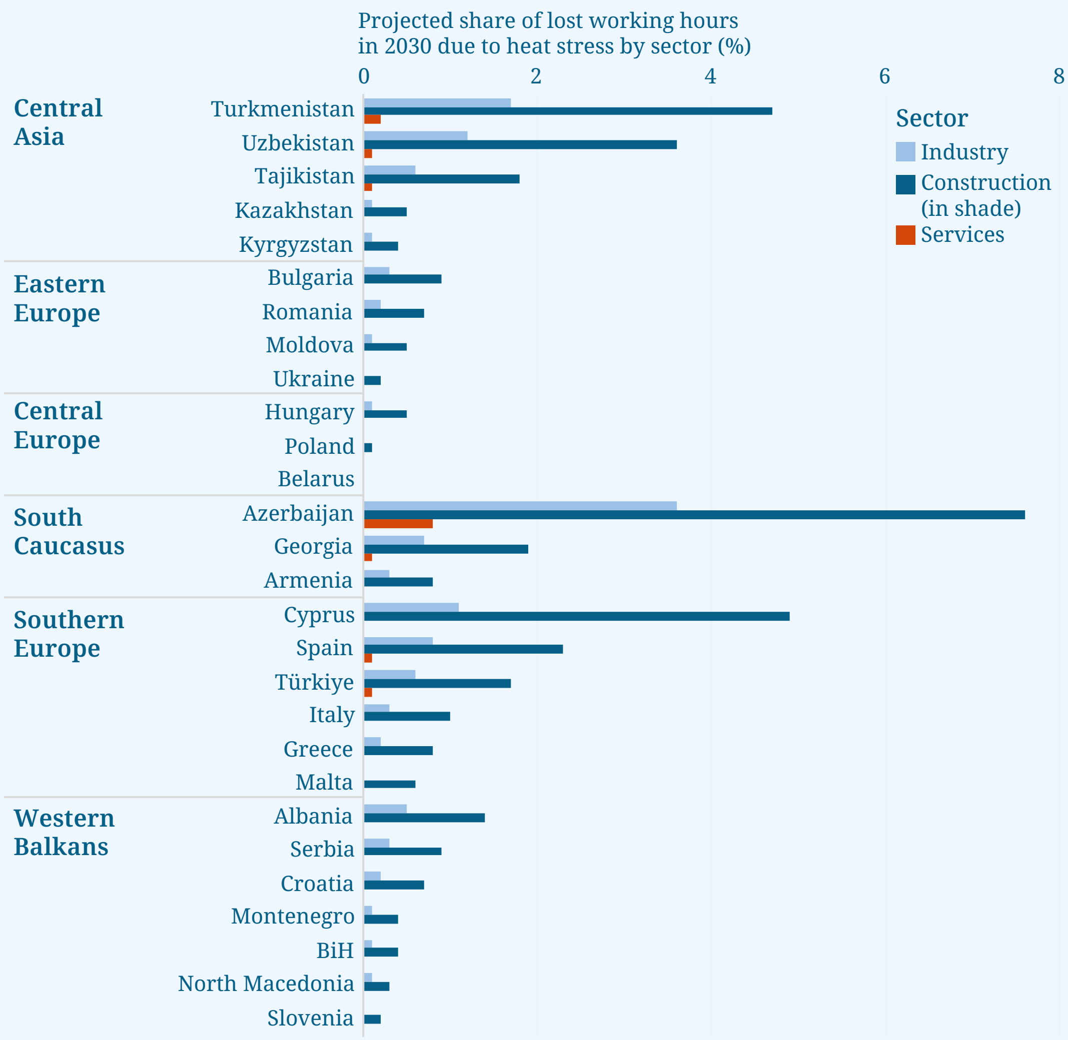
**59.** Renninger, A. and Holubowska, O., 2024. Extreme heat is associated with reductions in human activity. arXiv preprint arXiv:2409.20437.

**60.** Albouy, D., Graf, W., Kellogg, R. and Wolff, H., 2016. Climate amenities, climate change, and American quality of life. Journal of the Association of Environmental and Resource Economists, 3(1), pp.205-246. Sinha, P., Caulkins, M.L. and Cropper, M.L., 2018. Household location decisions and the value of climate amenities. Journal of Environmental Economics and Management, 92, pp.608-637.

**61.** Based on Szewczyk et al. (2021), who model labor productivity impacts across EU countries using 11 regional climate models under the RCP 8.5 scenario. See: Szewczyk, W., van Dingenen, R., Pisoni, E., Vanherle, K., and Ciscar, J.C., 2021. Economic impacts of climate change in Europe: cross-sectoral insights and policy implications. *Environmental and Resource Economics, 79*(2), pp.285–315. Available at: **https://doi.org/10.1007/s10640-021-00550-7**.

Cyprus and Greece are among the most exposed countries, with productivity losses up to 1.18 percent for Cyprus, up to 1.125 percent for Greece, with maximum GDP changes respectively of -1 percent and -0.9 percent. Croatia, Bulgaria, and Hungary are also highly affected, with maximum productivity losses around 0.5 percent and similarly sized negative effects on GDP. All these countries (with Spain, Italy, and Portugal) face higher economic impacts than the European average.

**FIGURE 2.8 Share of Lost Working Hours Due to Heat Stress in Europe and Central Asia (2030 Projection)**




*Source:* World Bank elaboration of Kjellstrom et al. (2019).

*Notes:* ILO estimates based on employment data from the ILOSTAT database and the HadGEM2 and GFDL-ESM2M climate models, assuming a global average temperature rise of 1.5°C by the end of the century (see the report for further methodological details). Productivity losses are calculated using exposure-response curves measuring the loss of work capacity for different work intensities and temperatures. The job lost count includes agricultural jobs, which still represent a significant share of the economy in Central Asia.

These modelled impacts appear lower compared with other world regions. This is mainly due to the cooler average yearly temperatures at northern latitudes, and economies more skewed toward the service sector.[62] Nonetheless, they show significant heat stress impacts on productivity in Europe, above all when accounting for the lower fraction of the year with hotter temperatures. This is compounded by the health effects of extreme heat, which are more worrying due to the aging population structure in many countries in the region. People in cooler climates are also less physiologically adapted to heat stress, which means that using absolute threshold temperatures (see Section 2.2) for work capacity loss may be underestimating the true impacts in the region.

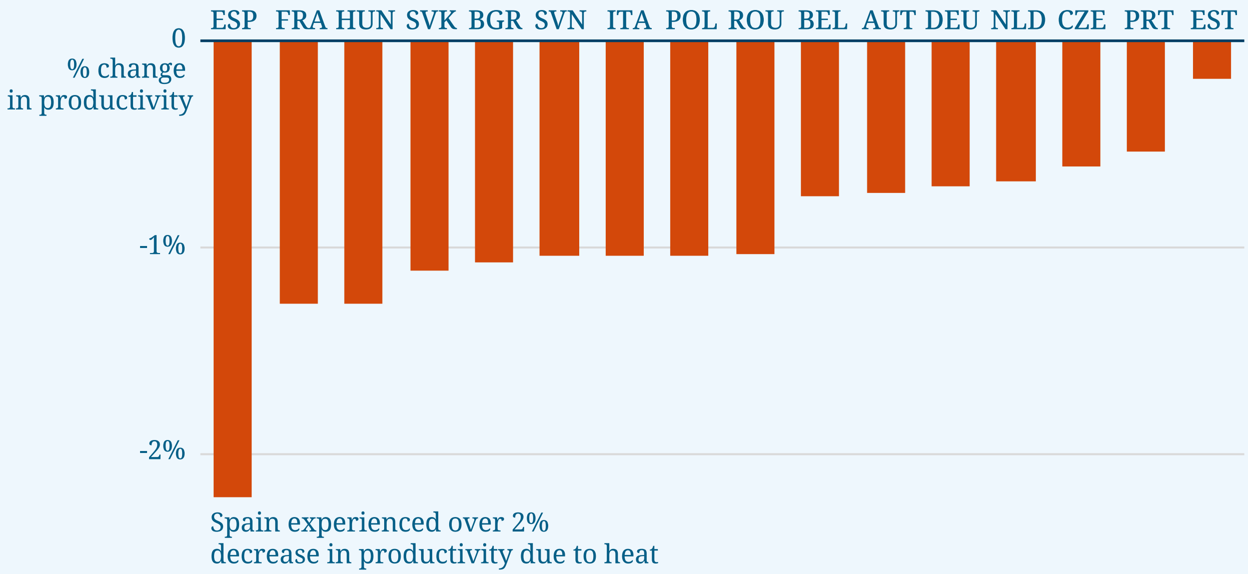
Real economic data shows that heat negatively affects firms' performance, but the effects are heterogeneous, and smaller enterprises bear nearly all the brunt. A recent study by the Organisation for Economic Co-operation and Development (OECD) sheds a light on the effective impacts of heat stress on firms by employing a newly constructed dataset with financial information from more than 2.7 million firms in 23 high-income countries.[63] The study finds sizable, statistically significant effects of heat stress, varying by country and firm characteristics.

An additional 10 days at a temperature above 30°C in a year, the study shows, reduces firms' labor productivity by 0.16 percent. The same number of days above 35°C and 40°C is associated respectively with a 0.34 percent and 1.9 percent fall. Figure 2.9 shows the projected productivity losses by country. Spanish firms have seen the largest productivity losses, at the same time as the country has faced the largest increase in hot days in the reference period. French and Hungarian firms witness relatively large productivity losses (around -0.125 percent) compared with Bulgarian, Italian, and Romanian ones, as the latter experiences greater increases in heat stress. As the estimates refer to an average location in the country, they may fail to fully capture the aggregate effects on the economy. This is especially true in Italy and Romania, where some of the areas with the largest concentration of firms are also those with worsening climate prospects.

**62.** Burke, Hsiang, and Miguel (2015), previously cited, argue that rising average temperatures could bring net economic benefits for many countries in Europe and Central Asia—primarily by enabling greater labor productivity during historically cold winter months. However, these potential gains may be offset as climate change also increases the frequency and severity of extreme heat events.

**63.** 20 European Union member countries (all but Cyprus, Greece, Ireland, Lithuania, Latvia, and Malta), the United Kingdom, Japan, and South Korea.

**FIGURE 2.9** **Changes in Labor Productivity Due to Increase in Hot Days between 2000–2004 and 2017–2021**




*Source:* World Bank elaboration based on Costa et al. (2024)[64]

*Notes:* The figure refers to the effects associated with 10 additional days at a temperature above 35°C. Labor productivity is measured as real value added per number of employees. The percentage change in productivity by country is measured at the mean location within the country.

The impacts of heat are compounded when multiple heatwaves occur within a single year, with productivity losses rising to nearly 4 percent during years with two heatwaves and exceeding 6 percent when there are three or more.[65] Sector-level estimates shed light on the role of adaptation. Firms in construction and manufacturing tend to experience losses close to the average, suggesting relatively effective adaptation—possibly aided by regulatory protections on working hours during peak heat periods in some countries.[66] In contrast, the accommodation and food services sector are the most affected, likely reflecting heat-induced declines in tourism demand.

These results also highlight potential limitations of parametric models based solely on the physiological effects of heat. While such models are invaluable to provide future loss estimates, they may fail to fully capture the actual effects of heat on the economy (see Box 2.2). First, the impact on high-intensity sectors may be overstated, especially in coun-

**64.** Costa, H., Franco, G., Unsal, F., Mudigonda, S. and Caldas, M.P., 2024. *The heat is on: Heat stress, productivity and adaptation among firms*. OECD Economics Department Working Papers, No. 1828. Paris: OECD Publishing. Available at: **https://doi.org/10.1787/6d9b91d5-en**.

**65.** The study employs several definitions of heatwaves. This estimate is obtained using the following: at least 5 days above the 95th percentile of the location's average summer maximum daily temperature in the the pre-sample period, 1995-1999. Costa et al. (2024).

**66.** However, the effect of heat on construction and manufacturing sectors may be underestimated for some firms as the registered location in the dataset refers to the headquarters, while production may be happening elsewhere.

tries with strong labor protections—although this may not be true in regions with weaker regulatory frameworks. Second, the models may underestimate the effects in sectors (e.g., services) where workers are not directly exposed to heat, but still experience significant disruptions. As a result, the overall economic impact of heat is likely greater than current estimates suggest.

## BOX 2.2 Interpreting Economic Modeling Estimates: A Practical Guide[67]

Several studies have provided estimates of the economic effects of heat stress, at regional, country, and subregional levels. This is done by first estimating lost work hours (or lost labor productivity) using work time loss functions based on temperature and effort required by different tasks. Such information is then plugged in a model that simulates the whole economy.

Alternative approaches, such as looking at variations in high-frequency (monthly, weekly) spatially disaggregated economic figures, or firm-level information, are very costly in terms of data inputs. Moreover, such data is often not available in most lower-income countries. Economic modeling at country level is far more forgiving, requiring fewer inputs from national accounts.

Different models will provide different estimates depending on the loss function used and how the economy is calibrated. For example, measuring lost working hours daily or monthly, accounting for seasonal patterns in economic activity, yields more accurate results, but also requires a larger amount of data (hence why more sophisticated efforts in the region tend to focus on EU countries).

Calibrating the model requires some restrictive assumptions at the onset. For example, often all workers in the same occupation or sector are treated as the same. However, there are large difference in work intensity and exposure to heat stress across firms and countries, due to different tasks and work environments for the same occupation, as well as varying adaptation capacity.[68] For example, firm level evidence suggests that higher-intensity industries cope better with excessive heat than some in the service sector. This means losses may be overestimated in the former and underestimated in the latter

Other features of these parametric modeling approaches generate some compounding or stifling effect on loss forecasts, which may not be fully verified. For example, more productive cities or countries will suffer higher losses for a given (heat-induced) productivity shock. However, some findings from firm-level data are suggestive of the contrary. It is possible that more productive firms are already more adapted or better at adapting. Keeping such notions in mind is important when trying to generalize findings from Western and Central Europe to countries in the rest of Europe and Central Asia.

**67.** Costa et al. (2024), previously cited.

**67.** García-León, D., Casanueva, A., Standardi, G., Burgstall, A., Flouris, A.D. and Nybo, L., 2021. Current and projected regional economic impacts of heatwaves in Europe. Nature communications, 12(1), p.5807.

**67.** Szewczyk, W., Mongelli, I. and Ciscar, J.C., 2021. Heat stress, labour productivity and adaptation in Europe—a regional and occupational analysis. Environmental Research Letters, 16(10), p.105002.

**68.** The model by Szewcyzk et al. (2021), previously cited, accounts for heterogeneity across countries by classifying work intensity for 43 occupations and pegging such occupations to different work intensities depending on the country.

The simple guide below is intended as a compass on how different characteristics of the modelled economy will influence the ultimate loss estimates.

Modeling exercises continue to be one of the best tools to provide clear and informative estimates of future heat-induced productivity and economic losses under several climate scenarios. Nonetheless, one should be aware of the implicit biases embedded in such estimates due to the numerous assumptions necessary for the model to work. Thus, efforts to keep investing in making better, higher frequency, and higher spatial resolution data available globally are crucial to a more complete understanding of the true effects of heat.

### Modelled losses due to heat exposure will ...

**INCREASE** | **DECREASE**

*IF...*

| | INCREASE | DECREASE |
|---|---|---|
| ...Average temperatures are predicted to rise ______. | *MORE* | LESS |
| ...For the same average temperature, its variation is ______.[*] | *HIGHER* | LOWER |
| ...The country is predicted to grow ______. | *FASTER* | SLOWER |
| ...The country's population / labor force is predicted to grow ______. | *FASTER* | SLOWER |
| ...If a country is ______ productive. | *MORE* | LESS |
| ...The industrial mix is ______ skewed towards highly exposed industries. | *MORE* | LESS |
| ...Labor and capital are ______. | *COMPLEMENTS* | SUBSTITUTES |
| ...If a country's future growth is ______ dependent on current growth.[&] | *MORE* | LESS |

Heat stress also disproportionately affects smaller businesses due to their lack of capacity to invest in adaptation measure. For example, larger firms pay significantly less for electricity, a key input to many temperature control mechanisms.[69] This results in larger firms experiencing productivity gains when facing additional heat stress (around 0.6 percent for large firms and 0.2 percent for medium large ones). Economic theory suggests that as some firms become relative more productive there should be a reallocation of the factors of production towards those. The data seem to show just that as heat stress is associated with both labor and capital reallocation towards more productive (often larger) firms. Thus, when facing increased stress, larger firms witness relatively larger increases in revenue growth compared to smaller ones.[70] Moreover, in warmer climates, firm growth is lower due to both reduced entry and increased exit rate.[71] Such forces modify the market structure, also mitigating the short-term effects of heat stress on firms' productivity, as larger, more productive firms grow and smaller, less-productive ones exit the market. However, in the long run, sectors will see higher concentration and lower competition, which may reduce the incentives to innovate and the productivity of the remaining leading firms.

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**69.** Ponticelli, J., Xu, Q. and Zeume, S., 2023. Temperature, adaptation, and local industry concentration. NBER Working Paper, (w31533).

**70.** Costa et al. (2024), previously cited.

**71.** Cascarano, M., Natoli, F. and Petrella, A., 2023. Entry, exit, and market structure in a changing climate. Bank of Italy Temi di Discussione (Working Paper) No, 1418.

## 2.5 Cities Bear the Economic Burden of Heat Stress—and It Is Growing

Future losses at the country level will account for over 2 percent of GDP in most Southern and Eastern European countries.[72] Despite differences in climate and economic modeling, separate studies provide consistent future loss estimates for high-income European countries. Southern countries and those with a higher share of high-intensity occupations are projected to suffer the highest losses.

Cyprus is the most affected country across the board, with projected GDP losses up to around 2.5 percent in 2050 and 4.2 percent in 2080. However, the highest potential predicted loss under any considered scenario could be 5.4 percent of GDP in Greece by 2080. Other countries that could potentially experience losses over 2 percent of GDP by 2080 in the worst-case scenario are Romania (4.6 percent), Bulgaria (4.1 percent), Spain (3.7 percent), Italy (3.0 percent), Croatia (2.6 percent), and Portugal (2.2 percent). Among the factors reducing overall GDP losses are trade amongst countries, and factors' substitutability. As non-EU economies are less integrated and have less flexible production technologies, they may expect an even higher negative economic impact.

In some of the most the exposed countries, such as Bulgaria and Greece, losses are also mitigated by negative demographic forces: As the labor force shrinks, labor becomes a relatively less crucial factor of production over time. A similar pattern may be expected for the Western Balkans, while in Central Asia, where population is growing steadily, the negative impacts of heat stress will be felt more acutely. However, regardless of demographic trends, increasing heat stress may be associated with a falling number of workers. Evidence from the rest of the world shows that firms adapt to excess heat by substituting labor with capital, leading to a fall in the labor share.[73] While this may be a desired outcome in economies with a shrinking population, elsewhere it is a recipe for disaster. Policy makers must be mindful of this potential outcome, especially in regions with a growing young population and inflexible labor markets.

In urban areas, most of the heat stress impact on the economy comes from the service sector, despite lower occupational exposure. A 2016 study calibrates a seven-sector model of three European metropolitan areas' economies: Antwerp (Belgium), Bilbao (Spain), and London (United Kingdom),[74] finding a substantial impact of heat stress. In a warm year in the far future (2081 to 2100), gross value added (GVA) is expected to shrink by 2.1 percent in Antwerp, 9.5 percent in Bilbao, and 0.4 percent in London, resulting in respective losses of €670 million, €2.5 billion, and €1.9 billion. The sectors driving these effects vary depending on the characteristics of the cities' economies. Despite low workers' exposure,

**72.** The country-level estimates in this section are derived from García-León et al. (2021) and Szewcyzk et al. (2021), both previously cited.

