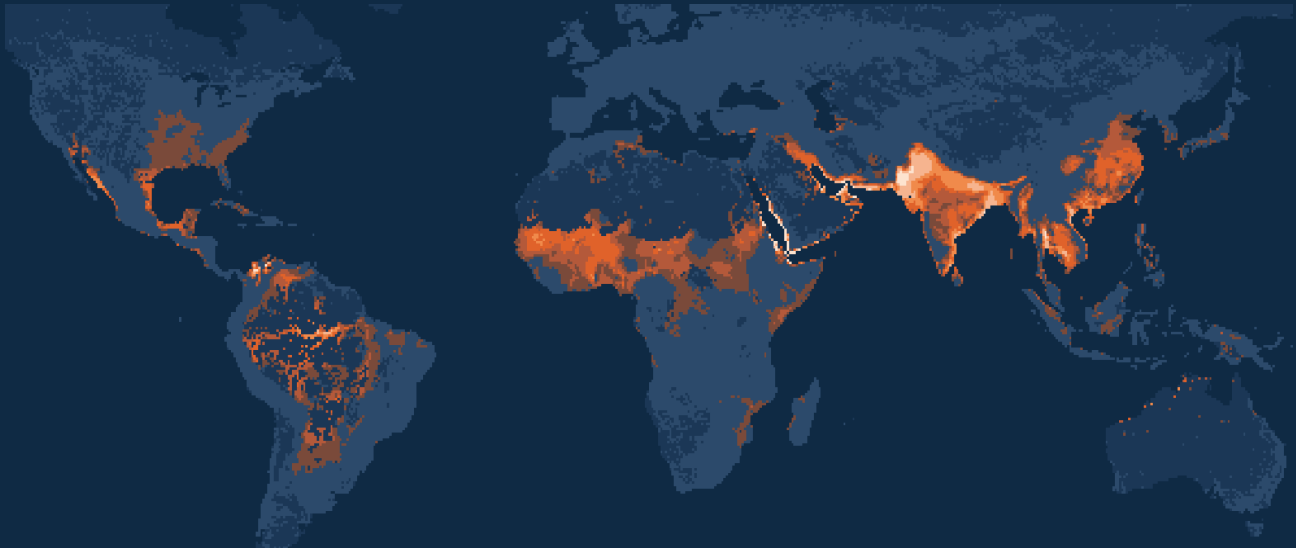


The Heat Trap

How the demographic centre of humanity is moving into the planet's most climate-exposed regions, and what it will take to keep the late twenty-first century liveable



Cover: projected days per year with a heat index above 41°C across inhabited land, 2080–2099 (SSP2-4.5). H Heuristics analysis of World Bank CCKP CMIP6 data.

About this report

The Heat Trap is the second report in the H Heuristics **Century Recalibration** series. The first report surveyed the broad forces reshaping the twenty-first century: European and East Asian demographic contraction, Africa's demographic rise, the economic convergence of Asia, and the overlapping stresses of climate change, pollution, poverty and conflict. This report takes one thread from that survey and follows it to its conclusion. That thread is the collision between **where humanity is growing** and **where the planet is becoming least habitable**.

Our argument is simple, and the evidence for it is strong. Over the rest of this century the demographic centre of humanity will move decisively into Sub-Saharan Africa and South Asia. These are the regions where heat, humidity and air pollution already press hardest on the human body, where adaptive capacity is thinnest, and where the next several degrees of warming will be felt first and most severely. The result is a structural humanitarian crisis that is slow-moving, global in scale and largely foreseeable. Because it is foreseeable, it is also addressable.

This report is written to raise awareness of that crisis among policymakers, funders, researchers, journalists and the wider public, so that it can be confronted while the most important choices are still open.

What is new in this analysis

Most studies of climate risk look at the climate or at the population, and few look at both at once. For this report, H Heuristics combined the **United Nations World Population Prospects 2024** (medium variant) with **CMIP6 climate projections from the World Bank Climate Change Knowledge Portal**, and weighted each country's climate by where its people actually live, using gridded population data from ISIMIP. This lets us follow the climate experienced by the *typical human being*, and not only the climate of the typical square kilometre, from 1950 to 2100 under four emissions pathways. It also lets us separate the effect of demographic change from the effect of climate change. The methods are set out in the Methodology and Data Notes.

How to read the numbers

Unless stated otherwise, "central" projections refer to the **SSP2-4.5** pathway, which produces roughly 2.7°C of warming by 2081–2100. That is close to where current policies are heading. We show **SSP3-7.0** (about 3.6°C) as a plausible high-risk pathway and **SSP1-2.6** (about 1.8°C) as an ambitious mitigation pathway. Projections are not predictions. They describe the consequences of choices that have not yet been made.

Suggested citation

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A NOTE ON LANGUAGE

This report is about places and conditions, not about peoples. Hundreds of millions of people in the regions discussed here are already building the adaptations the rest of the world will need: they are innovating, migrating, organising and governing under extraordinary constraint. When we write that humanity is moving "into" risk, we mean that the conditions of life are changing around the places where children are being born. Nobody is to blame for being born there. The crisis lies in the gap between the hazard and the protection available against it, and that gap is a product of policy, finance and history. It is not destiny.

KEY FINDINGS

At a Glance

The numbers below come from H Heuristics analysis of UN and World Bank data, unless another source is cited. Climate figures refer to the SSP2-4.5 pathway (about 2.7°C of warming by late century) unless noted.

57% of humanity will live in Sub-Saharan Africa or South Asia in 2100, up from 39% today	+2.1bn added to Sub-Saharan Africa's population by 2100, more than the entire net growth of the world (+2.0bn)	43% of all babies born in 2100 will be born in Sub-Saharan Africa, compared with 9% in 1950
+6.4°C rise in the average temperature of the place the typical human calls home, 1950–2100. Two-thirds of it is demographic	1.5bn people projected to live where the mean annual temperature is 29°C or higher , conditions almost absent from human history (2.5bn under SSP3-7.0)	4.6× increase in human exposure to "danger"-level heat (person-days with a heat index above 41°C), 2024–2100
2.2bn people projected to face 30 or more days a year of heat index above 41°C by 2100 (3.6bn under SSP3-7.0)	71% of the world's 817 million people in extreme poverty already live in Sub-Saharan Africa	6% of all fossil CO ₂ ever emitted came from Sub-Saharan Africa and South Asia, home to 57% of the people of 2100

Five conclusions

- 1. The typical human of 2100 will live in the hot, humid tropics.** The median person on Earth in 1950 lived in a climate like northern China's, at about 15°C. By 2100 the median person will live in a climate averaging nearly 26°C, closer to Kinshasa or Kolkata. Seven in ten people in the middle half of humanity will be in Sub-Saharan Africa or South Asia.
- 2. Demography and climate change compound one another.** Demographic change alone would move the "thermal centre" of humanity 4°C warmer between 1950 and 2100. Climate change adds roughly 2.3°C on top of that under current policies, and more on higher pathways.
- 3. Exposure is crossing physiological thresholds.** The share of humanity facing a month or more of dangerous humid heat each year rises from about 7% today to 22% by 2100 under SSP2-4.5 and 35% under SSP3-7.0. Within that group, the young, the old, outdoor workers and the poor face real survivability risk, as well as a deep loss of liveability.
- 4. Pollution, poverty and weak adaptive capacity concentrate in the same places.** Nearly all of humanity breathes air above the WHO guideline. The most polluted countries are among the fastest growing, and the region with most of the world's extreme poor is the region gaining most of the world's people.
- 5. The physics locks in the outcome for centuries, but the harm is still a choice.** Warming stops only when net CO₂ emissions stop, and it will not reverse for many centuries without large-scale carbon removal. The *harm* that follows from a given level of warming is not fixed in the same way. Cooling, clean air, health systems, decent work, finance and mobility can still change how the late twenty-first century is lived.

SECTION 01

Executive Summary

The twenty-first century is usually described through its headline transitions: the rise of Asia, the ageing of Europe and East Asia, the energy transition, the arrival of artificial intelligence. Beneath these runs a quieter shift that will shape the daily life of more people than any of them. **The human population is relocating, by birth rather than migration, into the regions of the planet that climate change is making least habitable.**

In 1950, one person in five lived in Europe. Fewer than one in fourteen lived in Sub-Saharan Africa. By 2100, under the [UN's medium-variant projections](#), Sub-Saharan Africa will be home to **3.35 billion people, one-third of humanity**, and South Asia to a further 2.41 billion. Together the two regions will hold 57% of the world's population. Between 2024 and 2100 Sub-Saharan Africa alone is projected to add 2.1 billion people. That is more than the world's entire net growth, because East Asia and Europe will together shrink by over a billion.

These are also the regions where heat and humidity already approach the limits of human tolerance, where air quality is among the worst on Earth, and where people have the fewest protections: the least electricity, the fewest air conditioners, the most outdoor and informal work, and the weakest health systems. The [IPCC](#) estimates that 3.3 to 3.6 billion people already live in contexts highly vulnerable to climate change, and it names West, Central and East Africa and South Asia among the global hotspots of vulnerability.

What we found

Our analysis combines UN population projections with population-weighted CMIP6 climate projections for every country. It produces four core findings.

First, humanity's home climate is warming much faster than the planet. The population-weighted mean annual temperature of the place the average person lives was about 17.3°C in 1950 and is 20.6°C today. Under SSP2-4.5 it reaches 23.7°C by 2100, and under SSP3-7.0 it reaches 24.6°C. Holding the climate fixed at 1991–2020 conditions, demographic change *alone* would raise it to 21.4°C. The world's people are moving into the heat faster than the heat is moving to them, and both processes are under way at once.

Second, the share of humanity living in near-unprecedented heat rises sharply. A mean annual temperature of 29°C or above, which [Xu et al. \(2020\)](#) identify as almost absent from the human experience of the last 6,000 years, today affects about 3% of humanity. By 2100 that rises to 15% (1.5 billion people) under SSP2-4.5 and 24% (2.5 billion) under SSP3-7.0. India, Nigeria, Sudan, Pakistan, Niger, Mali and Chad account for most of them.

Third, dangerous humid heat becomes a routine part of life for billions. We count the days on which the heat index, a combined measure of temperature and humidity, exceeds 41°C, the threshold the US National Weather Service classes as "danger". The average person experiences about 5 such days a year today. By 2100 that rises to about 18 under SSP2-4.5 and 33 under SSP3-7.0. Total human exposure rises 4.6-fold under SSP2-4.5. By 2100, 2.2 billion people would face at least a month of these conditions every year, 1.4 billion would face at least two months. In Pakistan and Bangladesh the national average would exceed two months a year, and in India it would be about seven weeks.

Fourth, the burden falls where responsibility is lowest and capacity is thinnest. Sub-Saharan Africa and South Asia have emitted about 6% of all fossil CO₂ since 1750. Sub-Saharan Africa already holds 71% of the

world's people in extreme poverty. Air pollution in the fastest-growing countries runs at 8 to 13 times the WHO guideline. Our decomposition shows that climate change drives most of the rise in per-person heat exposure, while demography decides *who* is exposed and *how many*.

Survivability and liveability

The phrase "survivability risk" needs care. The popular threshold of a 35°C wet-bulb temperature, beyond which even a healthy person at rest cannot shed heat, is likely to be crossed only rarely and locally this century. The more important finding is that laboratory research ([Vecellio et al., 2022](#)) puts real-world tolerance limits far lower, near 31°C wet-bulb for young, healthy adults and lower still for older people, children and anyone working. The crisis this report describes is therefore not mainly about sudden mass death. It is a chronic, compounding loss of **liveability**: lost sleep, lost work, lost schooling, lost harvests, more illness, and a steady rise in the number of days on which ordinary life becomes dangerous for those without cooling. For the most vulnerable groups, that loss of liveability becomes a direct threat to survival.

The long tail

Once emitted, CO₂ remains in the atmosphere for centuries to millennia. Roughly a quarter of any emission is still present after a thousand years. [Solomon et al. \(2009\)](#) showed that warming is largely irreversible for at least a millennium after emissions cease. Whatever level of warming the world reaches when it reaches net-zero is, to a first approximation, the level that the descendants of today's African and South Asian children will live with for many generations. Sea levels will keep rising for centuries after temperatures stabilise. The choices of the next three decades will therefore set the background conditions for a large share of all the humans who will ever live.

What must change

The trajectory is not fixed. The difference between SSP1-2.6 and SSP3-7.0 is the difference between 1.3 billion and 3.6 billion people facing a month or more of dangerous heat each year. Section 16 sets out an agenda built on six commitments:

- **Hold warming as low as possible.** Every tenth of a degree avoided spares roughly 140 million people from unprecedented heat ([Lenton et al., 2023](#)).
- **Make cooling a basic public good**, with efficient, affordable cooling, cool buildings and electricity access for the 1 billion or more people at high heat risk.
- **Treat clean air as climate adaptation**, cutting the PM2.5 exposure that multiplies the harm done by heat.
- **Build heat-ready health and labour systems**, including early warnings, heat action plans, worker protections and climate-resilient primary care.
- **Close the adaptation finance gap**, currently US\$187–359 billion a year in needs against roughly US\$28 billion in international public flows ([UNEP, 2024](#)).
- **Open safe pathways for mobility** within countries and across borders, so that moving to safety is a protected choice and not a desperate last resort.

The demographic future described here is not a threat. It is the future of humanity itself. The question is whether the systems that sustain human life will be rebuilt in time for the places where most of humanity will live.

SECTION 02

Introduction: The Century's Hidden Geography

Every era has a geography of human life: a pattern of where people are born, where they work and where they grow old. For most of recorded history that geography was set by the temperate and subtropical belts. These were the river valleys and plains of China, India, the Mediterranean, Mesopotamia, Mesoamerica and Western Europe, where agriculture flourished and human bodies could shed heat for most of the year. [Xu et al. \(2020\)](#) showed that for at least 6,000 years human populations clustered within a remarkably narrow "climate niche", centred on mean annual temperatures of about 11–15°C, with a secondary mode near 20–25°C associated with the South Asian monsoon.