**73.** Lyu, Z., Yu, L., Liu, C. and Ma, T., 2024. When temperatures matter: Extreme heat and labor share. Energy Economics, 138, p.107811.

**74.** Costa, H., Floater, G., Hooyberghs, H., Verbeke, S. and De Ridder, K., 2016. Climate change, heat stress and labour productivity: A cost methodology for city economies. London, UK: Centre for Climate Change Economics and Policy.

the large financial sector commands the highest share of losses in London (24 percent). In all three cities, over 60 percent of total losses comes from Services, underscoring the differences between urban and national economies. Construction losses represent only 4 percent and 6 percent of the total in Antwerp and Bilbao, compared to 18 percent in London. Conversely, the Belgian and Spanish cities have sizeable share of manufacturing enterprises, generating 24 percent and 19 percent of total losses, compared with only 6 percent in the UK capital.

To expand the understanding of heat stress effects on urban economies, an analysis for this study combined data on projected heat stress, labor productivity damage functions, and sectoral employment shares for 900 cities globally (including 62 in Europe and Central Asia). Figure 2.10 shows the resulting labor productivity loss estimates, accounting for structural transformation.[75] As nearly all urban areas have seen a shift from agriculture and manufacturing towards services, future losses are lower than if the current sectoral composition remained. This is more evident in the cities where a sizeable share of workers is still engaged in agriculture (i.e., Samsun, Plovdiv, Mykolaiv). As expected, cities in Southern Europe and Central Asia (except Kazakhstan) are the most affected. Of nine cities with a projected productivity loss in 2050 of 2 percent or higher, six are in Türkiye, with the remaining being Nicosia (Cyprus), Ashgabat (Turkmenistan), and Thessaloniki (Greece). The city of Adana, due to its high exposure and large manufacturing industry, is projected to face losses in 2030 that are larger than any other city at midcentury.

Tourism is an important economic pillar in the Europe and Central Asia region—for example in Türkiye and Greece where it represented more than 4% and 7% of economic outputs respectively in 2022—and it faces growing risks from extreme heat, particularly given its strong seasonal concentration in the summer months.[76] Warmer countries risk seeing a decline in peak-season visitors while cooler northern and mountainous areas may benefit from redistributed demand.[77] Urban destinations face particular challenges, as the urban heat island effect amplifies discomfort and health risks. A study from China, examining 280 cities, found that each 1°C rise in temperature was associated with an 8% drop in domestic tourist arrivals and a 6% fall in revenue—offering a useful parallel for cities in Europe and Central Asia.[78] Some countries in Europe have already begun repositioning their tourism strategies: Portugal and Spain's Canary Islands are promoting year-round, sustainable tourism, while Greece is marketing lesser-known destinations and off-peak travel. Actions to preserve the comfort of public spaces and strengthen early warning and health sector provision can help to mitigate impacts on tourist revenues (see Chapter 3).

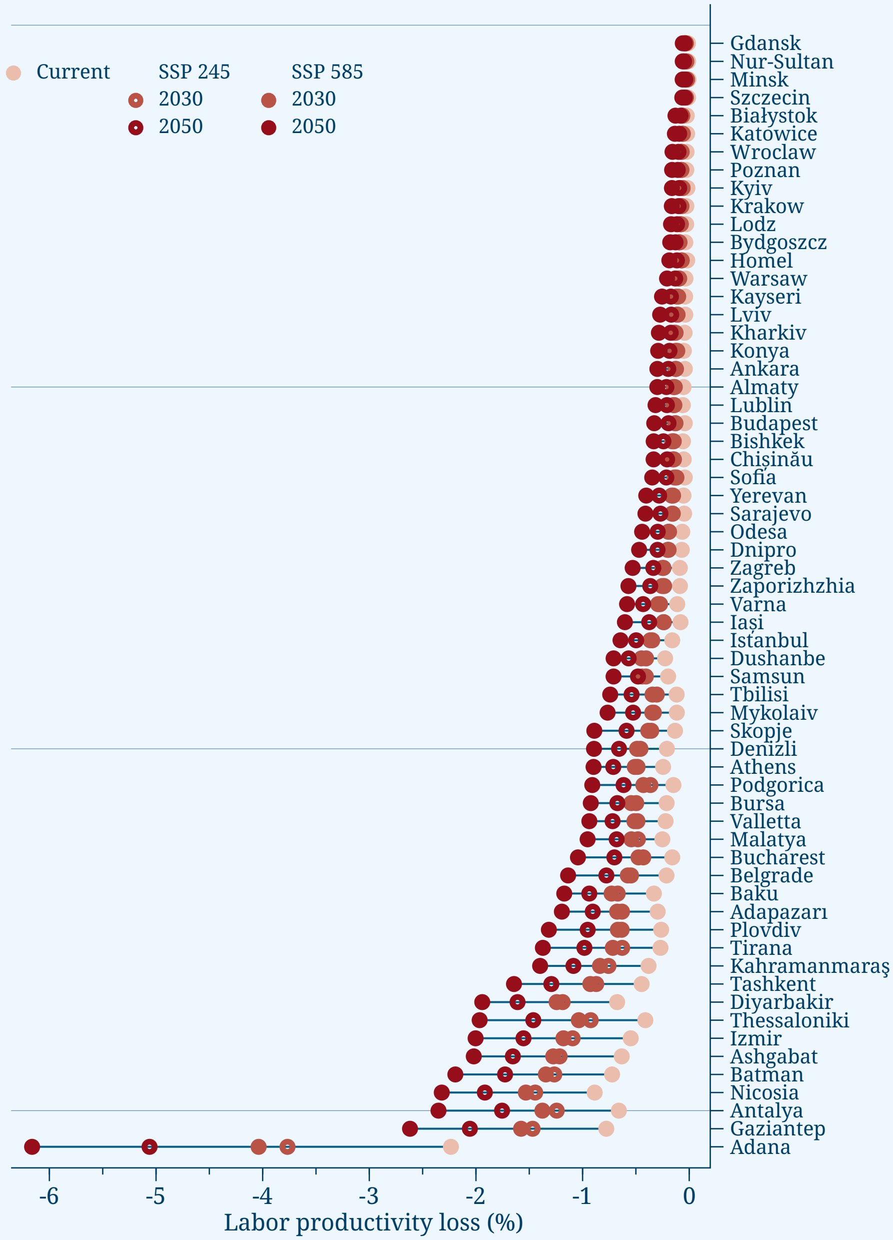
**75.** The Oxford Economics Global Cities Dataset includes projections up to 2035. For this analysis, the trend from 2000 to 2025 is used to extrapolate sectoral shares up to the year 2050.

**76.** OECD (2024), *OECD Tourism Trends and Policies 2024*, OECD Publishing, Paris, **https://doi.org/10.1787/80885d8b-en**.

**77.** Matei, N.A., García-León, D., Dosio, A., e Silva, F.B., Barranco, R.R. and Ciscar, J.C., 2023. *Regional impact of climate change on European tourism demand*. Luxembourg: Publications Office of the European Union.

**78.** Chang, D., Bu, N., Zhang, N. and Xiao, H., 2024. Climate change and tourism demand: Risks for extreme heat?. Heliyon, 10(17).

**FIGURE 2.10** Modelled Labor Productivity Loss for 62 Cities (2030 and 2050) under Different Climate Scenarios




*Source:* World Bank analysis.

*Notes:* The expected labor productivity loss is computed using heat productivity loss functions from Williams et al. (2024),[79] using an upper limit of 90 percent loss. Losses are attached to different industries by classifying them into three intensity levels following ILO's "Working on a Warming Planet" methodology. Heat stress is measured by the estimated total number of hours a worker experiences at different wet-bulb globe temperature (WBGT) in a year, under current climatic conditions, and projected ones in 2030 and 2050 under SSPs 2-4.5 and 5-8.5. The future industrial composition of the city is obtained from the Oxford Economics Global Cities Dataset. The productivity loss calculator assumes that workers are equally productive throughout their assumed eight-hour workdays, and across industries.

**79.** Williams, Emily, Chris Funk, Pete Peterson, and Cascade Tuholske. 2024. "High Resolution Climate Change Observations and Projections for the Evaluation of Heat-Related Extremes." Scientific Data 11 (1): 261. **https://doi.org/10.1038/s41597-024-03074-w**.

## 2.6 Heat Stress Is Putting Infrastructure under Strain

Infrastructure is particularly vulnerable to rising temperatures and the increasing frequency, intensity, and duration of extreme heat events. This is due to its long service life, high replacement cost, and interdependent nature. Most urban infrastructure in Europe and Central Asia was not built with future climate extremes in mind. Roads buckle under sustained heat, rail lines deform, power systems falter under surging cooling demand, and buildings—especially older ones—trap heat indoors. These impacts are not isolated; they cascade across systems. An overloaded power grid can affect water pumping stations, public transit operations, and the reliability of healthcare delivery. Because infrastructure systems underpin nearly every aspect of urban life, their vulnerability to heat has broad and compounding implications.

To assess how extreme heat affects urban infrastructure, this report focuses on aspects of exposure (the degree of heat a system to subject to), sensitivity (how heat affects performance or causes failure), adaptive capacity (whether the system can be adjusted or upgraded), and systemic importance (how critical the system is to overall urban functioning). This approach helps surface common themes, such as aging assets or interdependencies, as well as domain-specific dynamics. For example, while both buildings and power systems experience thermal stress, the modes of failure, population impacts, and options for adaptation differ significantly. The aim is to clarify where infrastructure systems are most vulnerable to rising heat—and why those vulnerabilities matter.

### Heat stress is already disrupting transport systems built for a cooler past

Urban transportation networks in Europe and Central Asia are integral to daily life, with many cities exhibiting high public transit utilization. For instance, in the European Union, coaches, buses, and trolleybuses accounted for 7.4 percent of inland passenger transport in 2020, with trains contributing 5.4 percent.[80] In Central Asian cities, public transport systems are being analyzed and compared with those in Southeast Asia and Europe to identify sustainable urban solutions.[81]

However, much of the existing transportation infrastructure was designed based on historical climate patterns and is increasingly ill-equipped to handle the intensifying heatwaves projected for the mid to late 21st century. Given the long service life of transport assets—

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**80.** Eurostat (2022) Key figures on European Transport. Link: **https://ec.europa.eu/eurostat/documents/15216629/15589759/KS-07-22-523-EN-N.pdf**.

**81.** Bespalyy, S. and Petrenko, A. Analysis of public transport in Central Asian cities in comparison with leading cities in Southeast Asia and Europe: the search for sustainable urban solutions, E3S Web of Conferences, 535, 04011 (2024). **https://www.e3s-conferences.org/articles/e3sconf/pdf/2024/65/e3sconf_escm2024_04011.pdf**.

ranging from 30 to 100 years for road bridges[82]—there is an urgent need to adapt these systems to future climate conditions.

Extreme heat poses several risks to transportation infrastructure. High temperatures can cause asphalt to soften, leading to rutting and potholes. This not only degrades road quality, but also increases maintenance costs and poses safety hazards. Steel rails expand in extreme heat, which can lead to track buckling.[83] Such deformations necessitate speed restrictions and can cause service disruptions. Overheating can affect the performance of buses and trains, leading to mechanical failures and discomfort for passengers. Roads in Central Asia often traverse arid and semi-arid landscapes, are susceptible to damage from temperature fluctuations and extreme weather events. In cities, the UHI amplifies the impacts, increasing the strain on transportation systems.

The financial implications are significant. A study[84] estimates that under a 4°C global warming scenario, increased extreme heat in Europe could cause annual transport operation and maintenance costs to rise by €4.8 billion, a 6.9 percent increase compared to current values. In Türkiye, the transport sector is particularly vulnerable to climate-induced disruptions. In the Kyrgyz Republic, extreme temperatures contribute to the loss of about 200 kilometers of road every year.[85] This loss not only incurs direct repair and maintenance costs but also disrupts economic activities reliant on these transport routes. Furthermore, the Türkiye Country Climate and Development Report (CCDR)[86] indicates that the country's road network is more vulnerable to disruption than those of European comparators, and its railway network is even more susceptible. The CCDR estimates that ensuring all new transport infrastructure assets are built to higher resilience standards would increase investment needs by nearly 11 percent.

## A warming climate is eroding the reliability of urban power systems

The region's electricity supplies are diverse. Hydropower remains a significant source in several countries, including Georgia, Tajikistan, and Kyrgyzstan. Natural gas and coal dominate in others, such as Kazakhstan and Ukraine, while Türkiye has been expanding its solar and wind capacities. However, rising temperatures are placing unprecedented stress on electricity systems, affecting generation, transmission, and distribution.

**82.** Tveter, E. and Tomasgard, T. How long do transport infrastructure last: evidence from Norwegian roads and rail network. European Transport Research Review 16: 30 (2024). **https://etrr.springeropen.com/articles/10.1186/s12544-024-00650-4**.

**83.** WIRED, 2019. Sag, buckle and curve: why your trains get cancelled in the heat. WIRED, 26 July. Available at: **https://www.wired.com/story/trains-cancelled-heat-uk/**.

**84.** Mulholland, E. and Feyen, L. Increased risk of extreme heat to European roads and railways with global warming. Climate Risk Management 34: (2021). Link: **https://www.sciencedirect.com/science/article/pii/S2212096321000942.**

**85.** Ebinger, J.O and Vandycke, N. Moving toward climate-resilient transport – the World Bank's experience from building adaptation into programs. World Bank (2015). Link: **https://thedocs.worldbank.org/en/doc/326861449253395299-0190022015/render/WorldBankPublicationResilientTransport.pdf**.

**86.** Türkiye CCDR, World Bank (2022). Link: **https://openknowledge.worldbank.org/entities/publication/01826a0c-059f-5a0c-91b7-2a6b8ec5de2f**.

Hydropower, while a key source of clean and reliable electricity, is highly susceptible to extreme heat and drought, which often occur together.[87] These conditions can lead to significant fluctuations in hydropower production. For instance, during the 2024 heatwave, Ukraine experienced record-breaking temperatures that exacerbated the strain on its power grid, already compromised by ongoing conflicts. The state electricity company reported that electricity consumption exceeded the generating capacity of Ukraine's running power facilities, forcing utility authorities to impose widespread blackouts across several regions. In Kyiv, most buildings were without power for at least 10 hours a day.[88]

Extreme heat affects not only hydropower, but also other components of the energy system. High temperatures reduce the capacity of transmission lines and increase line losses at a time when electricity demand is surging, particularly for cooling. Transformers and substations are also vulnerable; elevated temperatures can reduce their efficiency and lifespan, leading to potential failures. In Kazakhstan, studies[89] have highlighted increased energy consumption during heatwaves, underscoring the need for adaptive measures in energy infrastructure.

Thermal power plants, which rely on water for cooling, face challenges as higher air and water temperatures reduce cooling efficiency. Drought conditions, often accompanying heatwaves, can limit the availability of cooling water, necessitating power output reductions or even temporary shutdowns. Additionally, solar photovoltaic (PV) systems experience decreased efficiency at higher temperatures, with power output potentially decreasing by 0.3–0.5 percent for every degree above 25°C. Energy storage systems, such as lithium-ion batteries, also perform less effectively in hot conditions. Temperatures above their ideal operating range can damage the batteries and significantly reduce their storage capacity over time. These performance issues are critical to consider in efforts to build system resilience by combining solar PV with storage solutions.

Energy systems are deeply embedded in the functioning of urban life, and disruptions can cascade across sectors. During heatwaves, power outages can impair the functioning of water pumping systems, disrupt urban transit (as seen in cities that rely on electric-powered trams or metro systems), and compromise hospital operations at critical times. In settings where backup power is limited or aging, these risks are amplified, particularly in secondary cities across the region. As rising temperatures intensify cooling demand and strain electricity supply, the resilience of dependent systems becomes equally vital to consider.

**87.** Wasti, A, Ray, P, Wi, S., Folch, C., Ubierna, M. and Karki, P. Climate change and the hydropower sector: a global review. WIREs Climate Change 13:12. Link: **https://wires.onlinelibrary.wiley.com/doi/abs/10.1002/wcc.757?campaign=woletoc**.

**88.** Méheut, C. Ukraine's Devastated Energy Grid Battles a New Foe: A Sizzling Heat Wave. The New York Times (July 2024). Link: **https://www.nytimes.com/2024/07/17/world/europe/ukraine-heat-wave-electricity.html**.

**89.** Broomandi, P. et al. Extreme temperature events in Kazakhstan and their impact on public health and energy demand. Global Challenges 19:9 (2024). Link: **https://pmc.ncbi.nlm.nih.gov/articles/PMC11802326/**.

## Buildings trap heat—and the risks are rising indoors

Building stock across the region is increasingly vulnerable to extreme heat. Many structures, particularly older ones, were designed for colder climates and are ill-equipped to handle rising temperatures. The overheating of interiors has different impacts on workplaces, educational settings, social spaces, and housing. Features such as poor insulation, lack of ventilation, and materials that absorb and retain heat contribute to indoor overheating.

Soviet-era panel housing, widely present across Central and Eastern Europe and Central Asia, often uses concrete and asphalt materials that retain heat and offer limited thermal insulation. During heatwaves, indoor temperatures in these buildings can remain elevated overnight, exacerbating the risks of cumulative heat stress, especially for people on upper floors or in south- or west-facing units.

In densely built neighborhoods with limited tree cover or green space, building design interacts with the urban heat island effect to intensify heat exposure indoors. Surface materials such as dark roofs and asphalt paving further amplify ambient temperatures, reducing the capacity of buildings to cool down at night.

In Central Asia, many homes suffer from poor insulation, leaky windows, and uninsulated walls and roofs, leading to significant heat loss in winter and heat gain in summer. These inefficiencies not only result in drafty homes and high heating costs but also exacerbate indoor overheating during heatwaves, posing health risks to occupants.[90] In the United Kingdom, the proportion of homes experiencing overheating rose from 18 percent in 2011 to 80 percent in 2022,[91] highlighting the growing challenge of maintaining thermal comfort in existing housing, including those with higher insulation levels to combat winter cold but with insufficient ventilation.

In Ukraine, the situation is further complicated by the ongoing conflict, which has damaged infrastructure and disrupted energy supplies. Many residential buildings, especially in urban areas, rely on centralized heating systems that may not function reliably during extreme heat events. The prevalence of high-rise apartment blocks with limited ventilation exacerbates the risk of indoor overheating.

Thermal discomfort in buildings not only affects well-being, but also has economic implications—via impacts on labor productivity (see section 2.3). Moreover, inadequate indoor temperatures can exacerbate health issues, particularly among vulnerable populations.

**90.** See World Bank report, titled 'Toward a framework for the sustainable heating transition in Europe and Central Asia' (2023). Link: **https://www.worldbank.org/en/region/eca/publication/toward-a-framework-for-the-sustainable-heating-transition**.

**91.** Khosravi, F., Demski, C., King, L. Gross, L. and Scott, M. A nation unprepared: extreme heat and the need for adaptation in the United Kingdom. Energy Research and Social Science 124 (2025). Link: **https://www.sciencedirect.com/science/article/abs/pii/S221462962500146X?via%3Dihub**.

Older adults, for example, face increased risks of heat-related illnesses due to physiological factors and often live in housing that lacks adequate cooling mechanisms.

Low-income groups are disproportionately affected, as they are more likely to live in overcrowded, poorly ventilated homes without access to air conditioning. In Spain, research[92] has shown that heatwaves significantly impact mortality rates in lower-income districts, underscoring the intersection of socioeconomic status and heat vulnerability. Similarly, in Central and Eastern Europe, marginalized communities, such as the Roma,[93] often live in substandard housing with limited access to utilities, further increasing their exposure to extreme heat.

Air conditioning remains inaccessible to many low-income households, due both to affordability and infrastructure constraints. In parts of Central Asia and the Western Balkans, aging electrical systems may be unable to support high cooling loads, even in buildings where residents could afford appliances. This compounds existing energy poverty and widens the gap in adaptive capacity.

### BOX 2.3 Passive Cooling to Cut Indoor Heat Risk: Evidence from Shymkent, Kazakhstan

Across Central Asia, Soviet-era apartment blocks dominate the housing stock. Built with uninsulated concrete panels and minimal ventilation, these buildings are poorly equipped for today's climate—let alone the more extreme heat projected in coming decades. In Shymkent, Kazakhstan, digital modeling of a typical two-bedroom unit shows how high temperatures persist indoors, especially in summer, and how targeted passive upgrades can substantially reduce the risk.

Under current conditions, indoor temperatures in such flats exceed 35.7°C—a level considered hazardous for health—for 22 percent of the year. By 2070, this figure could rise to 35 percent in a moderate warming scenario (SSP 2-4.5) and to 47 percent in a high-emissions scenario (SSP2-8.5). Nighttime overheating is particularly severe: temperatures above 31.7°C—well beyond comfort thresholds—currently affect bedrooms 70 percent of the time, and this is projected to increase.

However, modeling shows that simple passive design upgrades—including better ventilation, external shading, reflective surfaces, and heat-aware occupant behavior—could eliminate extreme heat exposure under SSP2-4.5 and reduce it to under 10 percent even under SSP5-8.5. Overheating time in bedrooms could be cut by half or more. These improvements require no mechanical cooling, making them both affordable and energy efficient.

This case illustrates the urgent need—and clear opportunity—to improve thermal resilience in existing housing across the region. Scaled nationally, such measures can reduce health risks, lower energy demand, and protect lives as summer heat becomes more severe.

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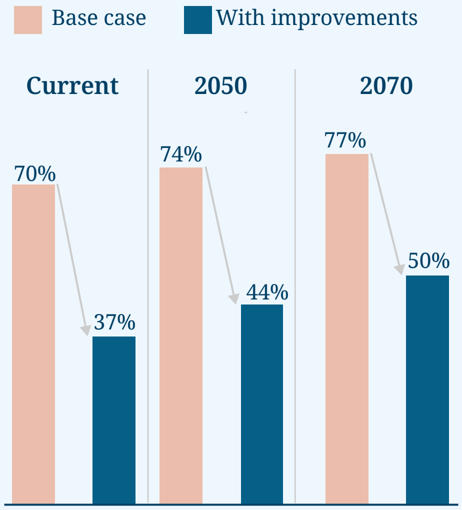
**92.** Lopez-Bueno, J.A. et al. The impact of heat waves on daily mortality in districts in Madrid: the effect of sociodemographic factors. Environmental Research 190 (2020). Link: **https://www.sciencedirect.com/science/article/abs/pii/S0013935120308902**.

**93.** Harper, K., Steger, T., and Filčák, R. Environmental Justice and Roma Communities in Central and Eastern Europe. Environmental Policy and Governance 19: 4 (2009). Link: **https://onlinelibrary.wiley.com/doi/10.1002/eet.511**.

**FIGURE 2.11** Building Upgrades Can Cut Indoor Heat Exposure in Central Asia's Aging Housing Stock

A: Projected daytime overheating (percent of year) with and without building improvements




B: Typical housing stock in Shymkent to which passive design upgrades were simulated

*Source:* World Bank analysis. Photo credit: Adrian Turner

*Notes:* Overheating hours were simulated using a building performance model. A typical two-bedroom flat in a Soviet-era apartment building in Shymkent, Kazakhstan was modelled. The projections assume a middle-of-the-road climate scenario (SSP2-4.5). The overheating threshold applied is 31.7°C (a moderate rather than severe overheating threshold).

# 3 What Needs to Be Done? An Action Agenda

In a region shaped by historically temperate climate, with little exposure to extreme heat, the trends and projections presented in Section 1, and the human and economic impacts outlined in Section 2, call for timely action to cool cities and build resilience to heat. Otherwise, Europe and Central Asia could face rising heat-related deaths, diminished quality of life, growing economic losses, and mounting infrastructure strain.

The good news is that many effective solutions are within reach. Local conditions can be significantly improved, and key systems can be made significantly more heat-resilient. This section lays out an agenda for action to tackle extreme urban heat in Europe and Central Asia.

### *An Action Agenda: Four Principles, Ten Strategic Actions*

Extreme heat is felt most acutely in the physical spaces of a city—its streets, markets, schools, homes, and workplaces. As heat risks escalate, making these spaces cooler becomes a critical priority. Urban planners, architects, developers, and residents all have roles to play, but it is government leadership that sets the enabling conditions for progress.

That said, cooling cities is a long-term endeavor, while heatwaves are immediate crises. Each episode can endanger thousands of lives and cost millions in lost productivity and damaged infrastructure. To manage both timelines, cities need a comprehensive approach to heat resilience—one that blends rapid emergency response with sustained investment in urban design, infrastructure, and governance. This requires clear leadership, legal authority, and coordination across sectors.

To guide such a response, this report presents an action agenda built on four principles: make city spaces cooler, save lives during heatwaves, adapt infrastructure for a hotter future, and embed heat resilience across government systems. Those four pillars—**Places, People, Infrastructure, and Institutions**—anchor 10 strategic actions outlined in the sections that follow.

**FIGURE 3.1** Places, People, Infrastructure, and Institutions: 10 Strategic Actions for Heat Resilience in Europe and Central Asia

**Places**
Make urban spaces cooler

1. Advance urban greening through strategic planning
2. Harness wind, shade and design
3. Upgrade building stock to tackle overheating risks

**People**
Protect the vulnerable during extreme heat

1. Save lives through heatwave early warning and response
2. Strengthen health system readiness
3. Protect heat-exposed workers and residents

**Infrastructure**
Adapt for a hotter future

1. Build resilience of energy systems
2. Integrate heat resilience into the transport sector
3. Prevent schools overheating

**Institutions**
Mainstream heat resilience into national and municipal strategies, operations and budgets

*Source:* World Bank elaboration.

## 3.1 Make Urban Spaces Cooler

The first three strategic actions focus on helping cities to reduce ambient temperatures and create cooler, more livable outdoor and indoor environments. From urban greening to climate-sensitive design and building upgrades, these interventions form the foundation for long-term urban adaptation.

### 1. Advance Urban Greening through Strategic Planning

Urban greening is an important strategy to reduce urban heat and improve livability. Trees and green spaces help cool ambient temperatures, improve air quality, and provide shade and respite during heatwaves. Yet green coverage remains uneven—often concentrated in wealthier areas, while central districts, low-income neighborhoods, and industrial zones lack sufficient vegetation.

To address these disparities and scale up impact, cities can adopt long-term greening strategies backed by dedicated budgets and policy commitments. A practical starting point is the so-called "3–30–300 rule":[94] Every city resident should see at least three trees from their home, live in a neighborhood with 30 percent canopy cover, and be within 300 meters of a public green space. These targets can be tailored to local conditions and embedded into urban development plans.

Where public budgets are tight, cities can tap into private investment through public-private partnerships, advertising revenues, or greening requirements tied to new developments. Brownfield and post-industrial sites offer promising opportunities for large-scale greening, as seen in Kraków, Poland, where efforts to green dense neighborhoods have benefits local residents.

Water availability is an emerging constraint, particularly in Southern Europe, the Western Balkans, and Central Asia. Greening efforts should therefore emphasize drought-tolerant species, rainwater harvesting, and low-maintenance designs. Investments in climate-resilient nurseries and urban forestry skills will be critical to sustaining these efforts as temperatures rise. Community participation—through tree adoption and partnerships with schools and local non-governmental organizations (NGOs)—can also reduce costs and build public support.

To succeed, urban greening must be strategic and sustained. Cities should develop 10–20 year master plans that link greening to spatial planning, land use, and climate adaptation strategies. These plans should set realistic planting and maintenance targets, identify priority neighborhoods based on heat exposure and access gaps, and identify resource needs.

**94.** Konijnendijk, C. (2021). Adopting the 3-30-300 rule for urban greening. *Urban Forestry & Urban Greening*, 64, 127354. Link: **https://doi.org/10.1016/j.ufug.2021.127354.**

## BOX 3.1 Urban Greening in Cities in Europe and Central Asia

### Vision Ljubljana 2025: A greener, cleaner, more compact city

Ljubljana faces severe urban heat island effects and legacy pollution. In 2007, the Slovenian capital launched the "Ljubljana 2025" strategy, which emphasized green and blue infrastructure, culminating in a 100,000 $m^2$ ecological zone in the city center.

Since 2010, over 40,000 trees have been planted. Green space now covers 75 percent of the city, and motorized traffic has been removed from much of the center, improving thermal comfort and air quality. Development has prioritized brownfield sites, including 120 hectares of new parks. A €20 million effort launched in 2012 revitalized the Ljubljanica River and added pedestrian bridges, boosting connectivity and livability while also improving thermal comfort for city residents. Ljubljana's citizen-centric planning and diverse funding mix—including municipal budgets, EU funds, national grants, and public-private partnerships—earned it the European Green Capital Award in 2016.[95]

### Tirana's Orbital Forest: A living perimeter to curb sprawl

Rapid urbanization is putting strain on Tirana's infrastructure, air quality, and climate resilience. Temperature differentials across the Albanian capital can exceed 4.3°C on hot days[96]. In 2015, a territorial reform expanded Tirana's footprint from 42 $km^2$ to over 1,200 $km^2$, and the city launched the "TR030" strategy, which prioritized compact development, energy efficiency, and resilience.

The Orbital Forest—a green belt encircling the city—is a centerpiece of this vision. It was conceived to limit urban sprawl, prevent deforestation, and cool the urban fringe. The plan calls for 2 million new trees by 2030; by 2019, more than 300,000 had already been planted. The Forest forms a 50 $km^2$ linear park around the urban core, protecting 1,100 $km^2$ of public land and connecting 14,000 hectares of parks, fields, and woodlands. The city plans to triple green space through three green and blue corridors in the city center, increasing resilience to flooding and heat, while improving air and soil quality.

**95.** European Environment Agency. 2017. "Ljubljana Wins European Green Capital Award for 2016." News release, February 20. **https://www.eea.europa.eu/highlights/ljubljana-wins-european-green-capital-2016.**

**96.** World Bank analysis using data from a citizen science mapping campaign (Heat Watch Albania) conducted by CAPA Strategies and the University of New York, Tirana; See Heat Watch Albania (**https://storymaps.arcgis.com/stories/0acc8804f35e4ca9b907bb93e0f1d11c**).

## 2. Harness Wind, Shade, and Design for Cooler Cities

Urban design plays a critical role in reducing heat exposure and improving comfort in cities. With their varied geographies—from coastal plains to mountainous valleys—cities across Europe and Central Asia are well-positioned to harness local climatic conditions through smart, climate-adaptive planning.

Natural sea breezes can reduce summer temperatures by several degrees. To preserve this benefit, urban planning should protect wind corridors by regulating building height, orientation, and density. Strategic layouts, such as stepped-back façades and wind-aligned streets, can increase airflow. Similar principles apply to mountainous cities where nighttime katabatic winds can offer natural cooling. Zoning measures that limit dense development in key ventilation corridors—and building façade design that enables natural ventilation into interiors to cool them when wanted—can help cities capitalize on these cooling air flows.

Shading is another powerful and often underused intervention. Well-designed shade—through trees, pergolas, canopies, or tensile structures—can reduce "feels-like" temperatures by up to a third.[97] Municipalities can scale up these efforts by streamlining permitting for shade structures, prioritizing coverage in high-footfall zones like markets, bus stops, and school entrances, and incorporating shade as a priority in planning documents. Providing shade to building façades and roofs can significantly reduce summertime heat transfer into interiors. Using deciduous trees or temporary summer awnings for shade is perfect for cooling only in the warmer months, as buildings will still be exposed to the sun in the winter, helping to reduce heating demand (see Box 3.2).

**97.** Turner, V.K., Middel, A. and Vanos, J.K., 2023. Shade is an essential solution for hotter cities. Nature, 619(7971), pp.694-697.

## BOX 3.2 Solar Protection for Everyone during the Summer in Seville


*Photo credit:* Ruggero Poggianella / Wikimedia Commons.

Seville is in one of Spain's hottest regions, where temperatures frequently exceed 30°C from May to September and can often reach 40°C or more during the height of summer. The sun is the primary source of heat during this period, making outdoor conditions challenging.

To mitigate the effects of extreme temperatures, the local government installs awnings across the city center every year.[98] These structures help create a more comfortable urban environment by reducing the thermal sensation in public spaces and minimizing the economic impact of overheating.

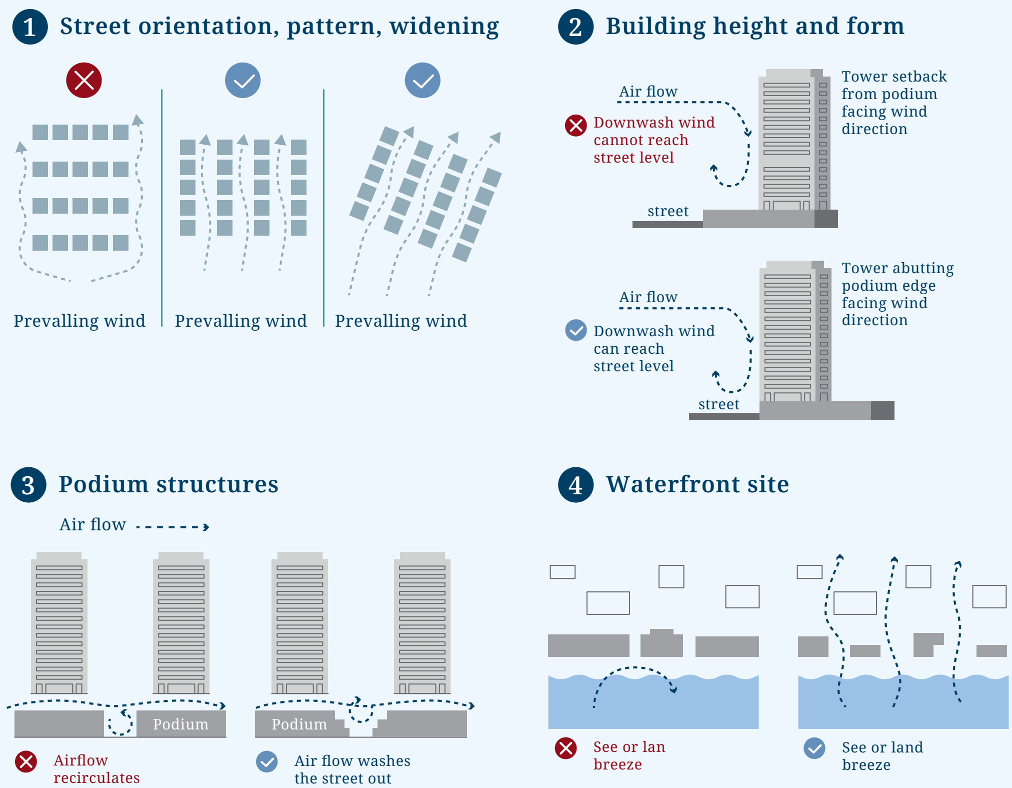
The awnings are set up in late spring and remain in place until early autumn, covering the hottest months of the year. This strategy not only enhances the livability of the downtown area, but also contributes to lower indoor temperatures in surrounding buildings. By shading facades and windows, the awnings reduce solar heat gain, making interiors cooler and more energy-efficient.

Blue infrastructure also plays a valuable cooling role. Restoring landscapes along riverbanks and creating parks, adding misting stations, and reintroducing urban water features such as decorative fountains can lower ambient temperatures while improving public spaces.

Beyond physical comfort, climate-sensitive design has economic benefits. Cooler, more inviting public spaces attract pedestrians, extend commercial activity, and can boost tourism revenues. Design competitions, development incentives, and updates to building codes can nudge private developers to apply climate-sensitive designs. Importantly, cities should base interventions on how, when, and by whom public spaces are used—ensuring that shade, airflow, water features, and greenery align with real patterns of occupation and movement. In an increasingly hot climate, successful public space design can play an important role in sustaining economic vibrancy during peak summer heat.

**98.** Cruz, E. & Jiménez, M. (2020). Adaptive strategies to reduce urban overheating in Seville: A case study of seasonal shading structures. Journal of Urban Climate.

## FIGURE 3.2 Design Principles for Harnessing Wind and Airflow in Urban Planning




*Source:* World Bank elaboration based on a figure by the Planning Department of Hong Kong SAR, China.

## BOX 3.3 Stuttgart Harnesses Wind to Combat Urban Heat and Air Pollution

Situated in a valley with poor natural airflow, Stuttgart suffers from severe urban heat and air quality issues. Growing development on surrounding slopes further limited air circulation. By 2050, the number of annual heat stress days in central Stuttgart is projected to exceed 60.[99]

The city responded by producing a detailed Climate Atlas in 1992 (updated in 2008), mapping topography, land use, and wind patterns to guide zoning reforms. The result is ventilation corridors: 100 meter-wide green spaces that channel cooler air from the hills into the city. The 2004 revision of Germany's Building Code reinforced these measures, ensuring that Stuttgart's regulations banned development in critical areas to preserve airflow. While high real estate values created pressure to develop on these lands, Stuttgart prioritized long-term health and livability. The city's approach demonstrates the value of localized climate research and cross-sector collaboration in aligning zoning, design, and public health goals.

**99.** Irmela Schlegel and Meinolf Kobmann. 2017. "Urban climatic studies summer heat load in Stuttgart as a basis for adaptation to climate change.". German Weather Service Department Climate. **https://www.dwd.de/DE/klimaumwelt/klimaforschung/klimawirk/stadtpl/stadtklimaprojekte/projekt_stuttgart/externe_links/abschlussbericht.html?nn=614926**.

## 3. Tackle Indoor Heat through Building Upgrades

Improving building performance is essential to reduce indoor heat exposure across Europe and Central Asia, where much of the housing stock predates modern thermal standards. Many mid-20th century structures—particularly Soviet-era multi-family blocks—lack effective insulation, exterior shading, and effective natural ventilation. In Ukraine, for instance, 69 percent of the residential stock—roughly 240 million square meters—are Soviet-era multi-family blocks constructed between 1950 and 1990.[100] Longer and hotter summer heatwaves now lead to excessive indoor temperatures, impacting comfort and health, especially affecting children and the older residents who make up a growing share of the population.

Given these conditions, upgrading the region's housing and public buildings is becoming increasingly urgent. Interventions must address both summer overheating and winter heating demand, integrating thermal comfort goals into national and municipal housing strategies. To ensure broad participation—especially among low- and middle-income households—governments must deploy accessible financing tools, including direct subsidies, concessional loans, and performance-based grants.

Several programs across the region provide promising models. In Romania, the Bucharest Multi-Family Housing Retrofit Program has modernized over 2,000 apartment units, cutting energy consumption by 40–50 percent while improving summer comfort. Kazakhstan's DAMU program offers subsidized credit for building envelope upgrades, and Georgia's Green Climate Fund-supported initiative targets heat resilience in aging residential buildings.