The twentieth century loosened that pattern. Medicine, sanitation, vaccines, fertiliser and electrification lowered mortality everywhere, and populations grew fastest where fertility stayed high, mostly in the tropics. The twenty-first century will complete the shift. Europe, East Asia and the Americas are ageing and, in many cases, shrinking. Population growth is now concentrated in tropical Africa and, to a lesser degree, South Asia and the Middle East. The human niche is being redrawn by demography, and at the same moment it is being redrawn by greenhouse gases.

Why this crisis is hard to see

The collision between these two shifts is easy to miss for three reasons.

It is slow. Each year the change is too small to register: a few more babies born in Kano and Kinshasa, a few fewer in Kyoto and Kraków, a fraction of a degree of warming. Over eight decades it adds up to a transformation of the human condition. Slow crises lack the vivid moment that mobilises public attention.

It is divided across disciplines. Demographers project population, climate scientists project temperature, and public health specialists study heat illness. Few analyses follow the climate experienced by the *typical human being* over time, which is the quantity that matters for welfare. This report sets out to fill that gap.

It happens far from the centres of attention. Global media, finance and research capacity are concentrated in the North Atlantic and East Asia. The people who will live this crisis most intensely are mostly not yet born, and they will be born in places that receive a small share of global attention. Heat deaths in Europe make headlines. Heat deaths in Bamako, Jacobabad or Patna are rarely counted at all. The [World Weather Attribution](#) analysis of the April 2024 Sahel heatwave noted that a single hospital in Bamako recorded 102 deaths in four days, while national mortality data simply did not exist.

The central argument

This report argues that **a majority of humanity in the late twenty-first century will live under conditions of chronic climatic stress, and that a large and growing minority will face periodic survivability risk.** The crisis follows from four facts, each well established on its own:

1. Population growth to 2100 is concentrated almost entirely in Sub-Saharan Africa, South Asia and adjacent hot regions (Section 3).
2. These regions are already the hottest and most humid places where large numbers of people live, and they will warm into conditions without precedent in human experience (Sections 4 and 6).

3. The human body has hard physiological limits on its ability to shed heat, and those limits are lower than once believed (Section 5).
4. The protective systems that make heat survivable, such as electricity, cooling, clean air, health care, decent work, water and secure housing, are least available in exactly these places (Sections 7 to 10).

Further consequences follow from these four: displacement and mobility pressures, conflict risk, and a profound question of justice (Sections 11 and 12). Because carbon dioxide persists for millennia, the warming reached this century will shape conditions for many centuries more (Section 13). We then describe what life may be like for the middle half of humanity in 2100 (Section 14), set out three pathways (Section 15), and propose an agenda for action (Section 16).

KEY TERMS USED IN THIS REPORT

Heat index (HI). A "feels-like" temperature that combines air temperature and relative humidity. A heat index above 41°C (106°F) falls in the US National Weather Service "danger" category: heat cramps and heat exhaustion are likely, and heat stroke is probable with prolonged exposure or physical activity. Above 35°C, sustained outdoor work becomes hazardous.

Wet-bulb temperature (Tw). The lowest temperature to which air can be cooled by evaporating water. It sets the limit on how well sweating can cool the body. At a Tw of 35°C even a healthy person at rest in shade cannot shed metabolic heat. Empirical limits are lower (Section 5).

Mean annual temperature (MAT). The yearly average of daily temperatures. We use it to describe the climate "niche" in which people live. Places with a MAT of 29°C or higher currently cover less than 1% of Earth's land and, historically, have held very few people.

Survivability vs. liveability. *Survivability* is whether a human body can physiologically tolerate conditions. *Liveability* is whether people can sustain ordinary life, including work, sleep, study, care and farming, at acceptable risk and cost. This report shows that liveability erodes long before survivability limits are reached.

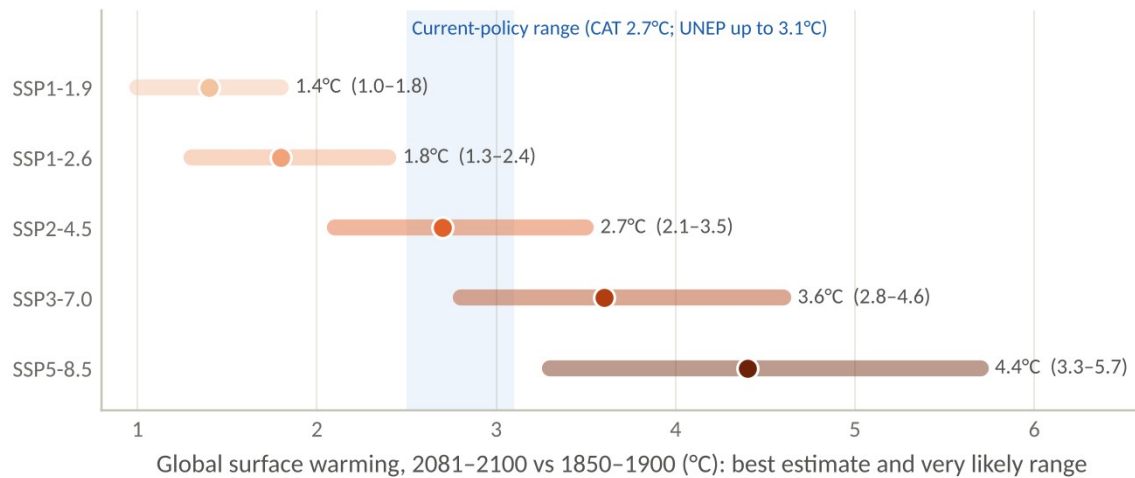
SSP scenarios. The Shared Socioeconomic Pathways used in IPCC AR6. SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5 yield best-estimate warming of about 1.8°C, 2.7°C, 3.6°C and 4.4°C by 2081–2100.

Where the world is heading

Before turning to the human geography, it is worth fixing the climate trajectory. 2024 was the first calendar year in which global average temperature exceeded 1.5°C above pre-industrial levels, at about 1.55°C according to the [World Meteorological Organization](#). The [Climate Action Tracker](#) estimates that current policies lead to about 2.7°C of warming by 2100. The [UNEP Emissions Gap Report 2024](#) finds that a continuation of current policies could lead to as much as 3.1°C. Those figures place the world near the middle of the IPCC scenario range, between SSP2-4.5 and SSP3-7.0, unless commitments are strengthened and delivered.

Figure 1 The warming range for this century

Best-estimate global surface warming for 2081–2100 relative to 1850–1900 under the five IPCC AR6 core scenarios, with very likely ranges. The shaded band marks where current policies are heading.



Source: IPCC AR6 WGI Summary for Policymakers, Table SPM.1; Climate Action Tracker (2024); UNEP Emissions Gap Report 2024. Chart: H Heuristics.

The IPCC is clear that every increment of warming matters. A heat extreme that occurred once every ten years in the pre-industrial climate becomes about 4.1 times more frequent at 1.5°C, 5.6 times at 2°C and 9.4 times at 4°C ([IPCC AR6 WGI SPM](#)). Once-in-fifty-year extremes rise even faster, by about 39 times at 4°C. These are global averages. In the humid tropics the shift is starker, because natural year-to-year variability there is small, so a modest warming pushes conditions outside anything previously experienced.

The rest of this report asks what these numbers mean for the human beings who will live through them.

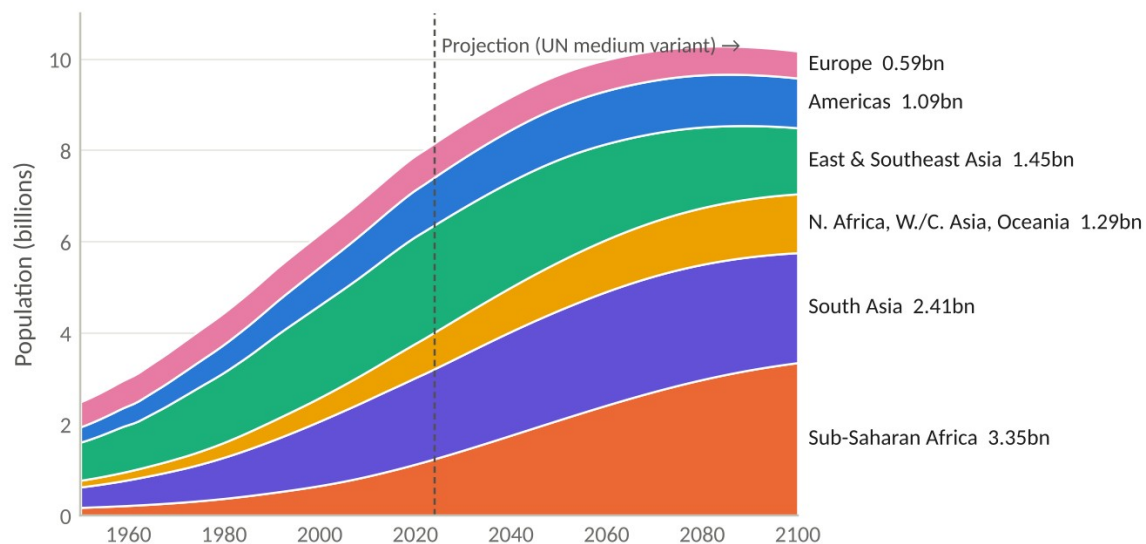
SECTION 03

The Demographic Arithmetic: Humanity Moves South

The United Nations' [World Population Prospects 2024](#) projects that world population will rise from 8.2 billion in 2024 to a peak of about **10.3 billion in the mid-2080s**, and then decline slightly to 10.2 billion by 2100. The global total hides a dramatic redistribution. Almost all remaining growth will occur in a band of countries running from the Sahel through Central and East Africa to the Middle East and South Asia. Much of the rest of the world will shrink.

Figure 2 World population by region, 1950–2100

Billions of people, UN medium variant. Sub-Saharan Africa grows from 7% of humanity in 1950 and 15% today to 33% by 2100.



Source: UN World Population Prospects 2024, via [Our World in Data](#). Regional groupings by H Heuristics.

Sub-Saharan Africa: the engine of growth

Sub-Saharan Africa's population was about 180 million in 1950. It is 1.24 billion today and is projected to reach **2.09 billion by 2050 and 3.35 billion by 2100**. Including North Africa, the continent as a whole reaches 3.81 billion, more than 37% of humanity. Between 2024 and 2100 Sub-Saharan Africa is projected to add 2.11 billion people. Over the same period the world adds 2.02 billion, so the region's growth more than accounts for the global total. East and Southeast Asia lose about 900 million people and Europe about 150 million.

The scale at country level is striking. The Democratic Republic of the Congo is projected to grow from 109 million to **431 million**, Tanzania from 69 million to 263 million, Ethiopia from 132 million to 367 million and Angola from 38 million to 150 million. Nigeria, already Africa's most populous country, more than doubles to **477 million**. Niger, which has one of the world's highest fertility rates and some of its harshest heat, grows from 27 million to 91 million.

South Asia: the largest bloc

South Asia remains the largest single concentration of humanity throughout the century. India peaks at roughly 1.7 billion in the early 2060s and ends the century at about 1.5 billion, still the world's most populous country by a wide margin. Pakistan doubles to **511 million**, overtaking Nigeria and the United States. Bangladesh peaks above 210 million. In total South Asia holds 2.41 billion people in 2100, about 24% of humanity, nearly the same share as today. What changes is that South Asia stops growing while Sub-Saharan Africa keeps growing fast.

Table 1 The world's most populous countries in 2100

Rank	Country	2024 (m)	2050 (m)	2100 (m)	Change 2024–2100	Median age 2024
1	India	1,451	1,680	1,505	+4%	28
2	China	1,419	1,260	633	-55%	40
3	Pakistan	251	372	511	+103%	20
4	Nigeria	233	359	477	+105%	18
5	DR Congo	109	218	431	+294%	16
6	United States	345	381	421	+22%	38
7	Ethiopia	132	225	367	+178%	19
8	Indonesia	283	321	296	+4%	30
9	Tanzania	69	130	263	+283%	17
10	Bangladesh	174	215	209	+20%	26
11	Egypt	117	162	202	+73%	24
12	Brazil	212	217	163	-23%	34
13	Angola	38	74	150	+296%	17
14	Sudan	50	85	137	+171%	18
15	Mexico	131	149	130	-0%	29

Source: UN World Population Prospects 2024 (medium variant), via Our World in Data. Median age from the same source.

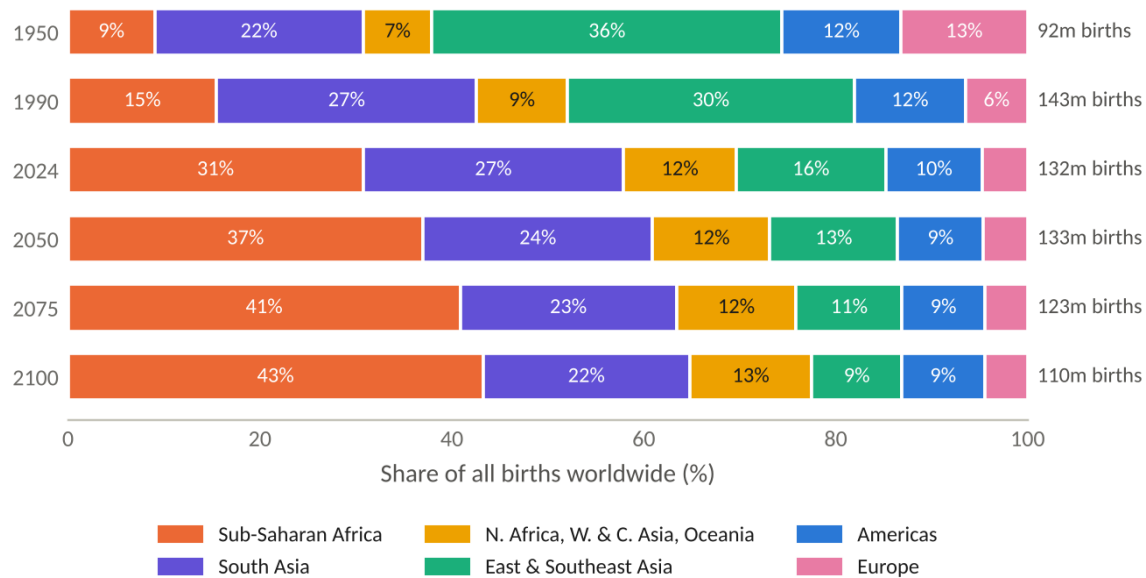
Of the fifteen most populous countries in 2100, ten are in Africa or South Asia, and an eleventh, Indonesia, lies in the humid tropics of Southeast Asia. The other four are the United States, China, Brazil and Mexico, and every one of them except the United States will have shrunk by then. Eleven of the fifteen are projected to have a population-weighted mean annual temperature above 24°C by the late century.