Beyond health and energy benefits, building retrofits also generate durable employment. A recent study estimates that every €1 million invested in building renovation creates between 15 and 29 jobs across countries in Europe and Central Asia, spanning trades such as construction, engineering, energy auditing, and materials manufacturing.[101] To scale up effectively, countries will need to invest in public awareness campaigns, training programs for construction professionals, and broader market development for high-performance building materials and services.

**100.** Low Carbon Ukraine (2021). Residential buildings in Ukraine – Analysis of the building stock and potentials for $CO_2$ emission reductions. Berlin: Low Carbon Ukraine, BE Berlin Economics GmbH. **https://www.lowcarbonukraine.com/wp-content/uploads/LCU_BuildingStockAnalysis_EN.pdf.**

**101.** Buildings Performance Institute Europe (BPIE) (2020) Building renovation: a kick-starter for the EU economy. Brussels: BPIE. **https://www.bpie.eu/publication/building-renovation-a-kick-starter-for-the-eu-economy.**

## BOX 3.4 Building Retrofits in Türkiye and Croatia Saved Energy and Cooled Buildings

After the 2020 earthquake, Croatian cities, particularly Zagreb, faced the daunting task of rebuilding tens of thousands of damaged structures. But city leaders saw an opportunity to make public buildings more resilient to earthquakes as well as more energy-efficient.

Since 2017, Zagreb has refurbished 57 schools and seven health facilities, and in 2022 it adopted the "Green Deal Construction Standard"[102] for all new public infrastructure. Nature-based solutions were a key element: green roofs and facades became standard features, improving insulation and helping to cool both buildings and the surrounding urban environment. These improvements also supported biodiversity and air quality goals.

The Green Urban Renewal Strategy provided the policy foundation, aligning building upgrades with long-term sustainability and resilience plans. Policy reforms included new building codes that mandated climate-proofing. Financial support was substantial: €600 million was mobilized for reconstruction and energy renovation. One major challenge was balancing the preservation of cultural heritage with the integration of modern technologies—necessitating innovative design and engineering.

Türkiye, too, faces overlapping risks. In 2023, it endured one of its hottest summers in history, with temperatures nearing 50°C in the southeast. It is also one of the most earthquake-prone countries in the region, with 76 quakes since 1900 causing cumulative losses over US$425 billion. Meanwhile, buildings consume about 40 percent of the country's energy, underscoring the urgency of integrated solutions.[103]

To address these intersecting vulnerabilities, Türkiye launched the Seismic Resilience and Energy Efficiency in Public Buildings Project in 2023, backed by a $265 million World Bank loan. The initiative aims to strengthen the seismic safety and energy performance of public buildings across the country. More than 175,000 public buildings are being assessed, with upgrades expected to benefit over 6 million people who rely on these spaces for services such as education and healthcare.

By coupling disaster resilience with energy efficiency, Türkiye and Croatia are demonstrating a "two-for-one" approach that maximizes returns on investment. These projects not only reduce emissions and utility costs, but also future-proof public assets against increasingly common heatwaves and earthquakes, laying the groundwork for safer, more sustainable urban development.

**102.** Adrien Dozol, Diego Ambasz, Tigran Shmis, Ana-Maria Boromisa, Lucia Brajkovic, Jure Kotnik, Danijel Marasović, Danica Ramljak, and Maria Ustinova. 2023. "Greening Public Human Development Buildings in Croatia: Support for the Implementation of the European Green Deal in the Croatian Health and Education Sectors." Washington, DC: World Bank Group.

**103.** Usta, Pınar & Cirik, Kamertap & Şakalak, Elifnur & Sever, Ali. (2024). A critical examination of the construction sector in Turkey in terms of sustainability. International Journal of Engineering and Innovative Research. 6. 10.47933/ijeir.1491574.

**BOX 3.5 Green Roofs and Walls in Novi Sad and Osijek: A Cross-Border Pilot**

The Croatia–Serbia border region faces rising urban heat and limited adaptive capacity. Osijek, Croatia's fourth-largest city, has one of the highest heat-related mortality rates in Europe[104]. In 2015, Novi Sad, the second-largest city in Serbia, experienced temperatures above 30°C for nearly half of the summer.

The two cities jointly implemented the GReENERGY project (2019–2022), funded by the EU. The main project objective is to improve the energy efficiency of public buildings with the usage of green roofs and walls, to produce and use renewable energy sources using solar panels and to promote energy effiency and green energy usage to public and private sector.[105] The project introduced nature-based solutions, including a 480 $m^2$ accessible green roof and an 80 $m^2$ green wall on a public school building in Novi Sad. In Osijek, a 160 $m^2$ green roof was added to a high school. Automated weather stations in both cities monitored performance, finding temperature reductions of up to 3°C and significant improvements in energy efficiency.

## 3.2 Protect Vulnerable People during Extreme Heat Events

The next set of three strategic actions focuses on addressing the human impacts of extreme heat, with particular attention to protecting the people who most at risk. These actions cover early warning systems, health system readiness, and targeted support for exposed workers and vulnerable residents to reduce heat-related death and illness.

### 4. Strengthen Heat Early Warning and Response Systems

Most heat-related deaths are preventable. They disproportionately affect people with high exposure—such as those living in poorly insulated homes, or working outdoors or in hot indoor spaces—as well as those with heightened physiological vulnerability, including older adults, pregnant women, and people with pre-existing health conditions. Simple, timely actions such as seeking shade, staying hydrated, and cooling the body can avert most heat-related illnesses. But these actions often require a prompt: from a trusted public alert, a healthcare worker, a worksite supervisor, or even a concerned neighbor.

**104.** Masselot, P., Mistry, M., Vanoli, J., Schneider, R., Iungman, T., Garcia-Leon, D., Ciscar, J. C., Feyen, L., Orru, H., Urban, A., Breitner, S., Huber, V., Schneider, A., Samoli, E., Stafoggia, M., de'Donato, F., Rao, S., Armstrong, B., Nieuwenhuijsen, M., Vicedo-Cabrera, A. M., ... EXHAUSTION project (2023). Excess mortality attributed to heat and cold: a health impact assessment study in 854 cities in Europe. The Lancet. Planetary health, 7(4), e271–e281. **https://doi.org/10.1016/S2542-5196(23)00023-2**.

**105.** See **http://www.greenenergy.rs**.

Many heat-related deaths occur outside of heatwaves, but extreme heat events are particularly dangerous. On such days, early warning systems can save lives. According to an analysis by the World Health Organization (WHO) and the World Meteorological Organization (WMO), the introduction of heat alert systems in currently uncovered countries could prevent up to 98,000 deaths globally every year.[106]

Following the deadly 2003 European heatwave, which caused nearly 70,000 excess deaths, many Western European countries developed robust heat-health early warning systems. Structured plans with clear alert protocols, public health measures, and institutional coordination have led to measurable reductions in heat-related mortality and emergency service pressure. Table 3.1 shows some of the benefits that have been documented in the region.

**Table 3.1 Do Heatwave Alerting and Response Plans Save Lives? Evidence from International Studies**

| Country | Intervention | Observed Impact |
|---|---|---|
| France | National Heatwave Plan (2004) including early warning systems and public advisories | 68% reduction in mortality during 2006 heatwave compared to 2003, after accounting for temperature differences[107] |
| Italy | Heat Health Watch Warning System (since 2004) with city-specific alerts and public health measures | 9–15% reduction in heat-related mortality in major cities following implementation[108] |
| Spain | Heat-Health Action Plans with regional adaptations | 10–15% reduction in daily mortality during heat events compared to pre-intervention years[109] |
| Germany | Heat Health Warning Systems and public information campaigns | Reduced emergency admissions and excess deaths observed during alert-triggered heatwaves[110] |
| Switzerland | National and cantonal heat warning systems and public health guidance | 27% reduction in excess mortality among seniors during 2015 heatwave vs. previous comparable years[111] |

*Source:* World Bank elaboration based on research sources cited.

**106.** World Meteorological Organization (WMO) & World Health Organization (WHO). (2023). 2023 State of Climate Services: Health. WMO-No. 1292. Geneva: WMO. Available at: **https://reliefweb.int/report/world/2023-state-climate-services-health.**

**107.** Fouillet, A., Rey, G., Wagner, V., Laaidi, K., Empereur-Bissonnet, P., Le Tertre, A., Frayssinet, P., Bessemoulin, P., Laurent, F., De Crouy-Chanel, P. and Jougla, E., 2008. Has the impact of heat waves on mortality changed in France since the European heat wave of summer 2003? A study of the 2006 heat wave. *International journal of epidemiology,* 37(2), pp.309-317.

**108.** Michelozzi, P., De'Donato, F.K., Bargagli, A.M., D'Ippoliti, D., De Sario, M., Marino, C., Schifano, P., Cappai, G., Leone, M., Kirchmayer, U. and Ventura, M., 2010. Surveillance of summer mortality and preparedness to reduce the health impact of heat waves in Italy. *International journal of environmental research and public health,* 7(5), pp.2256-2273.

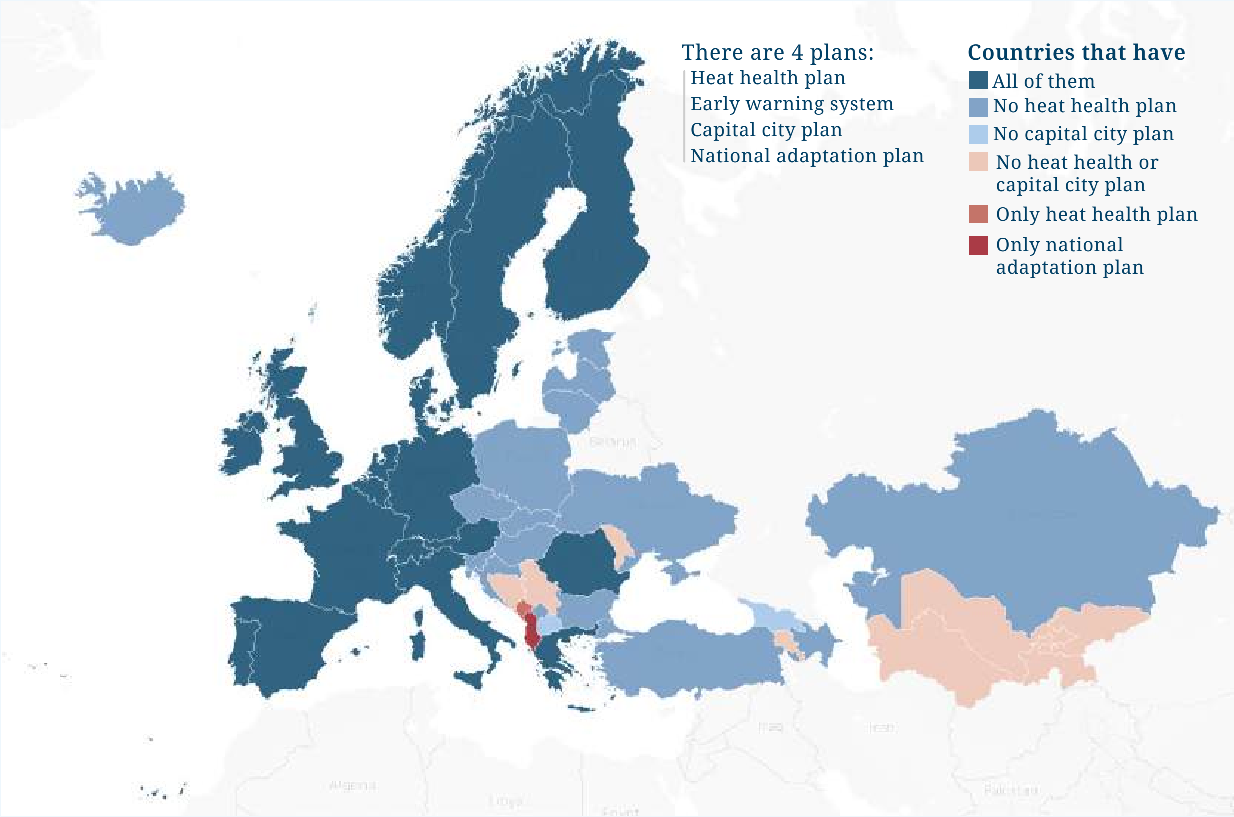
**109.** Díaz, J., Carmona, R., Mirón, I.J., Ortiz, C., León, I. and Linares, C., 2015. Geographical variation in relative risks associated with heat: update of Spain's heat wave prevention plan. *Environment international,* 85, pp.273-283.

**110.** Schuster, C., Tatar, M., & Walter, S. (2017). *Heat-related mortality and adaptation to heat in Germany: Evidence for regional differences*. Environmental Research, 155, 272–279. **https://doi.org/10.1016/j.envres.2017.02.023.**

**111.** Vicedo-Cabrera, A.M., Ragettli, M.S., Schindler, C. and Röösli, M., 2016. Excess mortality during the warm summer of 2015 in Switzerland. *Swiss medical weekly,* 146, p.w14379.

Yet in much of Europe and Central Asia, such systems are still limited. A regional policy mapping exercise assessed the integration of heat early warning systems across key policy domains—climate adaptation strategies, national heat-health plans, and local climate resilience planning in capital cities. It found 87 percent of countries in the region have some form of heat early warning system, with projected coverage rising to 98 percent under the UN's Early Warnings for All initiative.[112] However, serious gaps remain. Many of these systems are not embedded in long-term climate and health strategies, which reduces their effectiveness. The strongest systems are those backed by clear heat action plans, which ensure the warnings are not only issued, but acted upon. Figure 3.3 shows coverage and gaps across the region, focusing on dedicated heat health plans (including plans for major cities, in this case looking just at national capitals), national climate adaptation plans with health components, and heat early warning systems.

**FIGURE 3.3 Heat Adaptation and Early Warning Policies and Gaps in Europe and Central Asia**




*Source:* World Bank analysis based on national heat-health action plans and related policy documents.

**112.** See **https://earlywarningsforall.org/site/early-warnings-all**.

As of November 2024, only 28 percent of countries in the region had a heat health plan—or 38 percent if broader climate health plans are included. While nearly all countries in Europe and Central Asia have national adaptation plans, integration at the local level is weaker: only 69 percent of capital cities have relevant urban climate plans in place.

The Europe and Central Asia region benefits from strong meteorological capabilities, which can serve as a foundation for more integrated heat alert systems. Success requires formal coordination between weather and health agencies, joint planning protocols, and clearly assigned roles for key actors—such as hospitals, transit systems, elder care facilities, schools, and local governments. Many countries, including the UK, France, India, and Japan, use color-coded heat alert levels (e.g., yellow, orange, red), each linked to a corresponding set of institutional and public actions.

As explained in Section 1, air temperature is only one of several factors that determine the severity of heat stress risks. Alert thresholds should thus account for humidity, wind speed, and the conditions to which local residents are acclimatized. They should also clearly state who is most at risk (e.g., people with cardiovascular or respiratory conditions, outdoor workers, athletes) and simple ways in which people can protect themselves. Alerts should be issued only when health risks are demonstrably elevated, helping to maintain public confidence and avoid “alert fatigue.”

Effective communication is critical. Messaging must be clear, credible, and tailored to target audiences such as especially older adults, people living alone, tourists, and low-income or otherwise vulnerable households. Pre-tested health advisories, delivered through trusted channels and backed by clinical expertise, can help prompt life-saving behavior changes. By integrating meteorological forecasts with public health planning—well ahead of the summer season—countries in Europe and Central Asia can build timely, targeted heat early warning systems that protect lives. Box 3.6 examines the progress made in the region to date, as well as the work that must still be done.

## BOX 3.6 A Decade of Progress on Heat-Health Plans, But Critical Gaps Remain

Early warning systems (EWS) for extreme weather have undergone significant evolution, shaped by advances in science, shifts in public health priorities, and the rising visibility of climate risks. The first global technical report on heatwave early warning systems, published in 2004, noted that countries such as Azerbaijan, Belarus, Czechia, Greece, Latvia, Malta, Portugal, Serbia and Montenegro, Spain, Romania, North Macedonia, Turkey, and parts of southern Germany had already established some form of heat warning mechanism.[113] At the time, most countries used a single, national temperature threshold to trigger warnings—an approach that has since been replaced by more localized, risk-based systems.

A wave of national and regional health prevention and research initiatives followed the summer of 2003. The WHO Regional Office for Europe introduced a comprehensive framework for prevention, including heat health action plans. By the mid-2000s, many countries had adopted national heat health action plans that paired early warning systems with public health advisories and operational protocols. These systems have since matured into increasingly localized, risk-based alerting mechanisms.

As noted above, 87 percent of countries in the region now have some form of heat early warning system, though significant gaps remain. Vulnerability to heat is unevenly distributed, shaped by age, health, occupation, housing quality, and social factors. A World Bank review of national heat health action plans in 12 countries (see Figure 3.4) shows a heavy focus on older adults, who are referenced 434 times in national-level documents. Children and the unhoused also receive some attention.

Yet pregnant women and infants—whose susceptibility to heat is well established in medical literature—are rarely mentioned. Many policies also neglect risks to workers and to people with low-quality housing. Establishing heat early warning systems where they are lacking, ensuring such mechanisms address key vulnerable groups, and strengthening their overall reach and efficacy are crucial priorities to save lives in future extreme heat events.

**113.** Koppe, C., Kovats, R.S., Jendritzky, G. and Menne, B., 2004. *Heat-waves: risks and responses.* Copenhagen: World Health Organization Regional Office for Europe. Available at: **https://www.euro.who.int/__data/assets/pdf_file/0008/96965/E82629.pdf**.

## FIGURE 3.4 Frequency of Key Terms in National Heat Health Action Plans in 12 Countries

**Frequency of key term**

Less mentioned — More

| Key terms | Greece | Switzerland | Germany | Luxembourg | France | Spain | Portugal | Netherlands | Austria | North Macedonia | Belgium | UK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Medical | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Youth | 0 | 0 | 0 | 0 | 7 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Pregnant | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 3 | 4 | 0 | 0 |
| Condition | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 9 | 1 | 0 |
| Tree | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 0 | 5 | 2 | 0 |
| Homeless | 0 | 0 | 2 | 1 | 0 | 2 | 3 | 0 | 1 | 5 | 0 | 12 |
| Older | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 3 | 5 | 5 | 4 | 6 |
| Behaviour | 0 | 0 | 0 | 0 | 11 | 1 | 0 | 3 | 4 | 3 | 2 | 6 |
| Green | 0 | 1 | 0 | 0 | 3 | 2 | 3 | 2 | 4 | 11 | 2 | 3 |
| Young | 0 | 0 | 0 | 1 | 20 | 0 | 1 | 1 | 2 | 2 | 8 | 3 |
| Worker | 0 | 0 | 0 | 1 | 15 | 0 | 1 | 1 | 0 | 17 | 9 | 0 |
| Rough | 0 | 0 | 1 | 0 | 12 | 8 | 2 | 1 | 0 | 4 | 2 | 26 |
| House | 0 | 0 | 0 | 6 | 3 | 2 | 8 | 0 | 3 | 11 | 3 | 20 |
| Children | 3 | 0 | 1 | 2 | 3 | 7 | 16 | 9 | 3 | 8 | 24 | 16 |
| Elderly | 1 | 0 | 1 | 2 | 4 | 9 | 19 | 41 | 2 | 7 | 10 | 0 |
| Child | 3 | 0 | 1 | 2 | 5 | 8 | 18 | 15 | 3 | 9 | 25 | 17 |
| Cool | 2 | 2 | 1 | 0 | 15 | 5 | 4 | 22 | 12 | 24 | 36 | 1 |
| Communication | 0 | 0 | 6 | 2 | 18 | 13 | 6 | 21 | 28 | 17 | 17 | 66 |
| Warn | 0 | 12 | 17 | 3 | 2 | 7 | 6 | 22 | 75 | 8 | 37 | 37 |
| Alert | 0 | 0 | 0 | 9 | 11 | 19 | 37 | 6 | 3 | 30 | 50 | 145 |
| Old | 2 | 6 | 2 | 2 | 5 | 51 | 7 | 10 | 23 | 43 | 53 | 107 |

*Source:* World Bank analysis based on national heat-health action plans and related policy documents.