Where the babies are born

Births reveal the direction of change more clearly than population totals, because the children born today are the adults of 2060 and the elders of 2100. In 1950, 9% of the world's babies were born in Sub-Saharan Africa. Today the figure is **31%**. By 2100 it will be **43%**, and Sub-Saharan Africa and South Asia together will account for nearly two-thirds of all births on Earth. Independent forecasts point the same way. The Global Burden of Disease fertility study ([GBD 2021 Fertility and Forecasting Collaborators, 2024](#)) projects that more than half of all live births will occur in Sub-Saharan Africa by 2100.

Figure 3 Where the world's babies are born

Share of global births by region, selected years. Total annual births at right.



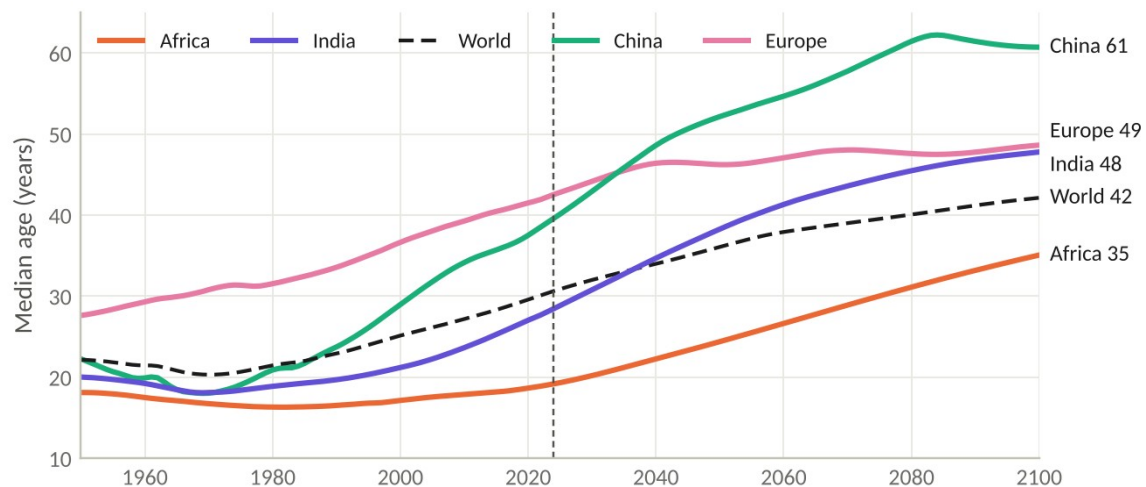
Source: UN World Population Prospects 2024, via Our World in Data. Chart: H Heuristics.

A young, then ageing, population

The populations moving into the heat are young today and will age through the century. Africa's median age is 19 today, compared with 43 in Europe and 40 in China. By 2100 Africa's median age rises to 35 and India's to 48, roughly where Europe is today. This matters for heat risk in two ways. A young population means a very large share of children, who are physiologically vulnerable to heat, and a huge cohort of young workers who will spend their working lives in the heat, often outdoors. Later in the century, the ageing of India, Bangladesh and eventually Africa will create something new: hundreds of millions of older people, the group most likely to die in heatwaves, living in the hottest places on Earth.

Figure 4 Median age, 1950–2100

Years, UN medium variant. Africa refers to the UN Africa region.



Source: UN World Population Prospects 2024, via Our World in Data.

How certain are these projections?

Population projections are more reliable than most long-range forecasts, because the parents of the next generation are already born. They are not certain, however. The main uncertainty is the pace of fertility decline in Sub-Saharan Africa. The UN medium variant assumes fertility in high-fertility countries continues to fall gradually. Other institutions expect faster declines: the Institute for Health Metrics and Evaluation ([Vollset et al., 2020](#)) projected a global peak of 9.7 billion in 2064 and 8.8 billion in 2100, with Sub-Saharan Africa still reaching about 3 billion.

The central conclusion does not depend on the variant. Even with faster fertility decline, Sub-Saharan Africa and South Asia hold a majority of humanity by late century. Their share is set less by future fertility than by the momentum of populations whose largest cohorts are entering their childbearing years now. Faster fertility decline in Africa, through girls' education, access to contraception and falling child mortality, is desirable for many reasons. It would reduce the *number* of people exposed to extreme heat. It would not change *where* humanity's centre of gravity lies.

THE URBAN DIMENSION

Most of this growth will be urban. The [UN World Urbanization Prospects](#) projects that 68% of humanity will live in cities by 2050, with close to 90% of the increase in Asia and Africa. [Hoornweg and Pope \(2017\)](#) project that by 2100 Lagos could hold about 88 million people, Kinshasa 83 million and Dar es Salaam 74 million, which would make them the world's three largest cities. Cities amplify heat through the urban heat island effect, which can add several degrees at night. [Tuholske et al. \(2021\)](#) found that urban exposure to extreme humid heat nearly tripled between 1983 and 2016, affecting 1.7 billion people. Population growth accounted for about two-thirds of the increase. More than 1.1 billion people already live in slums or informal settlements ([UN-Habitat](#)), with tin roofs, poor ventilation and little shade.

The demographic arithmetic, then, is not in serious doubt. The question this report asks is what kind of climate these people will live in.

SECTION 04

The Thermal Centre of Humanity

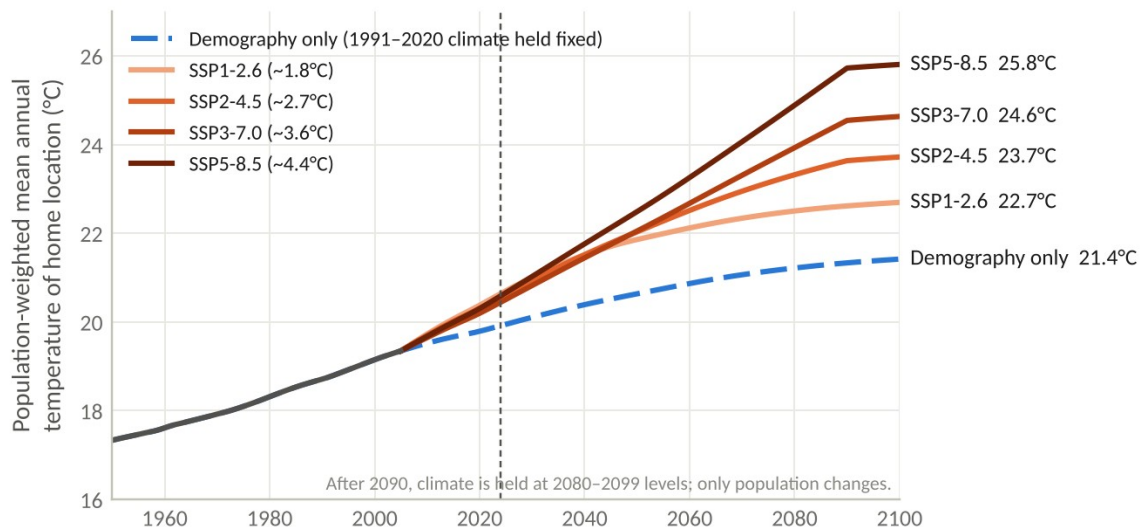
The usual way to describe global warming is a single number: the rise in global average surface temperature since pre-industrial times. That number averages over oceans, ice sheets, deserts and forests, most of which are empty of people. For human welfare a different quantity matters more: **the temperature of the places where people actually live**. We call this the *thermal centre of humanity*, the population-weighted average temperature of human homes.

To estimate it, we combined UN population data and projections for every country with population-weighted climate data. For each country we computed the average mean annual temperature experienced by its residents, using the 1991–2020 ERA5 climatology, and weighted each 0.5° grid cell by its population. China's population-weighted temperature, for example, is about 15°C. Its simple land-area average is nearer 7°C, because the cold, empty Tibetan Plateau dominates the map but not the population. We then added CMIP6 multi-model median warming for each scenario. The Methodology section gives details.

Two forces, one direction

Figure 5 The thermal centre of humanity, 1950–2100

Population-weighted mean annual temperature of the places where people live. The dashed line holds climate fixed at 1991–2020 conditions, isolating the effect of demographic change. Solid lines add projected warming under four scenarios.



Source: H Heuristics analysis of UN WPP 2024, ERA5 and CMIP6 (World Bank CCKP) climatologies, ISIMIP gridded population.

The result is the clearest single picture of the century's direction. In 1950 the average human lived in a climate with a mean annual temperature of about **17.3°C**. Today the figure is about **20.6°C**. By 2100 it reaches **23.7°C** under SSP2-4.5, **24.6°C** under SSP3-7.0 and **25.8°C** under SSP5-8.5.

The dashed line shows what would happen if *the climate had stopped changing in 1991–2020*. Demographic change alone raises the thermal centre from 17.3°C in 1950 to 21.4°C in 2100. Of the total 6.4°C shift between 1950 and 2100 under SSP2-4.5, about **4.1°C comes from humanity moving into hotter places through differential population growth**, and about 2.3°C from those places warming. This "demographic

warming" is not a metaphor. It is a change in the climate experienced by the average person, and it is happening on top of global warming.

Humanity is moving into the heat faster than the heat is moving to humanity, and both are happening at once.

The median human

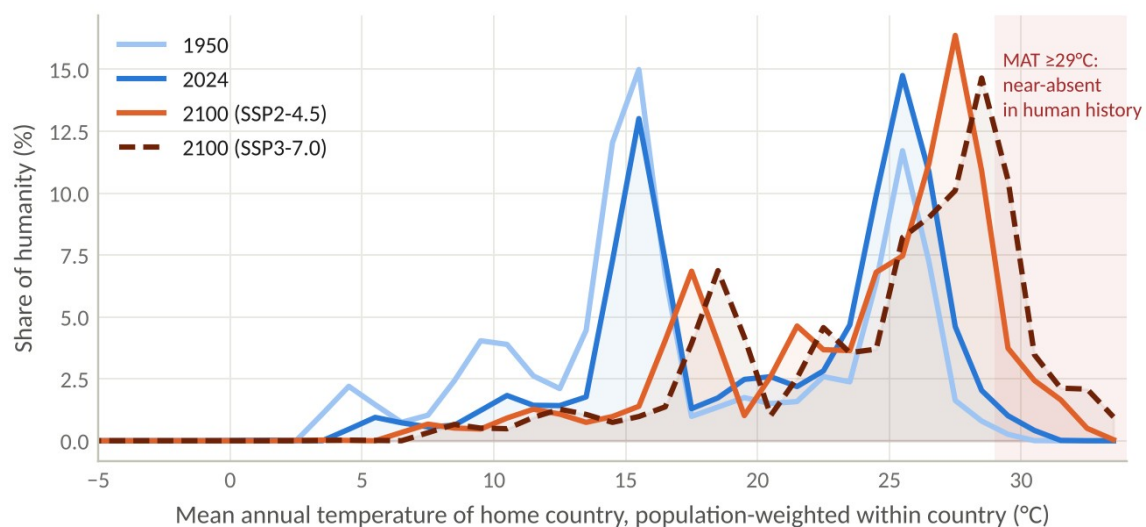
Averages can mislead, so we also tracked the **median human**: the person halfway along the distribution when all eight billion people are ranked from the coolest home climate to the hottest.

- In **1950**, the median human lived in a climate of about **15.0°C**, typical of the North China Plain. More than half of the middle 50% of humanity lived in East and Southeast Asia.
- **Today**, the median human lives at about **22.4°C**, comparable to the national average climate of Angola today. South Asia and Sub-Saharan Africa together account for 45% of the middle half of humanity.
- In **2100** under SSP2-4.5, the median human lives at about **25.7°C**, roughly the climate of the Congo Basin today, and under SSP3-7.0 at **26.8°C**. **Seven in ten people in the middle half of humanity, 40% in Sub-Saharan Africa and 30% in South Asia, will live in these two regions.** Europe will contribute almost nobody to the middle half of humanity.

This answers a question posed at the outset of this series: *what is life like for the middle 25–75% of humanity in 2100?* The middle half of humanity will live in places with mean annual temperatures between about **20.5°C and 27.5°C** (SSP2-4.5), overwhelmingly in tropical Africa and South Asia, mostly in cities, and mostly in countries that are still low or lower-middle income today.

Figure 6 How humanity is distributed across climates

Share of world population by the mean annual temperature of their home country, with temperatures population-weighted within each country. The 1950 distribution has twin peaks in the temperate zone (Europe, China) and the monsoon tropics. By 2100 the temperate peak has largely gone.



Source: H Heuristics analysis of UN WPP 2024, ERA5, CMIP6 (World Bank CCKP) and ISIMIP data. Country-level aggregation smooths within-country variation.

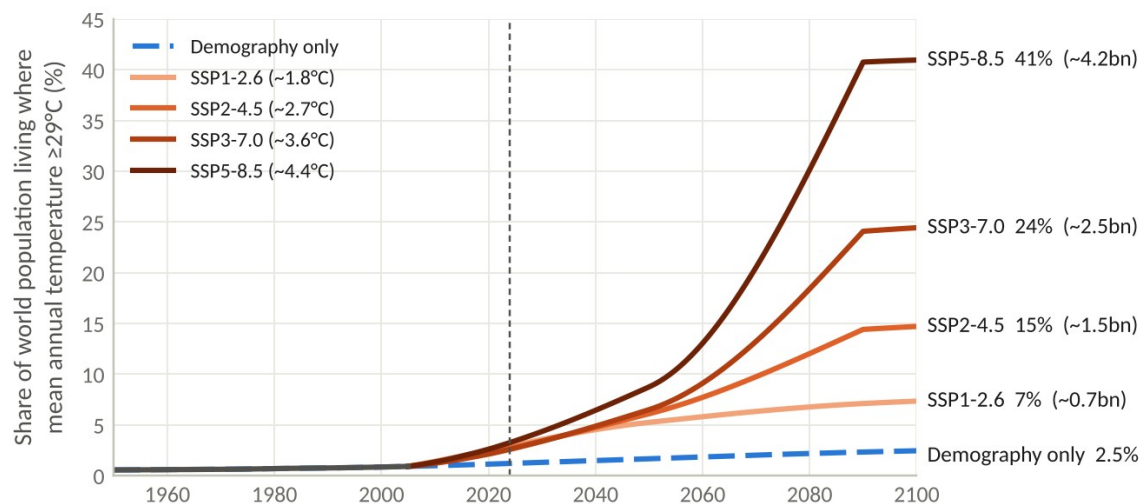
Leaving the human climate niche

[Xu et al. \(2020\)](#) found that a mean annual temperature of **29°C or above** is almost entirely absent from the history of human settlement. Today such conditions cover about 0.8% of Earth's land, mostly in the Sahara, where few people live. Under high emissions, they projected, this zone could expand to cover 19% of the land and to be home to about 3.5 billion people by 2070. [Lenton et al. \(2023\)](#) extended the analysis. They estimated that warming of 2.7°C would leave around 2 billion people (22% of the projected population) outside the human climate niche by the end of the century, with India (about 600 million), Nigeria (about 300 million) and Indonesia (about 100 million) most affected. Limiting warming to 1.5°C would reduce this to about 5%.

Our own grid-cell analysis, which uses only the 29°C criterion and the UN 2024 projections, reaches results of the same scale.

Figure 7 Share of humanity living where the mean annual temperature is 29°C or above

Percentage of world population living in 0.5° grid cells with a mean annual temperature of 29°C or more. Within-country population distribution held at 2021 patterns.

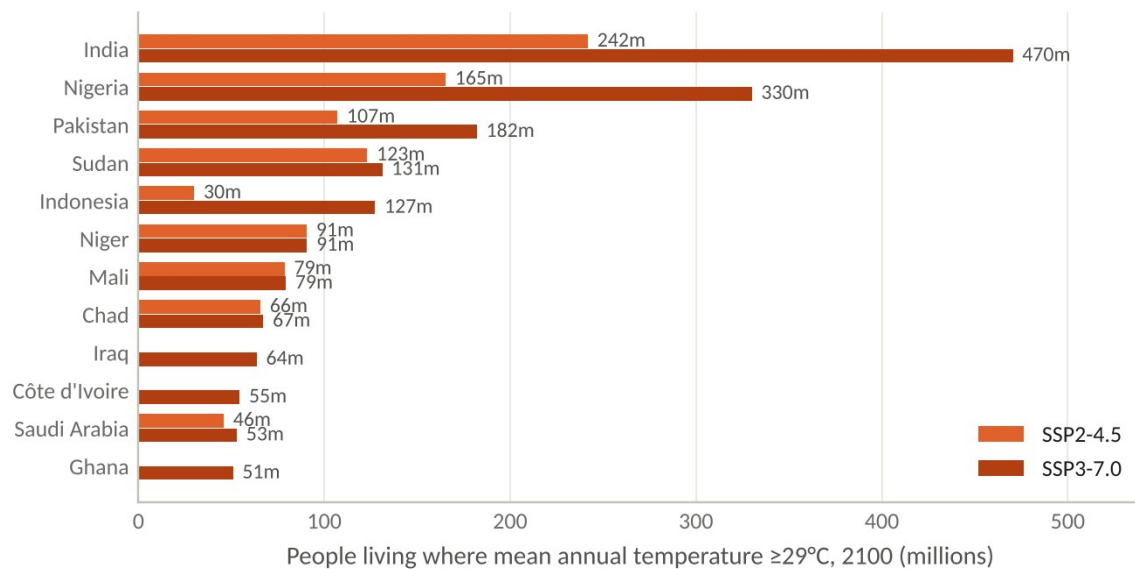


Source: H Heuristics analysis of UN WPP 2024, ERA5, CMIP6 (World Bank CCKP) and ISIMIP data.

About **3% of humanity**, roughly 220 million people, now lives where the mean annual temperature is 29°C or above. Under SSP2-4.5 this rises to **15% by 2100, about 1.5 billion people**. Under SSP3-7.0 it rises to 24%, about 2.5 billion, and under SSP5-8.5 to 41%. Even under SSP1-2.6 the figure more than doubles, to about 7%. Demography alone would roughly double the number exposed even without warming, because the hottest places are among the fastest growing.

Figure 8 Where the people living above 29°C will be

Millions of people living where the mean annual temperature is 29°C or more in 2100, by country, under SSP2-4.5 and SSP3-7.0.



Source: H Heuristics analysis of UN WPP 2024, ERA5, CMIP6 (World Bank CCKP) and ISIMIP data.

The geography is concentrated. Under SSP2-4.5, India accounts for about 240 million people in this category, Nigeria 165 million, Sudan 123 million and Pakistan 107 million. Niger, Mali, Chad and Burkina Faso are close to entirely inside the zone. Under SSP3-7.0, India's figure nearly doubles to 470 million and Nigeria's to 330 million, and Indonesia, Côte d'Ivoire, Ghana and Iraq join the list.

WHY MEAN TEMPERATURE UNDERSTATES THE PROBLEM

A mean annual temperature of 29°C is a blunt measure. It says little about humidity, nights or extremes, which are what injure people. A humid coastal city averaging 28°C can be far more dangerous than a dry inland city averaging 30°C. That is why the next two sections turn to the heat index and wet-bulb temperature, which capture the body's ability to cool itself. Mean temperature still has value as a *niche* indicator, because human settlement, agriculture and economic output have historically been organised around it. [Burke, Hsiang and Miguel \(2015\)](#) found that economic productivity peaks at an annual average temperature of about 13°C and declines steeply above that. By 2100 the median human will live roughly 13°C above that optimum.

SECTION 05

The Physiology of Heat: Where Survivability Ends

Humans are, by mammalian standards, extraordinary heat-shedders. We sweat profusely, we have little body hair, and we can walk for hours in the midday sun. That capacity has limits, and those limits are set by physics. The body produces about 100 watts of heat at rest and several times that during work. To keep its core near 37°C, it must lose that heat to the environment. When the air is hotter than the skin, at around 35°C, the only route left is the evaporation of sweat. Evaporation depends on how much moisture the air can still absorb, which is why **humidity, not temperature alone, determines the limits of human survival.**

The 35°C wet-bulb limit and why it is too optimistic

In 2010 [Sherwood and Huber](#) proposed a theoretical upper limit for human survival: a sustained wet-bulb temperature of 35°C. Under those conditions even a healthy person, resting naked in the shade in front of a fan with unlimited water, cannot lose heat, and the core temperature rises until death within roughly six hours. The threshold became a landmark in climate science. Climate model studies projected where it would first be crossed: the Persian Gulf ([Pal and Eltahir, 2016](#)), the densely populated agricultural regions of the Ganges and Indus basins ([Im, Pal and Eltahir, 2017](#)), and parts of coastal West Africa and the North China Plain.

The 35°C threshold is better understood as an absolute physical ceiling than as a practical limit. Three lines of evidence show that the real danger zone begins much lower.

Laboratory evidence. The PSU HEAT project at Pennsylvania State University measured the point at which young, healthy volunteers could no longer stabilise core temperature during light activity. In warm-humid conditions the critical wet-bulb temperature averaged about **30–31°C**, well below 35°C ([Vecellio et al., 2022](#)). A follow-up study using these empirical limits found that the area and population exposed to uncompensable heat stress is far larger than the 35°C threshold implies ([Vecellio et al., 2023](#)).

Age and health. Older adults sweat less, have reduced cardiovascular reserve, and often take medications that impair thermoregulation. [Vanos et al. \(2023\)](#) modelled survivability limits for young and older adults. Limits for those over 65 are substantially lower, and in many regions the margin between today's extremes and the survivable limit for older people is already narrow. Infants, pregnant women and people with heart, kidney or respiratory disease are also at elevated risk.

Observations. Wet-bulb temperatures of 35°C, once thought not to occur on Earth, have already been briefly recorded at a handful of weather stations in the Persian Gulf and Pakistan's Indus Valley ([Raymond, Matthews and Horton, 2020](#)). The same study found that the frequency of extreme humid heat events had more than doubled since 1979.

Table 2 Physiological thresholds and what they mean

Threshold	Approximate condition	What it means for people
Heat index 32–41°C	NWS "extreme caution"	Heat exhaustion possible with prolonged exposure or activity; outdoor work productivity falls sharply
Heat index above 41°C	NWS "danger"	Heat cramps and exhaustion likely; heat stroke probable with prolonged exposure or physical activity
Wet-bulb 28–30°C	Approximately HI 45–55°C	Many outdoor jobs become unsafe; older adults at high risk without cooling
Wet-bulb 30–31°C	Empirical limit, young adults, light activity	Core temperature can no longer stabilise; heat stroke risk escalates even for the fit
Wet-bulb 35°C	Theoretical limit, at rest in shade	Death within hours without artificial cooling, regardless of fitness or acclimatisation

Sources: US National Weather Service heat index categories; Vecellio et al. (2022); Sherwood and Huber (2010); Vanos et al. (2023). Heat index–wet-bulb equivalences are approximate and depend on temperature–humidity combinations.

From survivability to liveability

Most people do not die when a threshold is crossed. Bodies adapt somewhat, people seek shade, rest, drink water, move to cooler rooms, and turn on fans or air conditioners where they have them. Survivability is an extreme measure. The more widespread harm is the erosion of **liveability**, the ability to carry on the ordinary activities that make up a life:

- **Work.** Heavy outdoor labour becomes unsafe at moderate heat-stress levels. Productivity losses begin well before danger thresholds (Section 9).
- **Sleep.** Hot nights prevent recovery from daytime heat and are strongly associated with mortality. Warming is increasing night-time temperatures faster than daytime temperatures in many regions, and the urban heat island is strongest at night.
- **Learning.** Heat measurably reduces learning. Students in hotter years and hotter classrooms score lower on tests, and many schools in the tropics have no cooling at all.
- **Pregnancy and early life.** A meta-analysis in the *BMJ* found that the odds of preterm birth rise by about 5% for each 1°C increase in temperature, and by 16% during heatwaves ([Chersich et al., 2020](#)).
- **Care and daily life.** Cooking over open fires, fetching water, caring for the sick and travelling to market all become dangerous, and these tasks fall disproportionately on women.

THE SURVIVABILITY GAP

Exposure to dangerous heat is not the same as harm from it. A heat index of 45°C is an inconvenience for someone in an air-conditioned apartment with reliable electricity and an indoor job. For someone in a tin-roofed room with no fan, during a power cut, after a day of agricultural labour, it can be lethal. The International Energy Agency found that of the 2.8 billion people living in the hottest parts of the world, **only about 8% own air conditioners**, compared with about 90% of households in the United States and Japan ([IEA, The Future of Cooling](#)). The survivability gap, the distance between hazard and protection, is the core of this crisis. It is widest in exactly the places where humanity is growing.

Acclimatisation helps, up to a point

People who live in hot climates are physiologically acclimatised. They sweat earlier and more efficiently, and their cardiovascular systems adjust. Cultural adaptations such as siesta hours, building forms, clothing and

diet also reduce exposure. These matter, and they help explain why the same temperature kills more people in Paris than in Delhi. But acclimatisation cannot change the physics of evaporative cooling. It can shift tolerance by perhaps one or two degrees. It cannot help when the air is too saturated to absorb sweat. The temperatures projected for parts of South Asia, the Sahel and coastal West Africa by late century lie beyond the range that acclimatisation can address. In those places, survival on the worst days will depend on access to engineered cooling, cool refuges, or the ability to leave.

SECTION 06

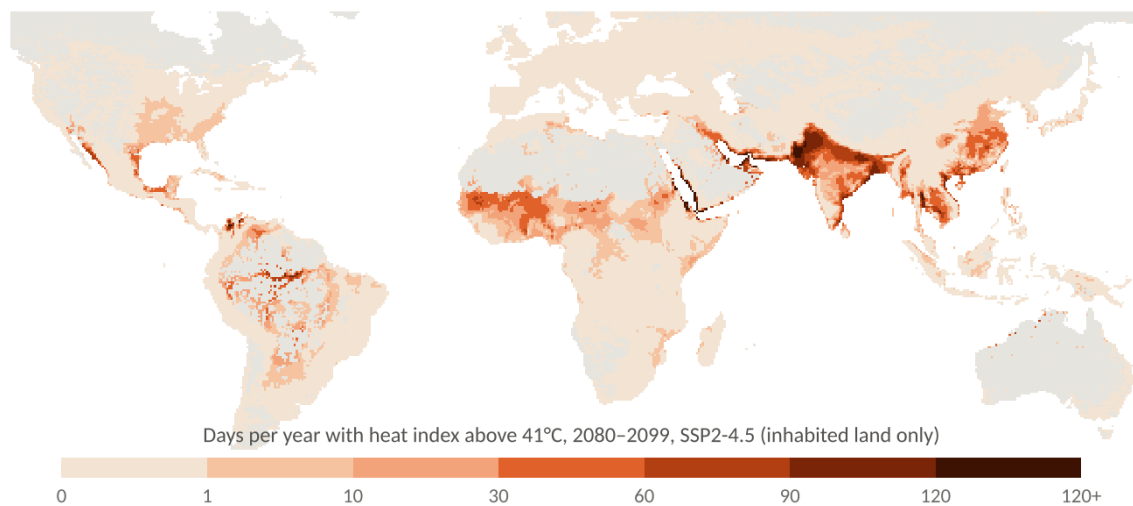
Humid Heat to 2100: Who Will Be Exposed

This section measures exposure to dangerous humid heat directly. We use the World Bank Climate Change Knowledge Portal's CMIP6 projections of the number of days each year on which the daily **heat index exceeds 35°C, 39°C and 41°C**. We weight these grid-cell projections by population within each country, scale them to UN national population projections, and follow them from the 1995–2014 baseline through mid-century to 2080–2099.