*Notes:* Frequency refers to the number of times each word appears in national-level heat-health action plans or equivalent documents. Dark red indicates zero mentions, while shades of blue indicate particularly large numbers of mentions. The analysis includes plans available in English or with verified translations. Results reflect differences in document length, terminology, and policy focus.

# 5. Build Health System Readiness for Extreme Heat

As temperatures rise and heatwaves intensify across Europe and Central Asia, health systems must be better prepared for climate-related risks. Major heatwaves sharply increase the burden on hospitals and clinics—not only from heatstroke and dehydration, but also from aggravated cardiovascular and respiratory conditions, which are prevalent in aging populations. In Bucharest, for example, ambulance callouts rose by 20 percent during a heatwave in August 2024.[114]

**114.** Kostova, D. (2023). Southern *Europe swelters: How heatwaves are affecting public health and transport.* Euronews, 20 July. Available at: **https://www.euronews.com/next/2023/07/20/southern-europe-swelters-how-heatwaves-are-affecting-public-health-and-transport**.

This pressure is expected to grow. This report's analysis of state-of-the-art climate model projections indicates that the frequency of severe or extreme heatwaves in the Western Balkans, Turkey, and Central Asia will more than double by 2050 (see Section 1). With many health systems already strained during seasonal peaks, targeted investments are urgently needed to strengthen infrastructure, equip personnel, and establish protocols for managing heat illness.

A starting point is ensuring that health infrastructure can withstand extreme heat. Hospitals, clinics, and care facilities must be designed—or retrofitted—to maintain safe indoor temperatures, especially in high-risk areas such as emergency departments, intensive care units (ICUs), and neonatal wards. Improved insulation, shading, and ventilation can reduce dependence on air conditioning while enhancing thermal comfort.

Clinical preparedness must also improve. In many countries, formal guidance on heat-related illness is incomplete or lacking. Medical staff need clear protocols on diagnosis and treatment, including the crucial first 30 minutes after symptom onset, as well as awareness of medications that increase heat vulnerability—such as diuretics, beta-blockers, and antipsychotics.

Stronger integration between weather and health systems is essential. In countries like France and the UK, forecasts are shared with frontline health workers in advance of extreme heat, enabling hospitals to anticipate patient surges, adjust staffing, and conduct proactive outreach. Primary care providers, including general practitioners and nurses, can play a vital role in checking on at-risk patients during heat alerts.

Finally, surveillance and data systems must track heat-related illness and mortality. In England, the UK Health Security Agency (UKHSA) operates real-time monitoring and works with the national meteorological office to review seasonal mortality trends. This informs annual updates to its Heat-Health Alert system.[115] Similar mandates for national public health institutes across the region could support an evidence-based, year-on-year improvement cycle, helping countries adapt more quickly and reduce preventable deaths as extreme heat becomes the new normal.

## 6. Protect Heat-Exposed Workers and Residents

During a heatwave, workers in high-risk occupations and vulnerable residents without access to cooling face severe—and sometimes fatal—risks. As extreme heat becomes more frequent across Europe and Central Asia, stronger protections for both groups will be critical.

**Protecting workers:** Heat exposure varies dramatically by occupation. At one end of the spectrum, some industrial employers, such as steel mills, heavy manufacturing plants and

**115.** UK Health Security Agency (UKHSA). (2023). *Adverse weather and health plan: Heatwave plan for England – Summer 2023*. London: Department of Health and Social Care. Available at: **https://www.gov.uk/government/publications/heatwave-plan-for-england.**

building contractors, are long accustomed to managing heat risks with protective gear and strict monitoring. At the other end, office workers in climate-controlled spaces face relatively little danger. In between, however, a wide range of occupations now demand greater attention. Restaurant kitchens, laundries, warehouses, and emergency services expose workers to extreme heat, often exacerbated by heavy uniforms or equipment. European trade unions have recently highlighted heat-related deaths among workers in outdoor occupations such as construction, dock work, and postal delivery services.[116]

Heat stress reduces productivity and contributes to large numbers of workplace injuries by affecting judgment, alertness, and physical performance. Studies show that productivity losses during extreme heat days can reach 20–30 percent in sectors such as construction, and that accidents such as slips, trips, falls and equipment mishandling spike on hot days.[117] The risks vary based on labor market characteristics: while medium or large firms may have established legal obligations and corresponding actions to assess risks and keep workers safe, workers in small businesses or informal employment lack such protections—with migrants, seasonal workers and subcontractors among the most vulnerable. For many, the economic pressure to keep working despite heat illness symptoms is severe, especially in piece-rate or daily-wage sectors.

Employers can reduce heat risks through technical measures, such as improving the ventilation in a restaurant kitchen, and through organizational measures, such as shifting work hours to cooler times of day. Indeed, EU Member States and accession candidates already include such obligations within their national health and safety frameworks, guided by EU-level requirements for workplace risk prevention.[118] Strengthening these measures further is a priority to protect lives, safeguard livelihoods, and maximize economic output. Table 3.2 provides examples of helpful actions, which may be voluntary or required by law or regulation.

The benefits go beyond preventing rare events like heatstroke deaths. For example, in California, implementing mandatory heat illness prevention standards—including requirements for water, shade, and rest breaks—has helped prevent an estimated 20,000 workplace injuries each year.[119] Meanwhile, for workers outside the formal sector, measures such as microinsurance schemes or targeted social protection programs could provide vital income security during heatwaves, helping them prioritize their health without facing income loss.

**116.** European Trade Union Confederation (2023) *Heat deaths at work up by 40% in the EU*. Available at: **https://www.etuc.org/en/pressrelease/heat-deaths-work-40-eu**.

**117.** International Labour Organization (ILO). (2019). *Working on a warmer planet: The impact of heat stress on labor productivity and decent work*. Geneva: International Labour Organization. Available at: **https://www.ilo.org/global/publications/books/WCMS_711919/lang–en/index.htm**

**118.** Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work (OJ L 183, 29.6.1989, p. 1–8). Known as the EU Framework Directive on occupational safety and health, it establishes general principles for managing workplace risks, including the obligation for employers to assess and mitigate all risks to workers' health and safety. While the directive does not explicitly mention heat stress, its broad scope encompasses environmental conditions that may endanger workers, making it applicable to heat-related risks.

**119.** Behrer, A.P., Park, R.J., & Goodman, J. (2023). *Reducing workplace heat exposure reduces work-related injuries. Nature Communications,* 14, 2881. https://doi.org/10.1038/s41467-023-38542-8.

### Table 3.2 Examples of Actions to Protect Heat-Exposed Workers

| Category | Action |
|---|---|
| Educational actions | • Inform heat-exposed workers about symptoms and risks of heat stress<br>• Encourage behaviors that mitigate heat stress: drink water; eat less but more frequently; reduce caffeine and alcohol; seek medical attention when needed<br>• Train workers to recognize heat illness symptoms and ensure that coworkers receive early intervention when needed ("buddy system") |
| Employer actions | • Organize work shifts to avoid exertion during hot afternoon periods<br>• Schedule breaks if heat becomes too intense<br>• Provide water and shade at work sites<br>• Conduct occupational health and safety assessments for heat risks<br>• Provide workers acclimatization time (for example, initial 50% workload)<br>• Adapt uniforms and encourage wearing of light, breathable garments |
| Government actions | • Consult heat-exposed workers to understand the risks they face and their needs for early warnings and working practice changes<br>• Disseminate heat early warnings to employers, labor unions, and heat-exposed workers<br>• Review and improve working practices for heat-exposed government staff and contractors<br>• Strengthen enforcement of occupational health and safety legislation |

*Source:* World Bank elaboration.

**Providing access to cool spaces:** Access to a safe, cool space during peak heat hours can mean the difference between life and death. Vulnerable groups, such as older adults living alone, unhoused individuals, and low-income residents in poorly ventilated homes, often lack this basic protection. Community cooling centers have emerged as a practical solution, offering respite during dangerous heat events.

Access to air-conditioned spaces on high-heat days has been found to reduce the relative risk of death by 66 percent for vulnerable populations compared with those without access.[120] Centers are typically located in existing air-conditioned buildings that are underused during the day, such as libraries, community centers, or places of worship. Most are operated by voluntary and community organizations, with municipalities playing a key role in coordination, public communication, and identifying underserved areas.

A high-profile example comes from Phoenix, Arizona—one of the hottest cities in the world. In 2023, Maricopa County recorded 643 heat-related deaths, up 52 percent from the previous year, with the highest burden among the unhoused population. In response, over 120 cooling centers operated in 2024, primarily hosted and funded by faith-based and community groups, with city and county governments operating centers in high-need areas like libraries. These centers received over 30,000 visits in the 2024 heat season.[121]

**120.** Bouchama, A., Dehbi, M., Mohamed, G., Matthies, F., Shoukri, M. and Menne, B., 2007. *Prognostic factors in heat wave–related deaths: a meta-analysis*. Archives of Internal Medicine, 167(20), pp.2170–2176. **doi:10.1001/archinte.167.20.ira70009**.

**121.** Maricopa County Department of Public Health, 2024. *Heat-Associated Deaths Report: 2023 Annual Summary.* Phoenix, AZ: Maricopa County Public Health. Available at: **https://www.maricopa.gov/1858/Heat-Surveillance**. Kwan, A. (2024). 30,000+ people visit Phoenix heat relief sites as excessive heat continues. *AZFamily*, 30 September. Available at: **https://www.azfamily.com/2024/09/30/30000-people-visit-phoenix-heat-relief-sites-excessive-heat-continues/**.

While Phoenix represents an extreme case in a high-income setting, it illustrates how a well-structured cooling center program can reduce mortality during extreme heat events.

However, experience with cooling centers highlights important barriers that need to be addressed. Some residents may be unaware of the centers, or unwilling or unable to travel to them—particularly those with mobility limitations, caregiving responsibilities, or mistrust of public institutions. Others may face challenges related to restrictive opening hours or find that centers are not adapted to their cultural or personal needs. Addressing these barriers—by working through trusted community groups, expanding hours, and ensuring facilities are welcoming and inclusive—is critical to realizing the full protective value of this intervention. For Europe and Central Asia, where air conditioning remains relatively rare and much of the housing stock is poorly adapted to heat, cooling centers can form a vital pillar of heat-health strategies, particularly if linked to early warning systems and public health outreach.

## 3.3 Adapt Infrastructure for a Hotter Future

The next three strategic actions address the urgent need to adapt critical infrastructure—energy systems, transport networks, and schools—to withstand intensifying summer heat. These interventions can help ensure that services remain reliable, safe, and inclusive in an increasingly hot climate.

### 7. Build Energy Systems' Resilience to Extreme Heat

As summer temperatures climb across Europe and Central Asia, energy systems are under increasing strain. Heatwaves drive up electricity demand—for air conditioning, refrigeration, and water pumping—while simultaneously degrading the performance of energy infrastructure. In countries like Türkiye and across the Western Balkans, electricity demand peaks that once occurred in winter are now shifting to summer. This shift was dramatically illustrated in June 2024, when an early-season heatwave triggered widespread blackouts across Montenegro, Croatia, Bosnia, and Albania, driven by surging demand and declining asset performance.[122]

Extreme heat impairs energy infrastructure in multiple ways. High ambient temperatures reduce the efficiency and capacity of transmission lines, which can sag dangerously or carry less power. Thermal power plants—which still account for a large share of electricity generation across the region—struggle to operate when cooling water becomes too warm or scarce, a pattern observed during past heatwaves in Central and Western Europe.[123] In cities, distribution components such as transformers and substations are particularly

**122.** Reuters (2024) 'Power outage hits Balkan states as heat overloads system, minister says', Reuters, 21 June. Available at: **https://www.reuters.com/world/europe/power-blackout-hits-montenegro-bosnia-albania-croatias-adriatic-coast-2024-06-21/**.

**123.** IEA (2018) Climate Resilience of Energy Systems: Managing the Risks of a Changing Climate. Paris: International Energy Agency.

vulnerable to overheating, with failures often coinciding with peak demand periods when cooling is most critical.

Upgrading infrastructure is essential for resilience. Modernizing the grid by upgrading transmission lines and distribution equipment with heat-tolerant materials is a key starting point for heat resilience of energy infrastructure. But demand-side solutions are equally important. Retrofitting buildings to reduce cooling needs and introducing peak demand management programs—such as time-of-use pricing or smart metering—can help flatten demand curves. Integrating rooftop solar and battery storage can provide emergency backup and reduce strain on the grid.

Adapting energy systems to a hotter climate is not just a technical imperative—it's central to public health, economic stability, and service continuity.[124] Diversifying the energy system with distributed and renewable energy also strengthens resilience. Local generation and storage systems—especially solar microgrids—can improve resilience to transmission failures, but they too require careful design and integration to withstand prolonged heat stress and peak demand. Meanwhile, improved forecasting of both weather and electricity demand can enable pre-emptive actions, such as adjusting generator dispatch or issuing public alerts to reduce peak demand.

**124.** IEA (2021) Empowering Cities for a Net Zero Future: Unlocking Resilient, Smart, Sustainable Urban Energy Systems. Paris: International Energy Agency.

## BOX 3.7 Paris Cools Buildings with River Water instead of Air Conditioning

Like many cities in Europe, Paris has faced extremely hot summers, with temperatures rising as high as 43°C in July 2024. While air conditioning offers short-term relief, its widespread use brings long-term costs. It is energy-intensive, emits waste heat, and contributes to higher urban temperatures—potentially adding up to 1°C to the surrounding air.[125] This creates a feedback loop where hotter temperatures drive more AC use, intensifying both energy consumption and heat pollution.

Following a succession of hot summers, the number of air conditioning installations in Parisian homes rose sharply, from 5 percent in 2005 to 13 percent in 2006[126], likely concentrated among high-income households. AC use can drive low-income households into energy poverty, with households spending 35–42 percent more on electricity when they own air conditioners.[127] Beyond environmental concerns, the adoption of air conditioning poses challenges for urban design, equity, and infrastructure.

Many of Paris's older, historic buildings cannot accommodate large-scale AC installations without compromising architectural heritage. Moreover, as heatwaves strain power grids, cities risk blackouts precisely when cooling is most critical—as seen in June 2024, when high temperatures caused water-pump failures and power outages across the Balkans.

To avoid these pitfalls, Paris is investing in district-scale cooling systems as part of a long-term, sustainable climate strategy. The "Paris Fraîcheur" network, a district cooling system in operation since 1991, offers a compelling alternative. Carbon-neutral since 2018, it draws water from the Seine, chills it at centralized plants, and distributes it via underground pipes to cool more than 2,000 buildings, including hospitals, museums, hotels, and offices. In the winter, the system doubles as a district heating network. By minimizing reliance on individual AC units, it significantly reduces energy use and eliminates the waste heat that contributes to the urban heat island effect.

District cooling also addresses practical concerns. In dense cities like Paris, rooftop space is valuable. Eliminating the need for rooftop cooling units frees space for green roofs, gardens, or solar panels. In 2022, the network cooled over 6 million m$^2$ of interior space across 89 km of underground piping. Paris now plans to expand the system by another 158 km, to serve an additional 2,300 buildings across all arrondissements by 2042. The €75 million investment prioritizes underserved neighborhoods and vulnerable populations, including daycare centers, hospitals, and elderly care homes. The system is financed through a public-private partnership between the city, energy utility ENGIE, and the public transport operator RATP.

The Paris Fraîcheur model demonstrates how infrastructure can leverage natural assets—in this case, river water—to deliver low-carbon, equitable cooling at scale.

**125.** De Munck, Cécile, Grégoire Pigeon, Valéry Masson, Francis Meunier, Pierre Bousquet, Brice Tréméac, Michèle Merchat, Pierre Poeuf, and Colette Marchadier. "How much can air conditioning increase air temperatures for a city like Paris, France?." International Journal of Climatology 33, no. 1 (2013).

**126.** Vincent Viguié et al 2020. Early Adaptation to heat waves and future reduction of airconditioning energy use in Paris. Environmental Research Letters. 15 075006 **Link.**

**127.** Teresa Randazzo, Enrica De Cian, Malcolm N. Mistry, Air conditioning and electricity expenditure: The role of climate in temperate countries, Economic Moelling, Volume 90, 2020. **Link.**

## 8. Integrate Heat Resilience into the Transport Sector

Transport systems are directly affected by rising heat. High temperatures can deform asphalt, buckle steel rails, and cause service delays or cancellations—particularly on aging infrastructure built for cooler conditions. These disruptions not only compromise safety and reliability, but also heighten health risks for passengers and workers.

To strengthen resilience, countries across Europe and Central Asia should update transport infrastructure standards to reflect future climate projections, recognizing that heat already poses safety threats in some places—and any infrastructure built or upgraded today needs to be able to withstand hotter conditions in the coming decades. Materials and design approaches should be updated—for example, by using high-performance asphalt in road resurfacing programs and rail fastenings that can accommodate thermal expansion. Climate risk screening should be a standard requirement for all public investments in transport infrastructure, especially for long-lived capital assets such as highways, bridges, tunnels, and rail lines.

Operational practices also need to adapt. Transport authorities should take stock of hot weather impacts on their assets and service standards and establish protocols to be followed during future temperature extremes. Collaboration with national meteorological agencies can help to establish and implement timely actions during heatwaves. Hot-weather protocols can include increasing the inspection frequency for heat-sensitive infrastructure elements (such as rail tracks, overhead power lines, and signaling equipment), implementing speed reductions when needed, and communicating health advice to passengers and staff (see Table 3.3).

Finally, cities and national governments should prioritize the thermal comfort of passengers as a core service quality issue. Ensuring effective ventilation in public transport vehicles, developing shaded walkways and waiting areas, and mapping and addressing heat hotspots in the transport network are all interventions worth considering.

**Table 3.3** Heat Impacts and Adaptation Measures in the Transport Sector

| | Roads and pavements | Rail systems | Public transport (vehicles and stops) | Passenger and worker health |
|---|---|---|---|---|
| Impacts | Asphalt softening, rutting and buckling<br><br>Roadside fires | Track buckling<br><br>Power line and signaling faults<br><br>Service disruption | Overheating in vehicles and at bus stops<br><br>Negative passenger experience | Heat illness and resulting service disruptions<br><br>Staff absenteeism |
| Solutions | Use asphalt mixes with a temperature performance range suited to the future climate<br><br>Conduct preventative maintenance in summer | Upgrade tracks with materials that tolerate thermal expansion<br><br>Establish hot weather protocols, including increased inspections and go-slow measures<br><br>Shield signaling equipment from heat | Ensure ventilation in buses, trains, and stations<br><br>Add shading or vegetation in high-use areas<br><br>Integrate vegetation and water access | Advise passengers to hydrate and avoid travel if feeling unwell<br><br>Provide shaded rest areas and water for transport workers |

*Source:* World Bank elaboration.

## 9. Prevent Schools Overheating

Excessive heat in classrooms impairs student concentration, reduces attendance, and diminishes learning outcomes. A meta-analysis of 18 studies conducted primarily in temperate climates found that lowering classroom temperatures from 30°C to 20°C can improve students' performance on cognitive tasks by about 20 percent.[128] The optimal temperature for learning was identified as below 22°C. In Europe and Central Asia, many school buildings are decades old and were designed for cold winters, not hot summers. In the decades to come, overheating in schools will become a significant challenge for education.

Governments must prioritize retrofitting schools to protect learning conditions as temperatures rise. Passive design strategies can control indoor temperatures without heavy reliance on air conditioning which, increases operational costs and puts pressure on a sometimes inadequate electricity grid. Policy measures will also be key. Thermal comfort standards should be embedded in school building codes and renovation guidelines, with dedicated funding streams for heat-resilient upgrades. Local education authorities should receive technical assistance to design and implement effective cooling solutions. Pilot projects—such as installing tree-lined courtyards, cool roofs, or ventilated façades—

**128.** Wargocki, P., Porras-Salazar, J.A. and Contreras-Espinoza, S., 2019. *The relationship between classroom temperature and children's performance in school: A systematic review*. Building and Environment, 157, pp.197–204. **https://doi.org/10.1016/j.buildenv.2019.04.042.**

can help build a regional evidence base and encourage wider adoption of successful approaches. Table 3.4 provides examples of design interventions.

National school design guidance should be developed to align educational goals with the design challenges of a warming climate. This includes setting clear standards for ventilation, thermal comfort, and indoor air quality in both new and existing school buildings. Practical precedents exist—such as the United Kingdom's Building Bulletin 101 (which establishes design targets for ventilation rates, indoor $CO_2$ levels, and indoor temperatures) and guidance on integrated schools design from the country's Chartered Institution of Building Services Engineers.[129]

Ensuring that schools remain safe and comfortable during the hottest months is critical to sustaining learning and protecting children's health. As climate change accelerates, education sector resilience planning must include keeping schools cool as a core priority—especially in parts of Central Asia, the South Caucasus, the Western Balkans and Türkiye where the school year will increasingly overlap with periods of extreme summer heat.

**129.** Department for Education (2018) *Building Bulletin 101: Guidelines on Ventilation, Thermal Comfort and Indoor Air Quality in Schools*. London: Department for Education.

CIBSE (2015) *Technical Memorandum 57: Integrated School Design*. London: Chartered Institution of Building Services Engineers.

## Table 3.4 Design Interventions to Reduce Overheating in Schools

| Designing spaces between buildings |
| --- |
| Use trees and landscape planting to provide shading and improve air quality adjacent to school buildings. In areas with cold winters use deciduous tree planting to let sun through in winter. |
| Provide outdoor shading, cooler areas of the landscape, and courtyards for school use and as sources of cooler ventilation air. |
| **Ventilating the interior** |
| Design spaces and interconnections between rooms to encourage natural ventilation being mindful of noise transfer issues. |
| Route air into the interior from spaces that are naturally cooler during the day, such as shaded courtyards and north elevations containing landscape planting and shade. |
| Work to reduce external daytime noise and insect issues around schools which discourage opening windows. |
| Consider use of quiet ceiling fans to provide air movement. |
| Encourage natural cross ventilation through interiors overnight or in early mornings to cool surfaces, ensuring openings are secure and weatherproof. |
| Use internal voids in multi-story schools to encourage natural ventilation from ground up to roof level. |
| **Planning the interior, walls and roofs** |
| Locate the most heavily occupied rooms in areas with the lowest heat gain from the outside. |
| Locate rooms so they catch summertime breeze across the site and benefit from that air movement. |
| Maximize the benefit of north-facing windows and skylights to provide daylight, and insulate these openings in the winter. |
| Shade windows and size them to provide optimum daylight with minimum heat gain and loss. Consider the use of screens and shading to reduce solar gain and provide privacy and security. |
| Use reflective colors on walls and roofs and encourage the use of breathable natural wall materials |
| Consider the use of low energy mechanical ventilation with heat pumps in buildings where the air tightness and ventilation levels can be tightly controlled. |
| **Renovating existing schools or converting buildings into schools** |
| Consider which new build strategies to reduce heat gains may be possible to adapt to utilise in the renovation. |
| Preparing design advice |
| Develop national school design guidance to advocate solutions to avoid overheating through passive design and active measures. |

*Source:* World Bank elaboration.

## BOX 3.8 From Tradition to Policy—Lessons from Vernacular Architecture

Design strategies that keep buildings cool have long existed across Europe and Central Asia. Shaped by local culture, climate and materials, these traditional approaches—collectively known as vernacular architecture—offer valuable lessons for managing summer heat.

Mid-20th-century buildings often ignored the design principles that can be observed in traditional buildings, relying instead on cheap energy for heating and cooling. These time-tested approaches offer inspiration for building design and insights for policy makers looking to improve housing performance without reliance on mechanical cooling.

**Ukrainian** houses were typically designed with an overhang to provide shading in summer, small windows and walls are carefully composed of locally sourced materials. The manzaka house featured a timber frame, thick earth-straw walls, clay plaster, and a thatched roof, designed to retain warmth in the winter and shield against the sun in the summer.

Protection from the heat of the summer sun is the main design driver for this madrasa (school) in Khiva, **Uzbekistan**, has a large entrance overhang, screens across windows, and a deep upper floor terrace all creating more comfortable spaces and shading walls.

In **Türkiye**, neighborhoods are cooled by trees and building configurations that allow natural breezes to flow. Vernacular construction incorporates materials with high thermal mass, such as brick, stone, and earth, which are highly effective for passive cooling methods like night cooling. Design features such as projections, eaves, awnings, shutters, and window screens significantly reduce heat gain, minimizing overheating in the summer.

Balconies, courtyards, and staircases are essential elements of **Georgia**'s vernacular architecture. In the 1990s, Soviet-era buildings in Tbilisi, which lacked insulation and ventilation, were enhanced with features such as balconies, patios, and semi-outdoor extensions. These additions improved thermal comfort and energy efficiency in both summer and winter, while creating new usable spaces.

The St. Jovan Bigorski Monastery in Mavrovo, **North Macedonia**, uses roof overhangs and small windows to keep the facades cool and then opens up the top floors with large openings to encourage cross ventilation from breezes above the forest.

*Photo credits:* © Perediankianka / iStock; © Anton Andreev / iStock; © Gokhan Sevim / iStock; © Dvornyk / iStock; © Dronesmedia / iStock

## 3.4 Mainstream Heat Resilience into Institutions

The final strategic action highlights how governments can embed heat resilience into core strategies, institutional mandates, and annual planning cycles. It underscores the importance of leadership, coordination, and sustained investment to scale and sustain impact over time.

### 10. Integrate Heat Resilience into Strategies, Operations and Budgets

The burden of extreme heat in Europe and Central Asia will only increase in the coming decades. National and city administrations in other regions have increasingly adopted "whole-of-government" responses to this challenge, including appointing Chief Heat Officers to lead on mainstreaming heat resilience across existing strategies and operations. In Europe and Central Asia, sustained action on heat resilience will enable cities to thrive despite rising temperatures.

A good first step for city or national leaders who are beginning to address heat risks might be to appoint an extreme heat task force to review evidence, gather and analyze data, consult affected groups, and recommend actions. Having initiated such a process, additional steps can include strengthening institutional and leadership mandates for heat resilience, integrating into national adaptation and sectoral strategies, revising urban planning instruments, aligning actions with available funds, and establishing monitoring mechanisms.

Leadership is crucial for heat resilience, which requires engaging a wide range of stakeholders in both the public and private sectors: from urban planning, health and meteorological departments to real estate developers, doctors, and citizen groups. Governments should assign a clear institutional lead for heat risk management, both nationally and locally. Responsibilities should include driving increased attention to heat resilience in the core operations and budgeting of government agencies, coordinating efforts before and during heatwaves, and reporting on progress.

Embedding heat resilience into national policy frameworks is an important step. National adaptation plans, national climate change frameworks, and sector strategies for health, education, housing and transport should identify priority actions and investment needs to reduce the health, economic and infrastructure impacts of extreme heat in future decades, thereby enabling coordinated action across ministries and levels of government. Since extreme heat impacts are seasonal with impacts concentrated in the hottest months, establishing an annual heat risk management cycle is important. Establishing goals and monitoring mechanisms for heat resilience can help ensure that these efforts produce results as cost effectively as possible.

## BOX 3.9 How the EU is Helping Cities Manage Urban Heat and Build Climate Resilience

### Emergency Response Coordination Centre: Surveillance and preparedness

The Emergency Response Coordination Centre (ERCC) plays a pivotal role during heatwave emergencies by monitoring conditions, issuing early warnings, and mobilizing resources such as medical teams and firefighting support. It ensures cooperation among EU countries to protect vulnerable populations. For instance, during the 2019 European heatwave, it activated its network to assist countries such as France and Italy, which faced extreme temperatures reaching up to 42.6°C in Paris. This coordination helped manage health risks and wildfires exacerbated by the heat.

### Tackling the urban heat island effect

The EU's Joint Research Centre is driving efforts to combat urban heat in European cities by equipping policy makers and urban planners with knowledge and tools to develop effective strategies for urban heat. The JRC's detailed policy guides and webinars with experts help cities implement practical, evidence-based solutions, including nature-based solutions, urban planning adjustments, and technological innovations to mitigate heat risks.

### Climate-ADAPT: A one-stop resource for cities

In partnership with the European Environment Agency, Climate-ADAPT provides cities with policies, data, and hands-on solutions like the URBACT program and Urban Innovative Actions, an adaptation toolkit to help local governments reduce the effects of increased heat on their communities through green infrastructure and building design. The program's Thermal Assessment Tool (TAT) helps cities visualize past and future heatwaves in Europe, enhancing understanding of heat risk and facilitating adaptation planning. Importantly, the platform helps align local efforts with EU policies and funding opportunities and serves as a central hub for knowledge sharing where cities can learn from each other and access expert guidance on heat adaptation.

### The European Urban Initiative (EUI): Cooling cities with nature

The EUI funds projects that boost urban greenery, helping cities combat air pollution, enhance biodiversity and protect citizens from rising temperatures. By supporting pilot projects and large-scale implementations, the initiative helps cities experiment with solutions like vertical gardens, climate resilient street design, and water-sensitive urban planning. In Athens, the Cooling Havens Project installs water-powered cooling spaces, while Amsterdam's RESILIO smart blue-green roofs cool social housing and manage rainwater.

### Destination Earth (DestinE): A digital model for smarter planning

The Destination Earth (DestinE) project is supporting cities in addressing urban heat by creating high-resolution digital twins of the planet. These advanced simulations help urban planners to analyze and predict extreme heat events with greater accuracy, helping cities to test data-driven decision-making. By integrating real-time climate data, DestinE enables cities to fine-tune heat resilience plans, optimize green infrastructure, and enhance emergency responses.

# 4 Getting It Done: Achieving Heat Resilience at Scale

As cities across Europe and Central Asia brace for more frequent and severe extreme heat events, the focus must shift from planning to execution. Section 3 laid out 10 strategic actions spanning places, people, infrastructure, and institutions. This section turns to the question of how, providing six cross-cutting recommendations on how to align mandates and financing across different levels of government, overcome institutional bottlenecks, and build on what cities are already doing.

Section 4.1 examines the governance architecture behind effective urban heat response—clarifying who leads, where mandates lie, and how institutions can be structured to drive action. Section 4.2 then turns to the systems, policies, and financing tools needed to embed heat resilience into planning, budgets, and service delivery at scale. Annex 1 packages the insights from Sections 3 and 4 into summary tables.

## 4.1 Who Leads? Governance for Heat Resilience

The impacts of extreme heat are hyperlocal: a difference in tree cover between two adjacent streets can translate into a temperature gap of several degrees; a shaded schoolyard may be habitable during a heatwave, while an unshaded one becomes dangerous. In much of the region, subnational governments—particularly municipalities—find themselves at the frontlines of rising heat risks, so they require the fiscal authority, flexibility, and financing to enable them to act.

## Clarify National vs. Local Mandates and Align Resources

Many of the most effective heat adaptation measures—retrofitting housing, installing reflective surfaces, expanding green infrastructure, adjusting building codes, and protecting vulnerable populations—fall squarely within the jurisdiction of local governments. However, a persistent challenge in urban climate adaptation is the misalignment between the responsibilities municipalities carry and the resources they control.[130] This mismatch results in local authorities being tasked with implementing adaptation strategies without adequate financial support or authority, often leading to ineffective implementation.[131] Local authorities often depend on intergovernmental transfers or project-based funding from national budgets, which may not be timely, flexible, or sufficient to support heat-related investments. Moreover, metropolitan regions face governance challenges, where overlapping jurisdictions and fragmented responsibilities exacerbate the difficulties in executing coherent adaptation plans.[132]

A recent World Bank analysis of adaptation readiness[133] across the region found that less than a quarter of European and Central Asian countries give subnational governments adequate fiscal and functional autonomy to lead urban adaptation efforts. Municipal capital budgets are often constrained, and in many cases, earmarked for pre-approved sectors that may not align with local heat risks. Moreover, while some national governments have sectoral adaptation plans, these rarely include implementation mandates or resource channels for cities and towns.

Moreover, reducing urban heat exposure is a highly distributed task: it depends on many institutions, each performing their part. National governments may provide funding or legal frameworks; subnational authorities often lead implementation; utilities and service providers ensure functionality; and civil society or the private sector can offer innovation, financing, or reach. Rather than assigning responsibility to a single actor, successful cities clarify who is responsible for what function, and then align mandates, financing, and capabilities accordingly. Table 4.1 identifies the level of government at which each of the 10 strategic actions would typically be implemented—and the roles of other levels—as well as other actors likely to be involved.

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**130.** Rogers, N., Adams, V. and Byrne, J. (2023) Factors affecting the mainstreaming of climate change adaptation in municipal policy and practice: a systematic review. Climate Policy, 23: 10. **https://www.tandfonline.com/doi/full/10.1080/14693062.2023.2208098.**

**131.** Oettle, N. (2019) Map vs territory: tackling the mismatch between adaptation policy and on-the-ground experience. **https://www.iied.org/map-vs-territory-tackling-mismatch-between-adaptation-policy-ground-experience.**

**132.** Nocentini, M.G. (2024) The governance of climate adaptation in metropolitan regions: a systematic review of emerging themes and issues. Urban Climate 55. **https://www.sciencedirect.com/science/article/pii/S2212095524001408**

**133.** Cities Climate Finance Leadership Alliance (CCFLA) (2022). State of Cities Climate Finance Report. Climate Policy Initiative. **https://www.climatepolicyinitiative.org/wp-content/uploads/2022/09/CCFLA-State-of-Cities-1.pdf.**

**Table 4.1** Who Should Do What? Responsibilities across 10 Strategic Actions

| Strategic Action | National Government | Regional / Provincial | Municipal Government | Other Actors |
|---|---|---|---|---|
| 1. Advance urban greening through strategic planning | Enabling | Shared | Primary | NGOs, developers, utilities |
| 2. Harness wind, shade, and design for cooler cities | Enabling | Shared | Primary | Architects, urban designers, private sector |
| 3. Tackle indoor heat through building upgrades | Enabling / primary (regulation, subsidies) | Shared | Shared / primary (implementation) | Landlords, housing associations |
| 4. Strengthen heat early warning and response systems | Primary (meteorological & health coordination) | Shared | Shared | National meteorological agencies, media |
| 5. Build health system readiness for extreme heat | Primary | Shared | Limited | Hospitals, health networks |
| 6. Protect heat-exposed workers and residents | Primary (labor laws, social protection) | Shared | Shared / enabling | Employers, trade unions, CSOs |
| 7. Build energy systems resilience to extreme heat | Primary (regulation, investment) | Shared | Enabling | Utilities, grid operators, regulators |
| 8. Integrate heat resilience into the transport sector | Primary (standards, major infrastructure) | Shared | Shared / enabling | Transit authorities, engineers |
| 9. Prevent schools overheating | Shared / primary (funding & regulation) | Shared | Shared / enabling | School boards, parent associations |
| 10. Integrate heat resilience into strategies and budgets | Primary | Shared | Shared | Finance ministries, audit bodies |

*Legend*

**Primary =** Holds main responsibility for financing, policy, or execution
**Shared =** Responsibilities are divided, often through co-financing or joint planning
**Enabling =** Supports through funding, standards, capacity building, or data
**Other Actors =** Non-government stakeholders playing operational or support roles

## Create an Institutional Home for Heat Action

Heat kills—but no one agency is responsible for preventing it. That's why extreme heat risk often slips through the cracks of city and national governments. Without a clear institutional home, heat resilience efforts tend to be fragmented, underfunded, or reactive.

Yet building resilience requires action from a wide cast of actors: planning and parks departments, transit operators, school boards, health systems, social care agencies, and meteorological services. Few existing structures are designed to bring these actors together. To close this gap, governments need to create visible, empowered institutional mandates for heat—whether by embedding responsibilities into existing agencies or by establishing new leadership structures altogether.

Cities are increasingly stepping up their responses. In 2021, Athens became the first European city to appoint a Chief Heat Officer. Other global cities as diverse as Seoul; Santiago, Chile; and Melbourne have launched legislative commissions, task forces, or inter-agency platforms to address heat. These models differ, but they share a common goal: turning heat resilience from a peripheral concern into a core public responsibility.

To support the design or strengthening of institutional mandates, decision-makers can use the following checklist to assess whether key enabling factors are in place:

- ☑ **Mandate clarity:** Does the lead institution have the authority to coordinate action across sectors?
- ☑ **Political backing:** Is the leadership (mayor, minister) visibly endorsing the effort?
- ☑ **Operational capacity:** Does the unit have staff, budget, and technical support?
- ☑ **Cross-sector reach:** Are transport, housing, and health actors meaningfully involved?
- ☑ **Public communication:** Is the institution able to engage residents and stakeholders?
- ☑ **Monitoring and accountability:** Are progress indicators or mandates formally tracked?

Decision-makers may also need to weigh different institutional formats when determining how best to lead and coordinate heat action. Several governance models are already in use, each with distinct functions, lead actors, strengths, and limitations (see Table 4.2).