The map of danger

Figure 9 Where dangerous humid heat will concentrate

Projected days per year with a heat index above 41°C in 2080–2099 under SSP2-4.5. Only inhabited land (grid cells with at least 2,000 residents in 2021) is coloured. Uninhabited land is shown in grey.



Source: H Heuristics analysis of World Bank CCKP CMIP6 multi-model median (0.25°) and ISIMIP gridded population.

The map shows the geography of risk. The most intense and widespread danger-level heat is concentrated in the **Indo-Gangetic Plain and the Indus Valley**, which hold the largest number of people at risk anywhere. It also covers the Bengal delta, the Gulf coast of Arabia and Iraq, the **Sahel from Senegal to Sudan**, coastal West Africa, mainland Southeast Asia and eastern China. Several of these regions already sit near the edge of human tolerance, and all of them are densely populated or growing quickly.

The global picture

Table 3 Humanity's heat exposure, today and in 2100

Indicator	2024	2050, SSP2-4.5	2100, SSP1-2.6	2100, SSP2-4.5	2100, SSP3-7.0
Population-weighted mean home temperature (°C)	20.6	22.0	22.7	23.7	24.6
Median human's home temperature (°C)	22.4	24.2	24.7	25.7	26.8
Share living where mean annual temp. $\geq 29^{\circ}\text{C}$	3%	6%	7%	15%	24%
Share with ≥ 30 days/yr heat index $> 41^{\circ}\text{C}$	7%	13%	13%	22%	35%
Share with ≥ 60 days/yr heat index $> 41^{\circ}\text{C}$	1%	3%	4%	13%	24%
Share with ≥ 100 days/yr heat index $> 35^{\circ}\text{C}$	13%	22%	20%	34%	44%
Days/yr heat index $> 41^{\circ}\text{C}$, average person	5	9	9	18	33
Days/yr heat index $> 35^{\circ}\text{C}$, average person	32	46	43	68	94
Person-days/yr heat index $> 41^{\circ}\text{C}$ (billions)	40	91	91	186	335

Source: H Heuristics analysis of UN WPP 2024, ERA5 and World Bank CCKP CMIP6 climatologies, ISIMIP gridded population. "2024" uses interpolated model climatology. "2100" combines 2080–2099 climatology with 2100 population.

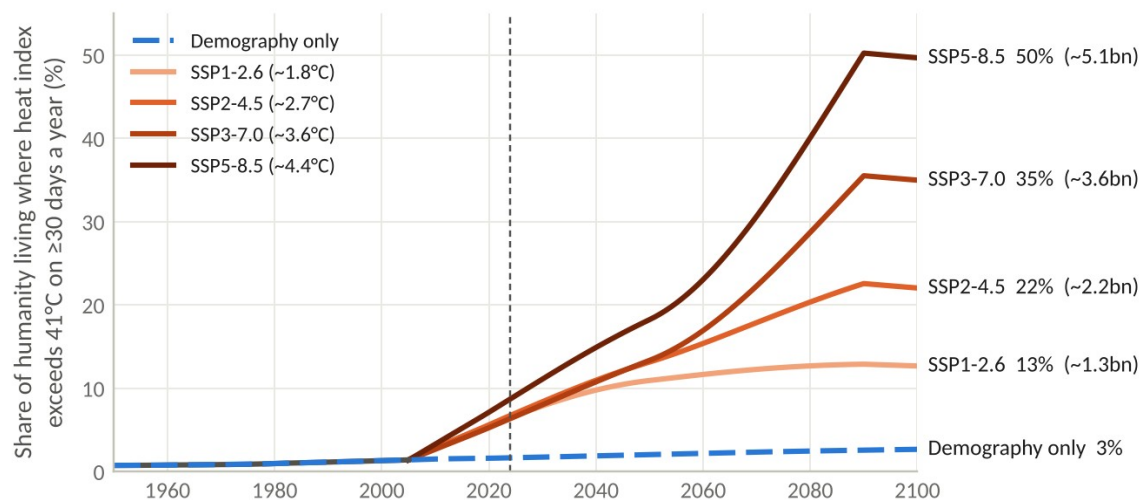
Under SSP2-4.5, the average person on Earth will experience about **18 days a year** with a heat index above 41°C by 2100, up from about 5 today. Under SSP3-7.0 the figure is 33. For heat index above 35°C , the threshold at which heavy outdoor work becomes dangerous, the average person goes from about 32 days a year to 68 under SSP2-4.5 and 94 under SSP3-7.0. That is roughly a quarter of the year.

These results are consistent with earlier global studies. [Mora et al. \(2017\)](#) found that about 30% of the world's population was already exposed to potentially deadly combinations of heat and humidity for at least 20 days a year, and projected that this would rise to about 48% by 2100 even with steep emissions cuts, and to about 74% under high emissions.

The averages, however, hide the concentration of risk in particular places.

Figure 10 Share of humanity facing a month or more of danger-level heat each year

Percentage of world population living where the heat index exceeds 41°C on at least 30 days a year. The dashed line holds climate at the 1995–2014 baseline.



Source: H Heuristics analysis of UN WPP 2024, World Bank CCKP CMIP6 and ISIMIP data.

Today about **7% of humanity**, about 550 million people, live where the heat index exceeds 41°C on 30 or more days in a typical year. Most of them are in northern India, Pakistan and the Persian Gulf. By 2050 the share roughly doubles, to between 11% and 18% depending on the scenario (13% under SSP2-4.5), because much of the mid-century warming is already locked in. By 2100 the scenarios diverge sharply:

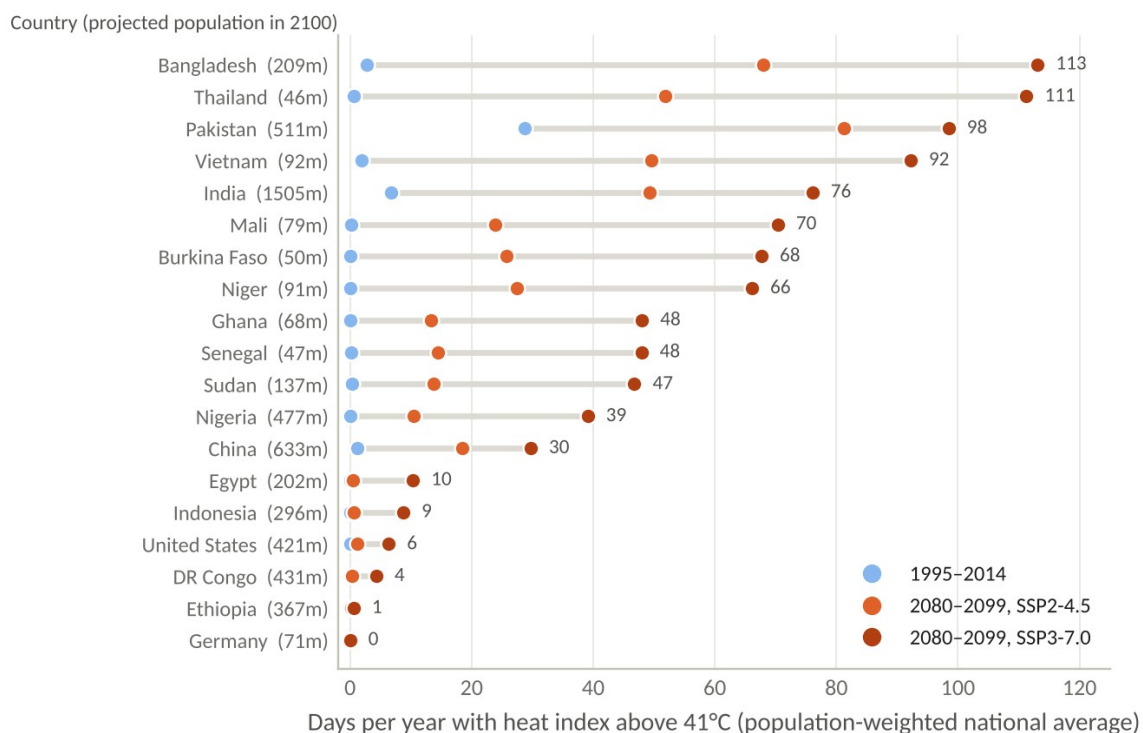
- **SSP1-2.6:** 13% of humanity, about **1.3 billion people**
- **SSP2-4.5:** 22%, about **2.2 billion**
- **SSP3-7.0:** 35%, about **3.6 billion**
- **SSP5-8.5:** 50%, about **5.1 billion**

The number facing **two months or more** of danger-level heat reaches 1.4 billion under SSP2-4.5 and 2.5 billion under SSP3-7.0, compared with about 100 million today. Under SSP2-4.5, India would account for about 670 million of these people, Pakistan 370 million and Bangladesh 140 million.

Country profiles

Figure 11 Days of danger-level heat in selected countries

Population-weighted national average days per year with a heat index above 41°C, baseline (1995–2014) and late century (2080–2099). Countries ranked by SSP3-7.0 values. Projected 2100 population in brackets.



Source: H Heuristics analysis of World Bank CCKP CMIP6 and ISIMIP data.

The country picture shows two distinct patterns of risk.

South Asia: from severe to extreme. South Asia already lives with dangerous humid heat. The 2022 heatwave in India and Pakistan was made about 30 times more likely by climate change ([World Weather Attribution](#)), and Jacobabad in Pakistan reached 51°C. By late century, the average Pakistani would experience about 81 days a year above a heat index of 41°C under SSP2-4.5, and 98 under SSP3-7.0. Bangladesh goes from about 3 days to 68, and to 113 under SSP3-7.0. India goes from 7 days to 49, and to 76

under SSP3-7.0. In northern India's most populous states, such as Uttar Pradesh, Bihar and West Bengal, local values are considerably higher than the national average.

Sub-Saharan Africa: from moderate to severe, and fastest-growing. Many African countries currently record few days above a heat index of 41°C, because temperatures are high but humidity and temperature peaks seldom coincide at the most dangerous levels. That changes with warming. Niger, Mali and Burkina Faso, which currently average almost no such days, reach 24–27 under SSP2-4.5 and 66–70 under SSP3-7.0. Nigeria goes from almost none to 10 and 39. The shift is starker at the lower 35°C threshold, which marks the limit of safe heavy work. Nigeria goes from about 11 such days a year to **118** under SSP2-4.5 and **176** under SSP3-7.0. Ghana goes from 11 to 146 and 217. These are places where most people work outdoors, few have cooling, and the population will double.

Table 4 Heat and air-quality profile of key countries

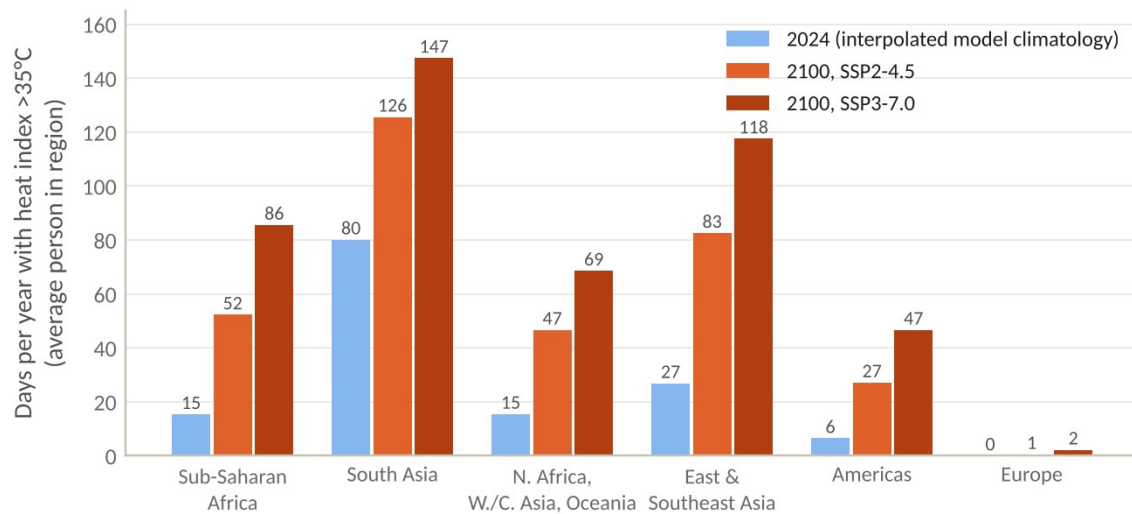
Country	Pop. 2100 (m)	Mean temp. now (°C)	Mean temp. 2090s, SSP2-4.5	Days HI>41°C, 1995–2014	Days HI>41°C 2090s, SSP2-4.5	Days HI>41°C 2090s, SSP3-7.0	PM2.5 (µg/m ³)
India	1,505	25.5	27.5	7	49	76	44
Pakistan	511	23.5	26.1	29	81	98	54
Nigeria	477	26.6	28.7	0	10	39	50
DR Congo	431	23.6	25.7	0	0	4	41
Ethiopia	367	19.4	21.6	0	0	1	20
Indonesia	296	25.6	27.5	0	1	9	18
Tanzania	263	22.5	24.6	0	0	2	25
Bangladesh	209	25.4	27.4	3	68	113	65
Egypt	202	22.5	24.9	0	0	10	41
Sudan	137	28.6	30.9	0	14	47	29
Niger	91	28.7	31.1	0	27	66	48
Mali	79	28.8	31.4	0	24	70	31
China	633	15.0	17.8	1	18	30	31
United States	421	14.2	17.0	0	1	6	8
Germany	71	9.7	11.8	0	0	0	9

Source: H Heuristics analysis of UN WPP 2024, ERA5 (1991–2020) and World Bank CCKP CMIP6 climatologies, population-weighted using ISIMIP data. PM2.5: population-weighted annual mean, 2024, via Our World in Data. HI = heat index.

Regional burden per person

Figure 12 Days of hazardous heat per person, by region

Days per year with a heat index above 35°C experienced by the average resident of each region.



Source: H Heuristics analysis of UN WPP 2024, World Bank CCKP CMIP6 and ISIMIP data.