**Table 4.2 Institutional Approaches to Heat Governance—Options and Trade-Offs**

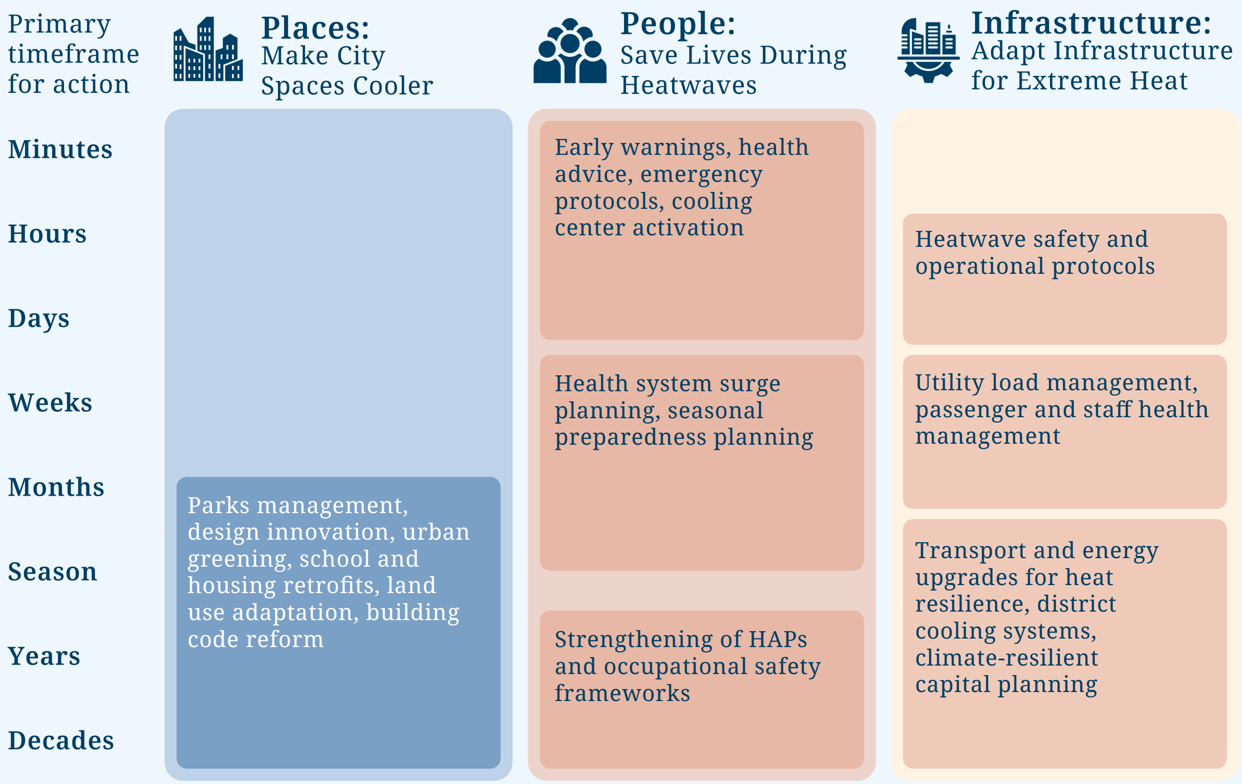
| Model | Function | Typical Lead Actor | Strengths | Limitations |
|---|---|---|---|---|
| Chief Heat Officer | High-level coordination, advocacy, visibility | Mayor's office or city executive | Clear leadership, public visibility | Needs mandate and resources to be effective |
| Heat Resilience Task Force | Multi-agency coordination, planning, or response | City manager or emergency department | Cross-sector reach | Risk of duplication or unclear authority |
| Embedded in Existing Unit | Added responsibilities for emergency management, urban planning or health units | Line ministry or city department | Leverages existing capacity | May lack profile or cross-sector reach |
| Parliamentary Commission | Review, inquiry, and recommendations | Legislative body | Elevates political attention | Limited operational role |
| Informal Inter-Agency Group | Coordination of implementation across departments | Planning or resilience unit | Flexible, low-cost | Depends on informal authority |

*Source:* World Bank elaboration.

## Integrate Short- and Long-Term Actions

Preparing for extreme heat requires interventions to cool urban spaces, make infrastructure resilient, and save lives during hot days, but, as shown in Figure 4.1, these actions differ in their implementation timeframes. Accordingly, city and national authorities need to team up to deliver comprehensive heat resilience strategies that integrate short-, medium-, and long-term actions.

**FIGURE 4.1** Timeframes for Key Heat Resilience Actions



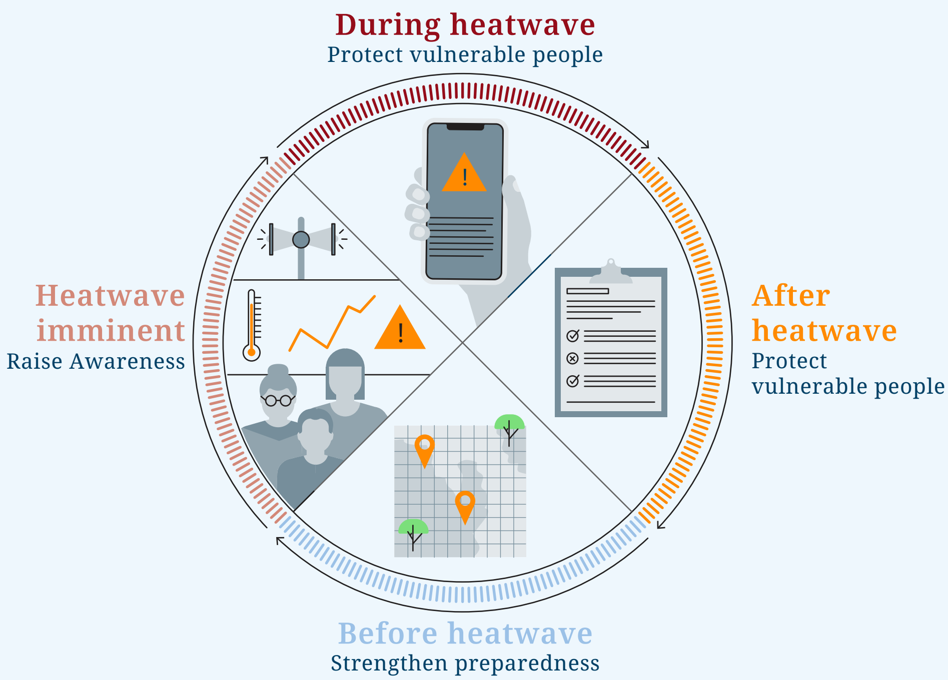

*Source:* World Bank elaboration.

Heat action plans have proven an effective way to integrate heat resilience interventions on different time scales. After the devastating 2003 heatwave in Western Europe, examples like the Heatwave Plan for England helped bring together long-run urban greening and urban design actions with near-term emergency management of heatwaves, helping to bring mortality levels in subsequent heatwaves below levels that would otherwise have been expected.[134]

In other world regions, countries such as India, Japan, and Chile increasingly issue color-coded alerts accompanied by health advice and activate emergency management protocols when dangerous temperatures are imminent. Ahmedabad's Heat Action Plan, which has served as a model for such plans across India, integrates short-term actions during heatwaves with long-term measures across several sectors, including strengthening the readiness of health systems and the quality of hospital and local clinic treatment for heat stroke cases, as well as long-term investments for cooler city spaces, like the planting of fast-growing "Oxygen Parks."[135]

Because hot weather follows an annual seasonality, heatwave preparedness and response should also follow an annual seasonality, strengthening preparedness in the run-up to the hot season, activating protocols when a heatwave is imminent, acting to protect the vulnerable during extreme heat events, and conducting after-action reviews before recommencing the cycle (see Figure 4.2).

**FIGURE 4.2** **The Heat Wave Risk Management Cycle**




*Source:* World Bank elaboration.

**134.** Kovats, R.S., Johnson, H., Griffiths, C., Devine, G., & Newton, A. (2019). *Evaluation of the Heatwave Plan for England: Final Report.* London: Public Health England. Available at: **https://piru.ac.uk/assets/uploads/files/evaluation-of-the-heatwave-plan-for-england-final-report.pdf.**

**135.** Hess, J. J., Saha, S., & Luber, G. (2018). *Pilot evaluation of the impact of India's first heat action plan on all-cause mortality in Ahmedabad, India.* Environmental Health Perspectives, 126(5), 057008. **https://doi.org/10.1289/EHP3063.**

As the review of heat policies in Europe and Central Asia conducted for this study showed, effective measures to respond during the active heat emergencies—i.e. on a timeframe of hours and days instead of years and decades—is currently lacking in many cases. Heat alert and response systems proved one of the most effective tools deployed by Western European countries after the deadly 2003 heatwave. Adopting or strengthening such mechanisms should be a top priority as the region faces growing extreme heat risks. Integrating both short-term and long-term actions to save lives while making spaces cooler and infrastructure heat-resilient will yield major benefits.

## 4.2 How to Deliver? Embedding Heat Resilience in Systems and Budgets

### Integrate Heat Risk into Plans, Codes, and Budgets

Making heat resilience a routine part of government planning and delivery requires more than stand-alone strategies. It calls for integrating heat considerations into the systems that guide long-term investment, regulate the built environment, and allocate public resources. Yet across Europe and Central Asia, these systems often fail to reflect the rising threat of extreme heat.

At the national level, many countries now include climate adaptation goals in national development or sectoral strategies. However, explicit attention to urban heat remains limited. Few national adaptation plans (NAPs) set out actionable measures to reduce exposure to extreme temperatures in cities—let alone funding frameworks or mandates for implementation. Heat resilience must be more clearly reflected in the plans and budgets of key sectors, including health, housing, education, and infrastructure sectors such as energy and transport.

Urban planning systems and building codes also need urgent revision. Many of the region's design standards were developed for cold climates and now risk locking in exposure to summer heat. Incorporating passive cooling, thermal comfort thresholds, shading requirements, and ventilation standards into building regulations can help ensure that new development is future-ready (see Box 4.1). Renovation guidelines and procurement rules should also reflect the imperative to reduce overheating risk in public buildings, especially schools and health facilities.

Mainstreaming heat into budgets is equally critical. Most municipal and sector budgets do not earmark resources for cooling interventions, and few national systems track heat-related spending or outcomes. Governments can embed heat into public investment management systems by incorporating climate risk screening into project appraisal, creating budget lines for heat adaptation, and linking funding to performance time-bound targets such uptake of weatherization subsidies or expanded urban tree cover.

## BOX 4.1 The UK's New Building Regulations: A Model for Managing Heat Risks

In countries where building standards have historically focused on cold-weather performance, there is growing recognition that improved insulation and airtightness can inadvertently increase the risk of overheating in summer. The United Kingdom, once considered a cool-climate country, has experienced a rise in summertime indoor heat risk, particularly in new homes with large windows, limited shading, and poor ventilation.

In response, new building regulations introduced in 2022 require that all new dwellings demonstrate compliance with specific overheating risk criteria.[136] The standard focuses on design-stage interventions such as window orientation, shading, ventilation, and thermal modeling.

These measures are now mandatory for building code compliance, with implementation shared among architects, engineers, and local authorities. The policy prioritizes passive cooling and good design before mechanical systems are considered. Implementation is distributed across architects, engineers, and local authorities.

### Required Actions to Comply with the UK's 2022 Overheating Standard

| Action | Purpose | Primary Responsibility |
|---|---|---|
| Thermal modelling | Identifies and quantifies overheating risks | Architects or building designers |
| Window design assessment | Evaluates amount, size, orientation, and operability for cooling | Architects, reviewed by building control |
| Solar control measures | Reduces solar heat gain using glazing or shading | Architects/specifiers; implemented by builders |
| Layout adjustment | Optimize cross-ventilation and airflow | Architects, planners |
| Consideration of external factors | Ensures operable windows are feasible despite noise/security issues | Designers in consultation with local authorities |
| Mechanical ventilation recommendation | Suggest low-energy systems to improve comfort | Mechanical engineers |

*Source:* UK Building Regulations Part O (2022) and associated government guidance.

Integration of the new overheating standard (known as "Part O") into the UK's national building code offers a valuable policy model for other countries facing a rising challenge of indoor overheating. By mandating passive design strategies early in the building process, governments can reduce overheating risk, improve occupant health, and avoid locking in long-term reliance on mechanical cooling.

**136.** HM Government (2022) Approved Document O: Overheating – Mitigation of Overheating in New Residential Buildings. London: Ministry of Housing, Communities and Local Government. Available at: **https://www.gov.uk/government/publications/overheating-approved-document-o**.

## Finance Heat Resilience at Scale

Even where city leaders are motivated and technically equipped, adaptation to extreme heat often comes down to a single unresolved question: Who pays? Unlike floods or earthquakes—where immediate capital is needed for rebuilding physical infrastructure—heatwaves are a people-centered hazard. Their costs are borne through excess mortality, illness, and lost productivity, making the case for financing preparedness, not just response.

The investment profile for heat resilience is unique. Funding is needed not just for capital-intensive upgrades—such as building retrofits or green infrastructure—but also for long-term operational continuity, including staffing, maintenance, and public outreach. While early warning systems and heat action plans are comparatively inexpensive, their effectiveness hinges on having dedicated staff to run forecasts, activate services, and coordinate across sectors. Ensuring permanent public health and emergency staff roles within municipal systems may cost little—but deliver lifesaving returns.

At the same time, the largest single financing need is building adaptation. Cooling the existing building stock—whether through green roofs, insulation, ventilation upgrades, or passive design—is essential to reducing indoor heat exposure. These upgrades require a mix of financing instruments, including, targeted subsidies and concessional loans to retrofit public buildings, schools, and hospitals, tax incentives or rebates for private landlords and homeowners to install cool roofs, shade elements, or reflective surfaces, and green building mandates and codes, combined with enforcement and financial support to avoid penalizing lower-income groups.

Despite these needs, however, less than a quarter of countries in Europe and Central Asia give subnational governments enough functional and fiscal autonomy to lead climate action.[137] The fiscal challenge is particularly acute in Central Asia. While cities such as Tashkent and Almaty face rising temperatures and demand for greener, cooler infrastructure, most local governments rely heavily on intergovernmental transfers and have little discretion over capital investments.[138] Kazakhstan's regional governments, for instance, control just 10 percent of total public investment, and local governments even less. Tajikistan and Kyrgyz Republic, meanwhile, face both fiscal constraints and high exposure to heat-related health risks, especially in fast-growing peri-urban areas. In these contexts, adaptive capacity is often undermined by fragmented budgets, unclear mandates, and the absence of performance-based funding models.

Despite these challenges, emerging financial mechanisms offer pathways to support city-level adaptation to heat. These include climate-informed intergovernmental transfers—

**137.** World Bank. 2021. The State of Cities Climate Finance Part 2: The Enabling Conditions for Mobilizing Urban Climate Finance. Link: **https://documents1.worldbank.org/curated/en/602521626243370465/pdf/The-State-of-Cities-Climate-Finance-Part-2-The-Enabling-Conditions-for-Mobilizing-Urban-Climate-Finance.pdf.**

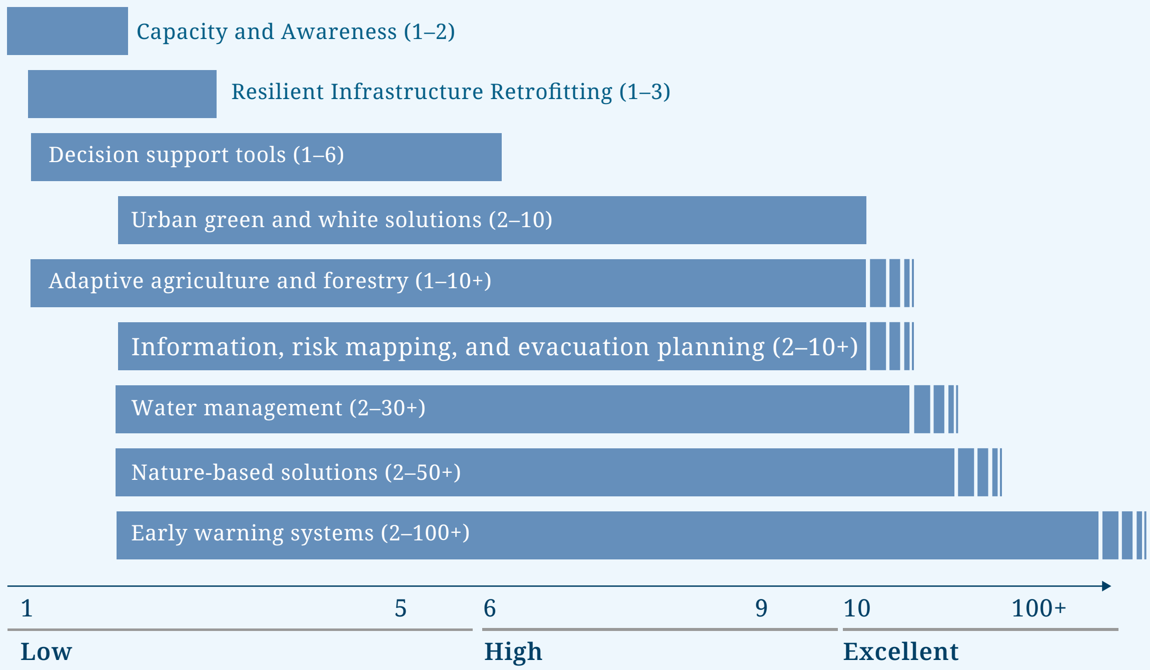
**138.** Huang, CY, Eisenberg, R, and Velasco, G. 2025. Reimagining Central Asian Cities for a Resilient and Low-Carbon Future. World Bank. Link: **http://hdl.handle.net/10986/42821.**

performance-based grants that can incentivize local governments to integrate climate considerations into their planning. Programmatic investment platforms can also allow for blending of donor support with national co-financing, allowing for greater mobilization of resources for urban adaptation projects. The Central Asia Water and Energy Program (CAWEP) has facilitated such multisector diagnostics to identify infrastructure needs related to heat resilience in cities across the region. Climate resilience scorecards or heat vulnerability indices can also help municipalities to prioritize investments.[139] These can be supplemented with private and blended capital, including green bonds, public-private partnerships, and impact investing, or with community-based solutions, such as pooled financing or microinsurance for vulnerable populations. Finally, blending these tools into coherent finance strategies is critical. Heat resilience cannot rely on project-by-project funding alone. Cities need predictable, flexible funding tied to performance—supported by scorecards, investment pipelines, and national policy mandates.

A rapid review of 60+ global case studies was carried out, which suggests that several heat adaptation measures deliver strong economic returns. Heat Early Warning Systems (HEWS), urban greening, and cool roof treatments are the most commonly implemented, with HEWS showing the highest benefit-cost ratios (BCRs), ranging from 11 to over 1800—though these vary depending on assumptions and valuation methods. Other measures with consistently high BCRs include labor protection strategies (7.1–50), information and monitoring services (1–36), and urban greening (up to 19.8). By contrast, measures targeting critical infrastructure, such as heat-resilient power lines or rail systems, often return BCRs below 1, suggesting they may not generate net benefits under current cost structures. These findings highlight the importance of prioritizing people-centered and preventive investments, particularly those that protect health, productivity, and urban livability at relatively low cost. See Figure 4.3 for a summary of BCR estimates across selected heat adaptation options.

**139.** World Bank and UN Capital Development Fund. 2024. Local Governments climate finance instruments – global experiences and prospects in developing countries. Link: **https://documents1.worldbank.org/curated/en/099041224090039327/pdf/P176128-08717094-191a-4353-ae09-b1c089264caf.pdf.**

**FIGURE 4.3 Benefit-cost Ratios of selected heat adaptation measures**




*Source:* Team review based on rapid assessment of 60+ case studies worldwide.

## Use Data, Evidence, and Early Wins to Drive Momentum

Experience around the world shows that data, evidence, and quick, visible wins are critical to getting heat resilience efforts off the ground. Often these efforts begin with a handful of individuals working with limited budgets and institutional support. City teams have found that collecting data on heat risks—alongside small-scale pilot projects—can demonstrate feasibility and build the case for larger investments.

In Miami, for example, the creation of the world's first Chief Heat Officer role helped launch an evidence-based approach that combined resident surveys, consultation meetings, and spatial analysis of heat exposure and vulnerability.[140] These efforts revealed how impacts varied by neighborhood and demographic group, strengthening the case for targeted interventions. As a result, city leaders committed to time-bound goals to expand shade and vegetation, provide financial support for home cooling improvements, and upgrade emergency shelters.[141]

**140.** Gilbert, J., Treuer, G., Pate, J., Makayev, B., & Gassman, S. (2024). *Rapidly developing a community- and evidence-based heat action plan: Lessons from Miami-Dade County, Florida.* Bulletin of the American Meteorological Society, 105(5), E789–E798. **https://doi.org/10.1175/BAMS-D-23-0055.1.**

**141.** Miami-Dade County (2022). *Miami-Dade County Heat Action Plan.* Office of Resilience, Miami-Dade County, Florida. Available at: **https://www.miamidade.gov/environment/library/2022-heat-action-plan.pdf**.