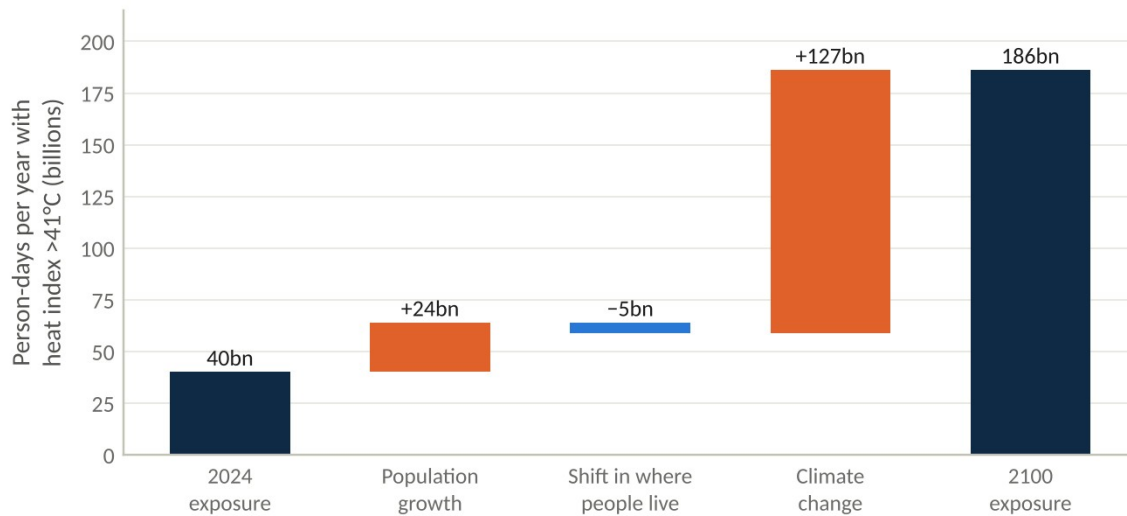
By 2100 the average resident of South Asia would face 126 days a year with a heat index above 35°C under SSP2-4.5, about four months, and 147 under SSP3-7.0. The average resident of Sub-Saharan Africa goes from 15 days to 52, and 86 under SSP3-7.0, a five-fold increase. The average European, by contrast, faces less than one such day. The gap between the climate of the world's growing populations and that of its wealthiest is widening.

Separating demography from climate

How much of the rise in exposure comes from population change, and how much from climate change? We decomposed the change in total exposure, measured as person-days per year with a heat index above 41°C, into three factors: growth in world population, the shift in where people live, and climate change. We used an exact Shapley decomposition.

Figure 13 What drives the rise in human exposure to danger-level heat

Change in global person-days per year with a heat index above 41°C, 2024 to 2100, SSP2-4.5, decomposed into population size, population distribution and climate change.



Source: H Heuristics analysis of UN WPP 2024, World Bank CCKP CMIP6 and ISIMIP data.

Total human exposure to danger-level heat rises from about **40 billion person-days a year to 186 billion**, a 4.6-fold increase. **Climate change accounts for about 127 billion person-days of the increase. Population growth accounts for about 24 billion.** The shift in where people live slightly *reduces* exposure on this measure, by about 5 billion person-days. That is because South Asia, which has by far the most danger-level heat today, shrinks slightly as a share of humanity, while Sub-Saharan Africa, which currently has less of it, grows.

The negative distribution term should not be misread. It reflects today's pattern of humid heat, which is concentrated in South Asia. It does not mean Africa's growth is safe. By the other measures in this report, including mean temperature, heat index above 35°C and the 29°C niche threshold, Africa's growth adds a great deal of exposure. And exposure alone leaves out vulnerability. The people added to the world's population this century will be added overwhelmingly in countries where incomes are lowest, cooling is scarcest and health systems are weakest. A day of heat index above 41°C in Kano or Kinshasa in 2080 carries a different risk from the same day in Dubai or Houston.

THE KEY INSIGHT FROM THE DECOMPOSITION

Climate change sets **how intense** the heat will be. Demography sets **who lives in it, and how many**. Development sets **how much harm it does**. Mitigation is the only lever on the first, and policy can act on all three. Under SSP1-2.6 total exposure in 2100 would be about 91 billion person-days, less than half the SSP2-4.5 figure and about a quarter of SSP3-7.0's 335 billion. Mitigation remains the largest single lever on the scale of this crisis.

SECTION 07

The Pollution Cycle

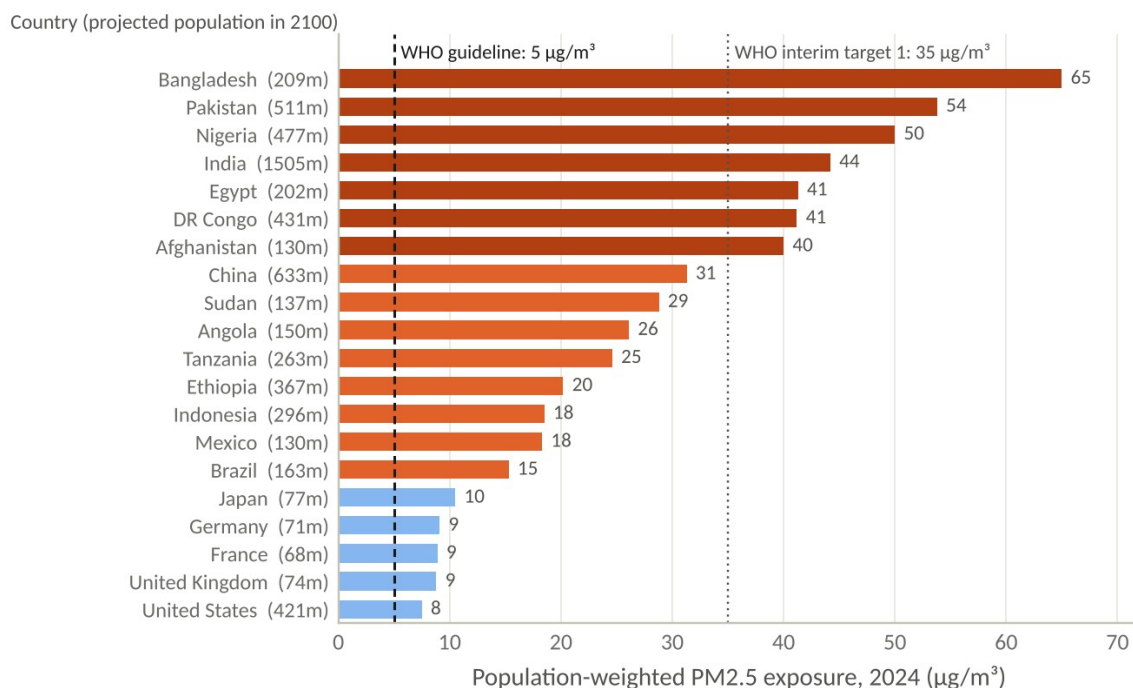
Heat is only one of the environmental stresses facing the fastest-growing regions. The second is the air itself. Fine particulate matter (PM2.5), particles smaller than 2.5 micrometres that penetrate deep into the lungs and bloodstream, is the world's largest environmental health risk. The [State of Global Air 2024](#) report estimates that air pollution caused **8.1 million deaths in 2021**, making it the second-leading risk factor for death worldwide, including more than 700,000 deaths among children under five. The Air Quality Life Index ([AQLI](#)) estimates that PM2.5 above the WHO guideline cuts about two years from the life expectancy of the average person on Earth, and considerably more in the most polluted parts of South Asia.

Almost no one breathes clean air

The [World Health Organization's 2021 Air Quality Guidelines](#) set an annual PM2.5 guideline of $5 \mu\text{g}/\text{m}^3$, with interim targets of 35, 25, 15 and $10 \mu\text{g}/\text{m}^3$ for countries far above it. In 2024 the population-weighted global average was about $30 \mu\text{g}/\text{m}^3$, **six times the guideline**. Fewer than one person in a thousand lives in a country whose average meets it.

Figure 14 Air pollution in the world's most populous countries of 2100

Population-weighted mean annual PM2.5 concentration, 2024. Countries listed with projected 2100 population.



Source: World Bank / Our World in Data, [outdoor air pollution exposure](#). WHO Air Quality Guidelines (2021). Chart: H Heuristics.

The ranking makes the problem plain. **Bangladesh ($65 \mu\text{g}/\text{m}^3$), Pakistan (54), Nigeria (50) and India (44)**, which will hold more than a quarter of humanity in 2100, are among the most polluted countries on Earth. Egypt, the Democratic Republic of the Congo and Afghanistan all exceed $40 \mu\text{g}/\text{m}^3$. By contrast, the United States, United Kingdom, France and Germany average $7\text{--}9 \mu\text{g}/\text{m}^3$. Regionally, the average South Asian

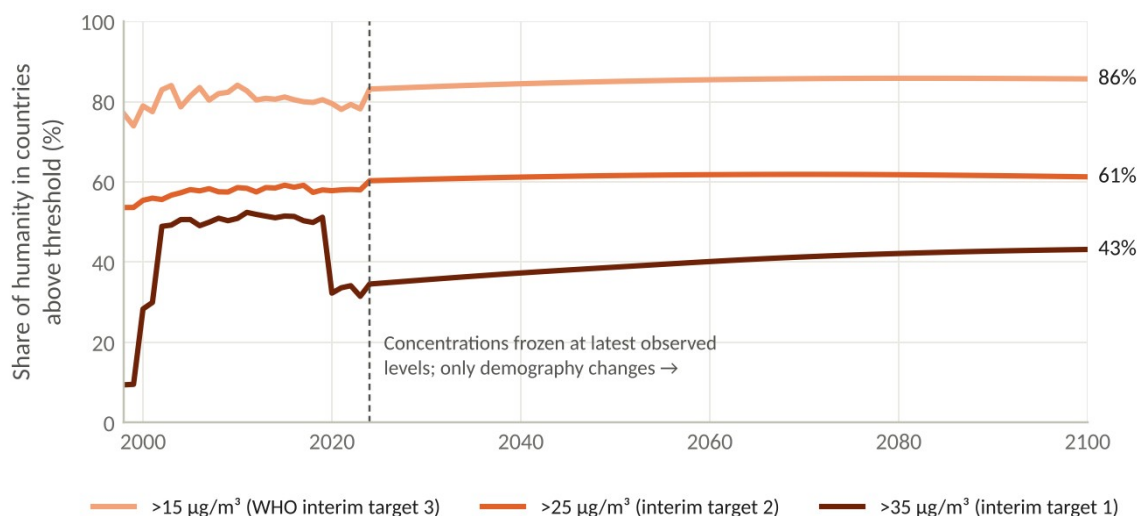
breathes air with about $47 \mu\text{g}/\text{m}^3$ of PM_{2.5} and the average Sub-Saharan African about 32, against about 12 for the average European.

Demographic drift towards dirtier air

Our analysis of heat found a "demographic warming" effect. Air quality shows a parallel "demographic pollution" effect. Holding every country's PM_{2.5} concentration fixed at its latest observed level and letting only population change, the population-weighted global average rises from 29.9 to $31.7 \mu\text{g}/\text{m}^3$ by 2100. The share of humanity living in countries above the WHO's *least ambitious* interim target, $35 \mu\text{g}/\text{m}^3$, rises from **35% to 43%**. Population growth is concentrated in the most polluted places.

Figure 15 Demography pushes humanity towards dirtier air

Share of world population living in countries whose population-weighted PM_{2.5} exceeds WHO interim targets. Observed to 2024, then concentrations frozen at latest levels so that only demography changes. The sharp fall around 2020 reflects China's clean-air gains taking it below $35 \mu\text{g}/\text{m}^3$.



Source: H Heuristics analysis of World Bank / Our World in Data PM_{2.5} exposure and UN WPP 2024.

The chart also contains real hope. The sudden drop in the share of humanity above $35 \mu\text{g}/\text{m}^3$ around 2020 is China. Between its 2013 Air Pollution Prevention and Control Action Plan and the early 2020s, China cut population-weighted PM_{2.5} by roughly 40%, among the fastest large-scale improvements in air quality ever recorded, which [AQLI](#) estimates has added years to Chinese life expectancy. Air pollution is not a fixed feature of development. It responds quickly to policy.

Why heat and pollution form a cycle

Heat and air pollution are not separate problems that happen to coincide. They reinforce one another through at least five mechanisms, which together form what this report calls the **pollution-heat cycle**:

- 1. Heat makes pollution more harmful.** Exposure to high temperatures and high PM_{2.5} together produces larger increases in mortality than either alone, especially for cardiovascular and respiratory disease. Heat also accelerates the chemical reactions that form ground-level ozone, a "climate penalty" on air quality.
- 2. Heat drives demand for cooling, which drives emissions.** Where electricity comes from coal, as in much of South Asia, every air conditioner switched on during a heatwave adds to local air pollution and to global warming. Where the grid fails, diesel generators fill the gap and emit at street level. The [IEA](#)

projects that the global stock of air conditioners could more than triple by 2050, with India alone accounting for a large share of new demand.

3. **Pollution has been masking warming.** Sulphate aerosols from coal burning and shipping reflect sunlight and cool the planet. The IPCC estimates that aerosols have offset about 0.4°C of warming (likely range 0.0–0.8°C). As regions clean their air, which they must for health, part of this masking will be removed and regional warming will accelerate. South and East Asia, where aerosol loads are highest, will feel this most.
4. **Drought, heat and land degradation generate dust and fire.** In the Sahel, harmattan dust and desert expansion add to particulate loads. Across South Asia, crop-residue burning, which is driven partly by tight sowing windows, sends smoke over the Indo-Gangetic Plain each autumn. Heat-stressed landscapes also burn more readily.
5. **Poverty locks in polluting fuels.** About 2.1 billion people still cook with wood, charcoal, dung or kerosene ([Tracking SDG7](#)), and most of them are in Sub-Saharan Africa and South Asia. Household air pollution concentrates exposure on women and young children. Cooking indoors with solid fuel during extreme heat compounds both hazards inside the home.