City–university partnerships are a recurring feature of effective heat resilience strategies. These collaborations bring critical technical expertise—in climate science, geography, and epidemiology—and help translate evidence into targeted, locally relevant actions. This model is already in use in Europe and Central Asia. Cities such as Novi Sad, Ljubljana, and Zagreb have worked with universities to map heat exposure using sensors and satellite data, while in Warsaw, studies have explored how older residents experience extreme heat, providing insights to inform planning and outreach.[142]

Alongside formal research, participatory methods have proven particularly valuable in addressing extreme heat. Community surveys, workshops and citizen science initiatives can improve the design of heat resilience interventions by revealing exposure patterns, coping challenges, and intervention opportunities that desk-based studies can overlook. These approaches also help generate public visibility and ownership by drawing attention to an often-invisible risk. Citizen-led heat mapping campaigns in the Western Balkans, for example, have helped cities identify areas of need and prioritize cooling interventions (see Box 4.2).

Building resilience to extreme heat is not a one-time effort—it requires continuous learning. Cities need systems in place to track what is working, where gaps remain, and how interventions can be improved. Monitoring health outcomes during heatwaves is particularly important. Public health authorities can play a key role by tracking indicators such as excess mortality and heat-related illness, helping decision-makers assess whether protective measures are having the intended impact. Evaluating how residents use cooling centers and shaded spaces, and gathering feedback from infrastructure users, can also inform adjustments. Embedding this evidence into decision-making—through annual reviews, budget processes, or public reporting—ensures that heat resilience measures are not only implemented, but continuously improve.

**142.** Savić, S. et al. (2022). *Urban Climate Lab: Local-scale UHI assessment in Novi Sad. University of Novi Sad.*

Perko, D. et al. (2016). Urban Heat Island in the Ljubljana City. *ResearchGate*. Available at: **https://www.researchgate.net/publication/307523282.**

Keković, I. et al. (2023). Surface Urban Heat Islands in Zagreb using Landsat 8 Data. *Sustainability,* 15(5), 3963. **https://doi.org/10.3390/su15053963.**

Kordasiewicz, A. et al. (2022). *EmCliC Project – Embodying Climate Change: Transdisciplinary Research on Urban Overheating.* University of Warsaw. Available at: **https://www.migracje.uw.edu.pl/projects/emclic-embodying-climate-change.**

## BOX 4.2 Shaping Cooler Cities through Citizen Science in the Western Balkans

In the summer of 2003, more than 50 local residents of Tirana, Vlora, and Shokra (Albania), as well as Sarajevo and Mostar (Bosnia-Herzegovina) took part in a citizen science heat mapping campaign.[143] The initiative provides a model for how engaging residents in urban planning can yield actionable datasets and identify targeted, locally supported actions to enhance resilience to extreme heat.

### Methodology: Vehicle-based heat mapping

To develop the heat maps, researchers at local universities recruited volunteers for a series of one-day field based measurement campaigns. The volunteers fitted temperature sensors to their cars, then drove pre-planned routes across the cities, taking one measurement per second. More than 50,000 measurements of near-ground air temperature and humidity were conducted in three separate vehicle traverses (conducted at 7–8 a.m., 12–1 p.m., and 5–6 p.m.).

### Same city, different climate: Temperature disparities

Thermal disparities between neighborhoods were striking. In Albania, the difference between the hottest and coolest neighborhoods reached 6.5°C in Shokdra, 6.4°C in Vlora, and 4.3°C in Tirana. Temperature disparities reached 8.2°C in Mostar and 7.4°C in Sarajevo. Across all five cities, temperatures were higher in areas with a greater density of asphalt, concrete, and other impervious surfaces and lower in areas with more green cover.

Hotter areas partly aligned with income disparities: residential areas with more expensive single-family homes were generally cooler, while areas with densely clustered apartment blocks and no vegetation were hotter. Dense city-center locations where commerce, retail, office jobs, and tourism are concentrated were also hotter.

### Identifying design interventions

After mapping city heat through vehicle-based sensors, the citizen science volunteers turned to identifying cost-effective actions to reduce the adverse impacts of heat based on technology and their local knowledge. Using thermal imagery cameras, participants documented hot spots—their impacts on daily life—at the street level.

The exercise identified local assets to preserve and build on. In Tirana, participants noted how broad-leafed trees in local parks provided deep shade where elderly people were resting and socializing. A riverside plaza in Mostar's Old City provided an appealing environment for residents and visitors.

Participants also identified opportunities to upgrade spaces where excessive heat detracted from comfort and health. The recommendations included changing heat-trapping ground materials in a playground near dense housing developments where heat stress made play and exercise less feasible for children; adding shade and greenery to high-traffic pedestrian routes; and improving the design of bus stops and commercial areas, including those where street vending takes place.

### Building a 'cool city coalition'

Following the heat mapping campaigns, city leaders, including the mayor of Tirana, helped publicize the findings through video and social media messages. Interactive web maps of the temperature datasets and design recommendations were shared with local stakeholders and media. The increased awareness of heat challenges and localized solutions helped accelerate steps to make the cities cooler.

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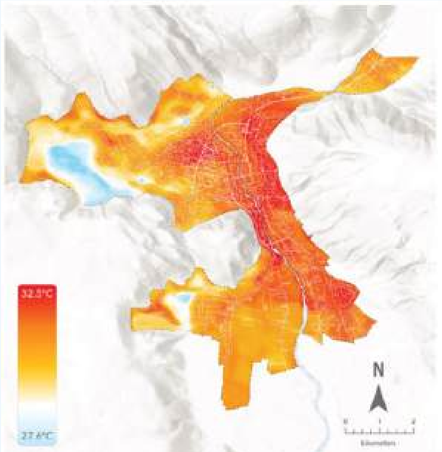
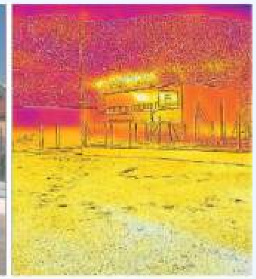
**143.** See Heat Watch Albania (**https://storymaps.arcgis.com/stories/0acc8804f35e4ca9b907bb93e0f1d11c**) and Heat Watch Bosnia-Herzegovina (**https://storymaps.arcgis.com/stories/cae76ed8572747ada2a52bd9c0c39cde**) .

## MOSTAR
Heat map (August 23,2023)



**14,171** Measurements | **40.7°** Max Temp (°C) | **8.2°** Temp Differential (°C)

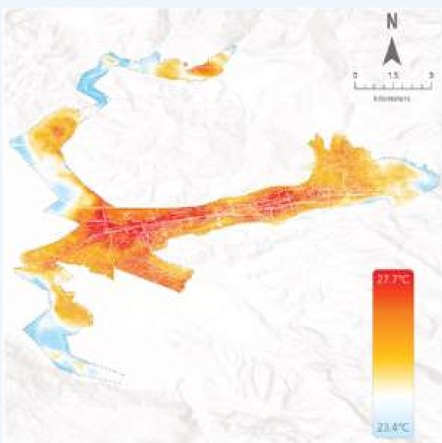
Priority location
### Children Playground



**Observation**
Lack of shade and greenery, too hot for children to play.

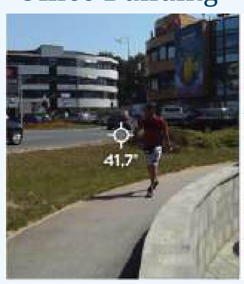
**Recommendations**
Changing the materials of the playground and planting trees.

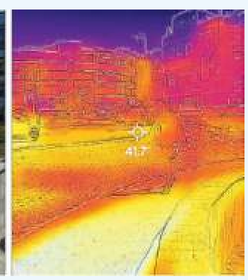
## SARAJEVO
Heat map (August 23,2023)



**19,329** Measurements | **34.5°** Max Temp (°C) | **7.4°** Temp Differential (°C)

Priority location
### Office Building




**Observation**
Dense urban area with office buildings. Pedestrian avoid route or walk fast

**Recommendations**
Increase green areas and shade

Citizen science volunteers in Albania (left) and Bosnia-Herzegovina (right)

# 4.3 Conclusion

Extreme heat is not a lurking threat. It is here, now, reshaping how cities function, how economies grow, and how people live and work. The longer cities delay adapting, the more expensive and painful it will become. Fortunately, the economics of early action are compelling. Investing in cooler streets, greener neighborhoods, smarter grids, and resilient infrastructure is not merely about survival—it is an opportunity to create better cities. Cities that are cooler are also more livable, more competitive, and more equitable.

Urban heat is a local challenge with local solutions. The experience of successful cities shows that building resilience is achievable, and that delay only compounds the costs. To avoid escalating losses in health, productivity, and infrastructure, action must accelerate. Every city, regardless of size or income, has tools it can deploy today.

The choice is clear: build heat-resilient cities now, through foresight and investment, or be forced to rebuild them later, through crisis and loss. The future belongs to those who prepare for it. Europe's and Central Asia's cities must move swiftly—and choose wisely.

# 5 Annexes

## Annex 1

### From Stocktaking to Action on Urban Heat

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 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. Table A2 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.[144]

**144.** 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.".

### Table A1 Key Questions and Actions for an Urban Heat Task Force

| Phase | 1. Take stock | 2. Build the evidence base | 3. Build a "cool city coalition" | 4. 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?<br>What are the city and other stakeholders already doing to cool urban spaces? Are the interventions working?<br>How could heat mitigation fit into existing strategies, plans, and commitments? | Which areas of the city have the most intense urban heat island effects?<br>Are there discernible reasons for differences in heat, e.g. types of building materials or green space?<br>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?<br>Which public and private sector actors could be effective champions for cooler city spaces?<br>Could residents' associations, professional bodies, or the private sector support design and upkeep of green assets and cool buildings? | Which place-based cooling interventions offer the biggest benefits?<br>Should City agencies' design and procurement standards or operational handbooks be revised to integrate cooling considerations?<br>What opportunities exist to increase green cover, make buildings cooler, integrate shade and water into urban design, and improve wind flow? |
| **Supporting measures** | Map urban greening stakeholders<br>Map urban design stakeholders<br>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<br>Pilot cooling interventions (such as cool roofs on schools or public housing) to evaluate potential investment options<br>Study impacts of buildings on wind to identify options for improved ventilation<br>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<br>Consult forestry stakeholders on options to preserve and increase green cover<br>Engage building owners and construction industry on indoor heat reduction options | Short-list investments for cooler and greener city spaces<br>Integrate passive design measures for overheating reduction into building codes<br>Mainstream heat mitigation into existing city department strategies<br>Initiate prefeasibility study for prioritized investment options |
| **People** | | | | |
| **Key questions** | Do authorities monitor heat-related death and illness and adjust hot-season planning based on the trends?<br>Do residents currently receive information about upcoming extreme heat?<br>How do doctors and hospital workers prepare for the hot season?<br>Does the national meteorological agency provide anticipatory heat stress forecasts? | How do deaths and hospital admissions vary with heat?<br>Which socioeconomic groups have a higher rate of death, illness, or hospital admission during extreme heat?<br>Do current weather forecasting products meet needs for protecting residents during heat?<br>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?<br>Which stakeholders need to disseminate information for vulnerable groups to reduce heat exposure and receive needed support?<br>Who is best positioned to alert vulnerable groups to heat risks and provide the needed support?<br>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?<br>At what heat stress threshold should alerts be issued? |

| Phase | 1. Take stock | 2. Build the evidence base | 3. Build a "cool city coalition" | 4. Identify and implement solutions |
|---|---|---|---|---|
| **Supporting measures** | Map public health and early warning system stakeholders<br>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<br>Identify heat stress thresholds associated with increased mortality and morbidity<br>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<br>Engage doctors to raise awareness of heat-related illnesses and prioritize response actions<br>Consult heat-exposed workers on their safety needs | Design and implement an impact-based heat early warning system<br>Identify response actions to accompany heat alerts in the health sector, in schools, and in heat-exposed workplaces<br>Plan public information actions with input from health professionals and affected groups |
| **Infrastructure** | | | | |
| **Key questions** | Have heatwaves caused electricity blackouts or load shedding?<br>Is summer heat a problem for safety and service quality on public transport?<br>Do homes, public buildings and schools overheat in summer? | Could service standards in energy and transport deteriorate in future due to rising temperatures?<br>What upgrades to roads, bridges, tracks, buses, trains and power lines could help?<br>Could indoor overheating problematic levels? | What roles could residents' associations, education authorities, architects and builders play in reducing indoor overheating risks?<br>How can architects, builders and local authorities ensure new-build homes will not overheat? | What building upgrades and code revisions could most efficiently keep buildings cool?<br>What barriers currently prevent a stronger private market for building retrofits from developing, and what financing models could overcome these? |
| **Supporting measures** | Conduct a desk review of heat impacts on key infrastructure sectors<br>Consult utilities, transport providers, architects and building occupants for their perspectives | Study how rooftop solar, storage, microgrids, and demand-side measures could strengthen energy resilience.<br>Use expert consultations and site surveys to evaluate shade, water and ventilation provision in transport systems. | Engage local transport providers in city heat action plans.<br>Partner with national infrastructure ministries and utility firms.<br>Communicate advice to train and bus passengers on staying well in heat. | Strengthen markets for building retrofit through incentives, subsidy, information and certification.<br>Integrate passive cooling in updated design guides for school buildings.<br>Identify investments for energy and transport resilience |

### 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.

## Table A2 A Simplified Catalog of Urban Heat Solutions

| | Implementation timeline | | | Heat type | |
|---|---|---|---|---|---|
| | Long-term action | Quick win (< 5 years) | Annual cycle (each summer) | Acute heat episodes | Chronic heat exposure |
| **1. Make Urban Spaces Cooler** | | | | | |
| **1. Advance Urban Greening Through Strategic Planning** | | | | | |
| Adopt an urban greening master-plan with targets, implementation budgets, partner roles, and political support | X | | | | X |
| Maximize green space, including through linear parks ("green corridors") and small parks in densely built-up areas, with ample vegetation and minimal paved areas | X | X | | | X |
| Choose nature-based solutions to achieve multiple benefits (e.g., cooling, clean air, biodiversity, flood protection, health, recreation) | | X | | | X |
| Support businesses and households to maintain trees at small and micro sites (street tree boxes, traffic medians) through sponsorship, tree stewardship, training, and sapling provision | | X | X | | X |
| Review land use regulations to balance strengthened tree preservation with real estate development, infrastructure access, and safety considerations | X | | | | X |
| **2. Harness Wind, Shade and Urban Design** | | | | | |
| Study ventilation patterns and introduce ventilation corridors and building regulations to maximize beneficial wind-flows | X | | | | X |
| Facilitate access to existing bodies of water (e.g., riverbanks, seashore) and add blue infrastructure (e.g., ponds within parks) | | X | | | X |
| Incorporate water features in public spaces, as well as drinking fountains | | X | | X | X |
| Reclaim road space for urban greening and shaded walking and cycling infrastructure | | X | | | X |
| Adopt a shade plan with supporting guidance, pilots and bylaws to support natural and engineered shade | | X | | X | X |
| **3. Tackle Indoor Heat through Building Upgrades** | | | | | |
| Strengthen market capacity for energy efficient upgrades and retrofit through subsidies, guarantees, standards and certification | | X | | X | X |
| Address indoor overheating in multi-family housing complexes in parallel with addressing seismic risk and winter cold | | X | | X | X |
| Mandate architects and builders to address overheating risk early in new homes, following models such as the United Kingdom's "Part O" code revision | X | | | X | X |
| Raise public awareness of passive cooling techniques and resulting energy savings, prioritizing low-cost, easy-to-implement options | | X | X | | X |

| | | | | | |
|---|---|---|---|---|---|
| **2. Protect Vulnerable People during Heatwaves** | | | | | |
| **4. Strengthen Heat Early Warning and Response Systems** | | | | | |
| Establish an early warning system with yellow, orange and red (or Level 1,2,3) alerts when temperatures exceed levels that predict increased mortality and illness | | X | X | X | |
| Engage doctors and marketing specialists to develop persuasive health messaging during heat alerts to achieve self-protective behaviors at scale | | X | X | X | |
| Establish an inter-agency response plan to be activated alongside heat alerts with roles for health, emergency management, public communications, and infrastructure providers | | X | X | X | X |
| **5. Build Health System Readiness for Extreme Heat** | | | | | |
| Establish clinical standards and training of healthcare personnel on diagnosis and treatment of heat-related illness | | X | X | X | X |
| Upgrade health care facilities to ensure they do not overheat | | X | | | X |
| Establish a public health surveillance function to monitor trends in heat-related illness, death, and health costs each year | | | X | | X |
| **6. Protect Heat-Exposed Workers and Residents** | | | | | |
| Make heat risk assessment a specific obligation of employers under occupational health and safety legislation, backed by sector standards and guidance | | X | | X | X |
| Adjust work schedules for public employees and contractors to avoid arduous tasks during the hottest hours | | X | | X | X |
| Reduce thermal load through ventilation and provide regular breaks and water availability | | X | | X | X |
| **3. Adapt Infrastructure for a Hotter Future** | | | | | |
| **7. Build Energy Systems' Resilience to Extreme Heat** | | | | | |
| Manage summer energy demand through mandatory minimum energy performance standards (MEPS), energy efficiency information, and incentives | | X | X | X | X |
| Upgrade energy infrastructure to increase heat resilience, and maintain regularly | X | | | X | |
| Plan and design energy systems for increasingly extreme weather conditions | X | | | X | X |
| Incorporate rooftop solar, storage, and microgrids for extra resilience | X | | | X | |
| **8. Integrate Heat Resilience into the Transport Sector** | | | | | |
| Ensure roads and bridges are heat-resilient by using asphalt binders with higher heat ratings and allowing for thermal expansion of steel | X | | | X | X |
| Maintain and, as needed, upgrade buses, trains, catenary lines, and tracks to ensure they can function well in extreme heat | | X | | X | |
| Increase shade in pedestrian areas and at bus stops through awnings, covered shelters and trees | | X | | X | |

| | | | | | |
|---|---|---|---|---|---|
| Ensure good ventilation on buses and trains and in stations | | X | | X | |
| Establish hot weather protocols, including increased inspections and go-slow measures | | | X | | X |
| **9. Prevent Schools Overheating** | | | | | |
| Upgrade school buildings for heat resilience | | X | | | X |
| Develop national guidelines for heat resilience in school buildings and education systems management | X | | | X | X |
| **4. Mainstream Heat Resilience into Institutions** | | | | | |
| **10. Integrate Heat Resilience into Strategies, Operations and Budgets** | | | | | |
| Create a Heat Action Plan (stand-alone or as part of climate action plan) | | X | | X | X |
| Create an institutional mechanism for effective coordination and collaboration on heat issues (e.g. a Chief Heat Officer or a multi-agency task force) | | X | | X | X |

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# Unlivable

**How Cities in Europe and Central Asia Can Survive – and Thrive – in a Hotter Future**

Urban areas across Europe and Central Asia are heating up—unevenly and with far-reaching effects. From Tirana to Tashkent, urban areas across this vast and varied region are experiencing a sharp rise in temperatures, an increase in heatwaves, and growing risks to public health, economic output, and infrastructure. This report explores the emerging challenge of extreme heat, explaining what is at stake, what cities are doing, and what needs to happen next.