THE AEROSOL PARADOX

Cleaning the air in South Asia is one of the most important public health interventions available anywhere. Over the coming decades it could save millions of lives. Because sulphate aerosols are currently masking some regional warming, however, rapid cuts in coal-related air pollution without parallel cuts in CO₂ and methane would temporarily *intensify* regional heat. The resolution is not to keep the air dirty. It is to cut **both** pollutants together: replace coal with clean power, which cuts CO₂ and particulates at once, and cut methane, the fastest-acting lever on near-term warming. This is one more reason why mitigation and adaptation in the global South cannot be separated.

A compounding burden

The regions gaining most of humanity's future population therefore carry a double environmental load: heat at the edge of physiological tolerance, and air that shortens lives by years. Each makes the other more dangerous. Both fall hardest on the same people, those who work outdoors, live in poorly ventilated housing, cook with solid fuel, and cannot afford clean electricity or cooling. The pollution–heat cycle is a cycle of exposure, and it is also a cycle of poverty.

SECTION 08

Water, Food and Land Under Strain

Heat and pollution act directly on the body. Climate change also acts through the systems that feed and water people. The regions examined in this report are, overwhelmingly, places where large shares of the population still depend on rain-fed agriculture, local water sources and natural resources for their livelihoods. That dependence turns a climate shock into a food, income and health shock within weeks.

Monsoons and rainfall: more water, less reliably

South Asia's agriculture, economy and culture are organised around the summer monsoon. Climate models broadly project that total monsoon rainfall will *increase* with warming, by around 5% per degree Celsius according to a multi-model assessment ([Katzenberger et al., 2021](#)). They also project that it will become more **variable**: wetter extremes, longer dry spells within the season, and less predictable onset. For a farmer, an unreliable monsoon can be worse than a weaker but predictable one. Floods destroy crops and housing, and failed rains in the critical sowing weeks destroy the season.

In the Sahel, the picture is uncertain and regionally mixed. After the catastrophic droughts of the 1970s and 1980s, rainfall partially recovered, but with more intense storms and higher temperatures that raise evaporation. In the Sahel and the Horn of Africa, where rain-fed agriculture and pastoralism support hundreds of millions of people, even unchanged rainfall becomes less effective as heat increases evaporation from soils and crops.

Groundwater: the hidden buffer running down

The Indo-Gangetic Basin holds one of the world's largest aquifer systems, and it is one of the most heavily exploited. Groundwater irrigation underpins food security for hundreds of millions of people across India, Pakistan, Nepal and Bangladesh. [MacDonald et al. \(2016\)](#) found widespread depletion in parts of the north-west of the basin, together with serious water-quality problems, including salinity and arsenic, across much of the rest. Warming increases irrigation demand, because hotter crops need more water. A study in *Science Advances* found that when farmers adapt to warming by pumping more, **India's rate of groundwater loss could triple** by mid-century ([Bhattarai et al., 2023](#)).

Melt from Himalayan glaciers and snow sustains the Indus in particular through the dry season. Rising temperatures are expected to increase meltwater at first and then reduce it later in the century as glaciers shrink. The resulting *peak water* and decline would leave the Indus Basin, home to more than 300 million people by late century, under severe pressure.

Crops near their thermal limits

Most staple crops have temperature thresholds above which yields collapse. Maize, the staple of much of Sub-Saharan Africa, is especially sensitive to days above about 30°C. Rice yields fall when night-time temperatures rise and when heat strikes during flowering. A major crop-model intercomparison ([Jägermeyr et al., 2021](#)) projected that, under high emissions, global **maize yields could fall by about 24%** by late century, with losses emerging as early as the 2030s, while wheat yields could rise in higher latitudes. Losses

are concentrated in low-latitude regions, the same places where population and food demand will grow fastest.

The implications go beyond yields:

- **Labour on farms.** Much of the harm from heat in agriculture comes through human bodies, not crops. Smallholder farmers and agricultural labourers lose working hours during the hottest parts of the day and season (Section 9).
- **Livestock.** Cattle, goats and poultry suffer heat stress, with falling milk yields, fertility and growth. Pastoralist livelihoods across the Sahel and the Horn of Africa are directly exposed.
- **Fisheries.** Warming lakes and coastal waters reduce fish stocks, an important protein source in West Africa, around Lake Victoria and in coastal South Asia.
- **Nutrition.** Elevated CO₂ reduces the concentrations of zinc, iron and protein in staple grains, a quiet threat to populations already burdened by micronutrient deficiencies.

Coasts and deltas

Many of the fastest-growing cities sit on low-lying coasts or deltas: Lagos, Dhaka, Kolkata, Karachi, Dar es Salaam, Abidjan, Alexandria and Mumbai. The IPCC projects global mean sea-level rise of roughly **0.44–0.76 m by 2100 under SSP2-4.5** and 0.63–1.01 m under SSP5-8.5, with higher outcomes possible if ice sheets become unstable. For deltas that are also subsiding through groundwater extraction and sediment starvation, relative sea-level rise will be faster. Storm surges, salinisation of soils and drinking water, and the loss of coastal land compound the heat and pollution burden in these cities. The population living in low-elevation coastal zones worldwide is projected to exceed one billion by 2050.

COMPOUNDING, NOT ADDING

These stresses do not simply add up. They interact. A heatwave during a drought raises demand for irrigation just as groundwater falls. A failed harvest pushes families to sell livestock, take children out of school, or send a family member to work in the city, often into outdoor construction work in the heat. A flood contaminates water supplies just as high temperatures accelerate the growth of pathogens. The IPCC's Sixth Assessment found that between 2010 and 2020, human mortality from floods, droughts and storms was **15 times higher in highly vulnerable regions** than in regions with very low vulnerability ([IPCC AR6 WGII](#)). Compounding is the mechanism that turns hazard into crisis.

SECTION 09

Poverty, Work and the Adaptation Gap

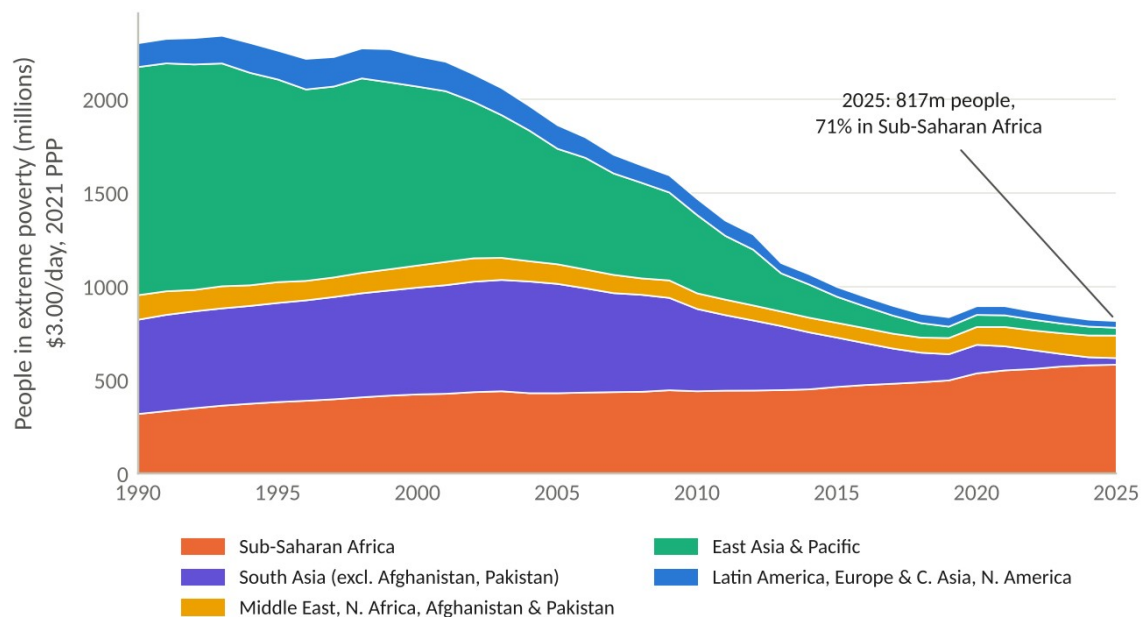
Exposure to heat becomes harm through vulnerability. The single strongest predictor of vulnerability is poverty: the lack of money, assets, services and choices that would allow people to protect themselves. On this dimension the geography of the coming century is again unforgiving.

Extreme poverty has moved to Africa

In 1990, 2.3 billion people lived in extreme poverty, measured by the World Bank's international poverty line of US\$3.00 a day (2021 prices). Most of them were in East Asia and South Asia. Since then China's economic transformation, followed by India's, has lifted well over a billion people out of extreme poverty. This is one of the great achievements in human history. The decline has largely bypassed Sub-Saharan Africa, where the number of extreme poor has grown with population, from about 320 million in 1990 to about 584 million today.

Figure 16 The geography of extreme poverty has shifted to Sub-Saharan Africa

Number of people living below US\$3.00 a day (2021 PPP), by World Bank region. Values for recent years are nowcasts.



Source: World Bank Poverty and Inequality Platform, via [Our World in Data](#). Chart: H Heuristics.

Today about **817 million people** live in extreme poverty, and **71% of them are in Sub-Saharan Africa**. The region that holds most of the world's extreme poor is also the region gaining most of the world's people and some of the steepest increases in heat. Poverty, population growth and climate exposure now share one geography.

How poverty turns heat into harm

Poverty shapes heat risk at every step:

- **Housing.** Informal housing with metal roofs, little insulation and poor ventilation can be several degrees hotter indoors than outdoors at night. More than a billion people live in slums or informal settlements.
- **Energy.** About **685 million people** still had no electricity in 2022, more than 80% of them in Sub-Saharan Africa ([Tracking SDG7, 2024](#)). Without electricity there are no fans, no refrigeration for food and medicines, and no air conditioning. Many more people have electricity that fails during the heatwaves when it is most needed.
- **Cooling.** The [IEA](#) estimates that only about 8% of the 2.8 billion people living in the hottest regions own air conditioners. Sustainable Energy for All's *Chilling Prospects* series estimates that more than a billion people face high risks from lack of access to cooling.
- **Water.** People without piped water cannot drink, wash or cool themselves adequately during heatwaves, and fetching water exposes them further.
- **Health care.** Heat illness is treatable if recognised early. Many of the fastest-growing regions have too few health workers, clinics without reliable power, and no systems to monitor heat deaths.
- **Information.** Heat early warnings only help if they reach people and if those people can act on them, for example by staying home from work without losing income.

Work in the heat

Around the world, **outdoor and informal workers** carry the heaviest burden of heat. These include farmers, construction workers, street vendors, rickshaw drivers, brick-kiln labourers and waste pickers. They cannot choose when to work, and they lose income if they stop. In India, more than 80% of employment is informal. In much of Sub-Saharan Africa the share is higher still.

The International Labour Organization projected that heat stress would reduce total working hours worldwide by **2.2% by 2030**, equivalent to 80 million full-time jobs, with **South Asia and West Africa** hit hardest ([ILO, 2019](#)). The [Lancet Countdown 2024](#) estimates that heat exposure caused the loss of **512 billion potential labour hours in 2023**, a record, worth an estimated US\$835 billion in lost income, concentrated in low- and middle-income countries and in agriculture.

Our projections suggest these losses will grow steeply. By 2100 under SSP2-4.5 the average person in Sub-Saharan Africa would face about 52 days a year with a heat index above 35°C, and the average South Asian about 126. On such days strenuous outdoor work is unsafe without long rest breaks. For an economy where most work is physical and outdoors, that is a structural constraint on output, not an occasional disruption.

The macroeconomic drag

Heat is a constraint on development itself. [Burke, Hsiang and Miguel \(2015\)](#) found that economic productivity rises with temperature up to an annual average of about 13°C and then declines steeply. Under unmitigated warming they projected that average global incomes would be about 23% lower in 2100 than in a world without climate change, with the losses concentrated in hot, poor countries. [Diffenbaugh and Burke \(2019\)](#) estimated that warming since 1960 has already widened the gap between the world's richest and poorest countries by about 25%.

The places where humanity will grow are the places where heat most constrains the growth that would let people protect themselves from heat.

This is the heart of the **heat trap**. Development is the most powerful form of adaptation, because wealth buys cooling, better housing, health care and mobility. Heat itself slows development, most of all in the regions that need it most. If growth fails, the populations gaining most of humanity's future numbers will be caught between rising hazard and stalled capacity.

The adaptation gap

The world is not yet financing a way out. UNEP's [Adaptation Gap Report 2024](#) estimates that developing countries need **US\$187–359 billion a year** for adaptation this decade, while international public adaptation finance was about **US\$28 billion** in 2022. That leaves a gap of roughly an order of magnitude. At COP29 in 2024, countries agreed a new collective goal of [at least US\\$300 billion a year by 2035](#) for climate finance as a whole, covering mitigation and adaptation. That is far short of the needs identified by developing countries. Most adaptation finance arrives as loans, adding to debt burdens in countries that already spend more on debt service than on health.

DEVELOPMENT AS THE DECISIVE VARIABLE

None of this is inevitable. Today's high-income countries, from Singapore to the United Arab Emirates to the southern United States, show that people can live safely in extreme heat when they have reliable electricity, cooling, good housing and strong public health systems. Singapore, one of the hottest and most humid cities on Earth, is also one of the wealthiest. The question for the twenty-first century is whether the hundreds of millions of people being born into similar or harsher climates in Africa and South Asia will reach similar levels of protection, and how fast. Each decade of delay leaves another cohort of children growing up exposed.

SECTION 10

Health Systems Under Heat

Climate change is, above all, a health crisis. The [World Health Organization](#) estimates that between 2030 and 2050 it will cause about 250,000 additional deaths a year from undernutrition, malaria, diarrhoea and heat stress alone. That is a conservative figure, because it leaves out many pathways. This section looks at how the demographic shift into hot regions changes the health burden.

Heat mortality is already large and largely invisible

A global study in *The Lancet Planetary Health* ([Zhao et al., 2021](#)) estimated that about 5 million deaths a year between 2000 and 2019 were associated with non-optimal temperatures, of which roughly 490,000 a year were linked to heat. The share linked to heat was rising. The [Lancet Countdown 2024](#) reported that heat-related deaths among people over 65 had risen by **167% compared with the 1990s**, far more than the rise expected from population ageing alone.

These figures almost certainly undercount deaths in Africa and South Asia. Heat rarely appears on a death certificate. It acts by worsening heart, lung and kidney disease, and many deaths in low-income countries are never registered at all. When researchers estimate heat mortality, they rely heavily on data from Europe, North America and East Asia, where records exist. The regions where most of humanity will live are the regions where the health effects of heat are least measured.

Projected mortality

The most comprehensive economic analysis of future heat mortality ([Carleton et al., 2022](#)) combined mortality data from 40 countries with projections of income growth and adaptation. Under high emissions, it projected that climate change would raise global mortality by about **73 deaths per 100,000 people a year by 2100**, comparable to the death rate from all infectious diseases today. That projection already *includes* the benefits of rising incomes and adaptation. The burden is extremely unequal. Cold, wealthy regions may see net benefits from fewer cold deaths, while hot, poor regions, including much of Sub-Saharan Africa, South Asia and the Middle East, see mortality increases several times the global average.

Children, mothers and the old

The demographic profile of the hottest regions concentrates heat risk on the groups that are most physiologically vulnerable.

Children. UNICEF's analysis [*The Coldest Year of the Rest of Their Lives*](#) found that 559 million children were already exposed to high heatwave frequency in 2020, and that by 2050 virtually every child on Earth, more than 2 billion, would be. Children dehydrate quickly, cannot regulate their own exposure, and depend on adults who may themselves be overwhelmed.

Pregnancy and birth. Heat during pregnancy raises the risk of preterm birth, stillbirth and low birth weight ([Chersich et al., 2020](#)). In countries where many births already happen without skilled attendants, heat adds to maternal and newborn risk.

Older people. Later in the century, the ageing of India, Bangladesh and eventually Africa will put hundreds of millions of older adults into the hottest climates on Earth. India's median age is projected to rise from 28 today to 48 by 2100. In many households older people are cared for at home by family members without cooling. The heatwaves that kill older people in Europe today will be more frequent and more severe in places with fewer protections.

Disease in a warmer world

Warmer temperatures expand the range and the transmission season of many infectious diseases.

- **Dengue** and other mosquito-borne viruses are expanding rapidly. WHO recorded more than 14 million dengue cases in 2024, a record ([WHO](#)). Rapid, unplanned urban growth with poor water storage and drainage provides ideal breeding conditions for *Aedes* mosquitoes.
- **Malaria** transmission is moving into higher altitudes in the East African highlands, which were historically protected by cooler temperatures. In the hottest lowlands, conditions may eventually become too hot for some mosquito species, but that is little comfort when other risks rise. A study in *The Lancet Planetary Health* projected that, under high-emission and high-population scenarios, several billion additional people could be at risk of malaria and dengue by the 2070s ([Colón-González et al., 2021](#)).
- **Water-borne and food-borne disease**, including cholera and diarrhoeal disease, rises with heat and flooding, especially where sanitation is poor.

Chronic and hidden harms

Repeated heat exposure damages health in ways that do not show up in heatwave mortality figures. Chronic kidney disease linked to heat and dehydration has emerged among agricultural workers in Central America, Sri Lanka and India. Heat raises rates of violence, suicide and mental illness, worsens sleep, and impairs cognitive function and learning. Combined with the PM2.5 exposure described in Section 7, the result is a population whose health is persistently eroded, and the cumulative loss of healthy life years may exceed the toll of acute deaths.

HEALTH SYSTEMS AT THE POINT OF FAILURE

Health systems themselves are exposed. Hospitals and clinics without reliable power cannot keep vaccines or insulin cold, and they cannot cool patients with heat stroke. During heatwaves, demand for emergency care surges just as health workers are themselves strained. The [Lancet Countdown](#) and the WHO both call for *climate-resilient health systems*: solar-powered clinics, cool rooms, heat-health early warning systems, surveillance that counts heat deaths, and training to recognise and treat heat illness early. These are relatively low-cost investments with very high returns, and they are almost entirely absent from most of the countries examined in this report.

SECTION 11

Mobility, Conflict and the Trapped

When conditions become unliveable, people move. Migration is one of humanity's oldest and most effective forms of adaptation. Public debate about "climate migration" often imagines mass flows of people from the global South to Europe and North America. The evidence points somewhere quite different, and in some ways more troubling.

Most climate mobility will be internal and regional

The World Bank's *Groundswell* report ([Clement et al., 2021](#)) projected that, under pessimistic scenarios, up to **216 million people could be internal climate migrants by 2050**. These are people moving within their own countries, away from failing agriculture, water scarcity and rising seas. Sub-Saharan Africa accounted for the largest share, at up to 86 million, followed by East Asia and the Pacific (49 million) and South Asia (40 million). The study also found that early action on emissions and inclusive development could cut these numbers by up to 80%.

Climate mobility is already visible. The [Internal Displacement Monitoring Centre](#) recorded **45.8 million internal displacements caused by disasters in 2024**, the highest figure since its records began. Most were driven by floods and storms, and most of those displaced returned home, but often to more precarious circumstances.

Most of this movement is **rural-to-urban**. That moves people out of exposed farming livelihoods, but into the expanding informal settlements of cities that are themselves heat islands, often into construction and other outdoor work. Migration can reduce one kind of climate risk while increasing another.

The trapped populations

The UK Government's landmark *Foresight* review ([2011](#)) identified a group that rarely features in public debate: **trapped populations**. These are people who are exposed to worsening environmental conditions but lack the resources to move. Migration takes money for travel, for housing on arrival, and for the period without income. It also takes networks, documents and information. The poorest households, and especially older people, people with disabilities and women with care responsibilities, are often least able to leave.

This creates a cruel paradox. As climate shocks deplete household assets, they can *reduce* the ability to migrate just as the need rises. The people most exposed to the heat trap may be the least able to escape it. Our projections suggest that by 2100 under SSP2-4.5 about 1.5 billion people will live where the mean annual temperature is 29°C or above, and about 2.2 billion will face a month or more of danger-level heat every year. Neither international migration nor internal movement can relocate populations on that scale. The overwhelming majority of people in these regions will stay where they are. **Adaptation in place is not optional. It is the main event.**

International migration and borders

International migration will still grow, and it matters. Mobility between countries in the global South, such as from the Sahel to coastal West Africa or from Bangladesh to the Gulf, already dwarfs migration to Europe.

Labour migration to the Gulf states itself raises heat-safety concerns, because many migrant workers labour outdoors in some of the hottest conditions on Earth.

Ageing, shrinking populations in Europe, East Asia and North America will face labour shortages that migration could help fill. Well-designed labour mobility pathways, with skills partnerships, safe recruitment and protections, could benefit both origin and destination countries. They could also give millions of people in the heat-exposed regions a protected choice to move. The alternative, rising pressure met by closed borders, militarised routes and deaths in the Mediterranean and the Sahara, has a humanitarian cost of its own.

Climate, conflict and fragility

A large body of research links heat and climate shocks to conflict. A meta-analysis by [Hsiang, Burke and Miguel \(2013\)](#) found that each standard-deviation shift towards hotter temperatures or more extreme rainfall increased the frequency of interpersonal violence by about 4% and of intergroup conflict by about 14%. Climate is rarely the sole cause of conflict. It acts as a *threat multiplier*, intensifying competition over land and water, undermining livelihoods, weakening state legitimacy and making recruitment by armed groups easier.

The Sahel illustrates the risk. Across Mali, Burkina Faso and Niger, which are among the countries with the fastest-rising heat exposure in our analysis, conflict between armed groups, pastoralists, farmers and states has displaced millions of people. A heatwave in 2024 that WWA found would have been impossible without climate change struck populations already living through insecurity and displacement. Our projections show these three countries alone growing from about 74 million people today to about 220 million by 2100.

MOBILITY AS ADAPTATION

Policy should treat migration neither as a threat nor as a solution in itself. It should be a **protected option**. That means planning for urban growth so that migrants arrive into serviced land rather than informal settlements. It means portable social protection, regional free-movement agreements such as those of ECOWAS and the African Union, labour mobility pathways to ageing economies, and, as a last resort, legal frameworks for planned relocation of communities from places that become uninhabitable. Each of these reduces the human cost of a movement that will happen whether or not it is planned.

SECTION 12

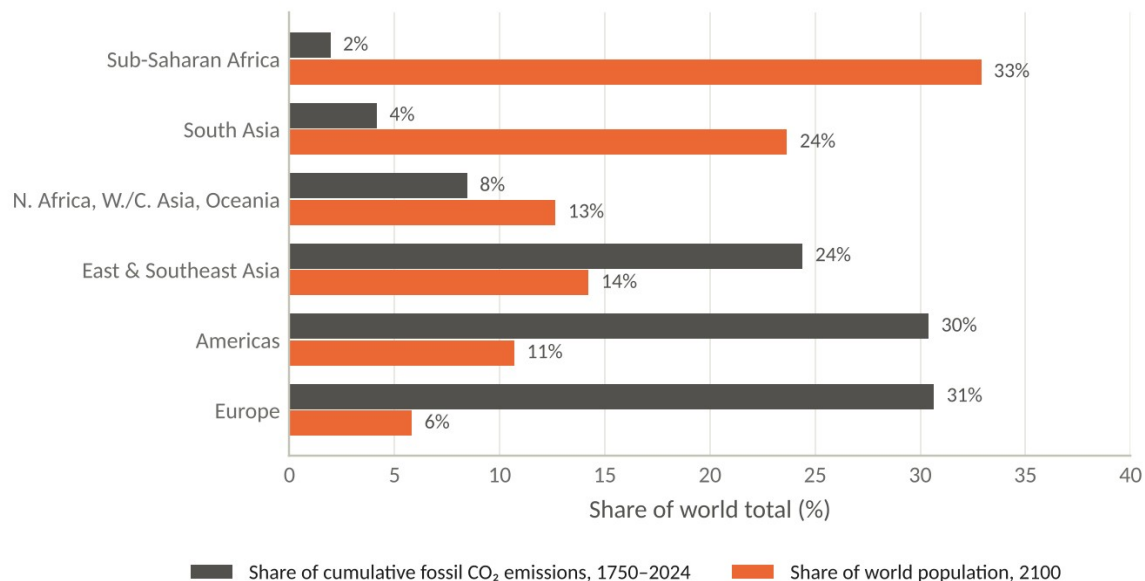
Responsibility and Justice

The heat trap is a humanitarian crisis. It is also a crisis of justice. The people who will live with the worst of the century's heat have contributed almost nothing to causing it.

Who caused it and who will live with it

Figure 17 Responsibility versus exposure

Each region's share of cumulative fossil CO₂ emissions from 1750 to 2024, compared with its share of the world's population in 2100. Fossil and industrial CO₂ excluding land-use change.



Source: Global Carbon Budget via [Our World in Data CO₂ dataset](#); UN WPP 2024. Regional aggregation by H Heuristics.

Since 1750, Europe and the Americas have produced about **61% of all fossil CO₂ emissions**. In 2100 they will be home to about 17% of humanity. Sub-Saharan Africa has produced about **2%** of cumulative fossil emissions and will be home to **33%** of humanity. South Asia has produced about 4% and will hold 24%. In total, the two regions that will hold 57% of the people of 2100 produced about 6% of the CO₂ that is warming the planet.

The gap is just as stark today. In 2024 the average American emitted about 14 tonnes of CO₂ from fossil fuels and industry, and the average European Union or Chinese citizen around 6–9 tonnes. The average Indian emitted about 2.2 tonnes, the average Nigerian 0.6, and the average resident of Niger or the Democratic Republic of the Congo about 0.1. [Lenton et al. \(2023\)](#) put this injustice in personal terms: the lifetime emissions of about **1.2 average Americans** (or 3.5 average global citizens today) are enough to expose **one future person** to unprecedented heat. That person will most likely live in India, Nigeria or the Sahel.

Three dimensions of injustice

The heat trap involves injustice of three distinct kinds.

1. **Historical.** Accumulated CO₂ from two centuries of industrialisation in Europe, North America and, more recently, East Asia is the primary cause of warming. The places that grew rich through fossil fuels are, mostly, cool places that will suffer least.
2. **Intergenerational.** Because CO₂ persists for millennia (Section 13), today's emissions impose costs on people who are not yet born. Most of those people will be born in Africa and South Asia. They have no vote in the decisions being made now.
3. **Capability.** The ability to adapt, whether through cooling, wealth, health systems or the freedom to move, is distributed almost inversely to exposure. Even where adaptation is technically possible, it is often financially out of reach for the people who need it.

The children who will inherit the hottest climates in human history are being born now, in the places that did least to create them.

What justice implies

Justice in this context is not abstract. It has practical implications that appear throughout the agenda in Section 16:

- **Mitigation by high emitters.** The fastest route to reducing harm in Africa and South Asia is cutting emissions in the high-emitting economies, which remain the largest annual sources.
- **Finance at scale, mostly as grants.** Adaptation and loss-and-damage finance should flow at the scale of need, primarily as grants, and should not add to debt burdens. The [Fund for responding to Loss and Damage](#) established after COP27 is a start, but pledges remain at the level of hundreds of millions of dollars against needs measured in hundreds of billions.
- **Access to clean energy.** Africa has about 60% of the world's best solar resources but only about 1% of installed solar capacity ([IEA Africa Energy Outlook 2022](#)). Affordable capital for clean energy is both a mitigation and an adaptation priority. It is also the foundation of cooling.
- **A voice for the future.** Global decisions about climate, finance and development should give weight to the populations that will bear their consequences, including future generations and the countries whose share of humanity is rising fastest.

A SHARED INTEREST, NOT CHARITY

This is not simply a moral claim on wealthy nations. In a connected world, instability, pandemics, supply-chain disruption and forced displacement do not stay within borders. The economic future of the global economy also runs through Africa and South Asia, which will supply much of the world's workforce, consumers and innovation by mid-century. Investing in liveable conditions in the regions where humanity is growing is the most important investment available in the shared future of the species.

SECTION 13

The Long Tail: Centuries and Millennia

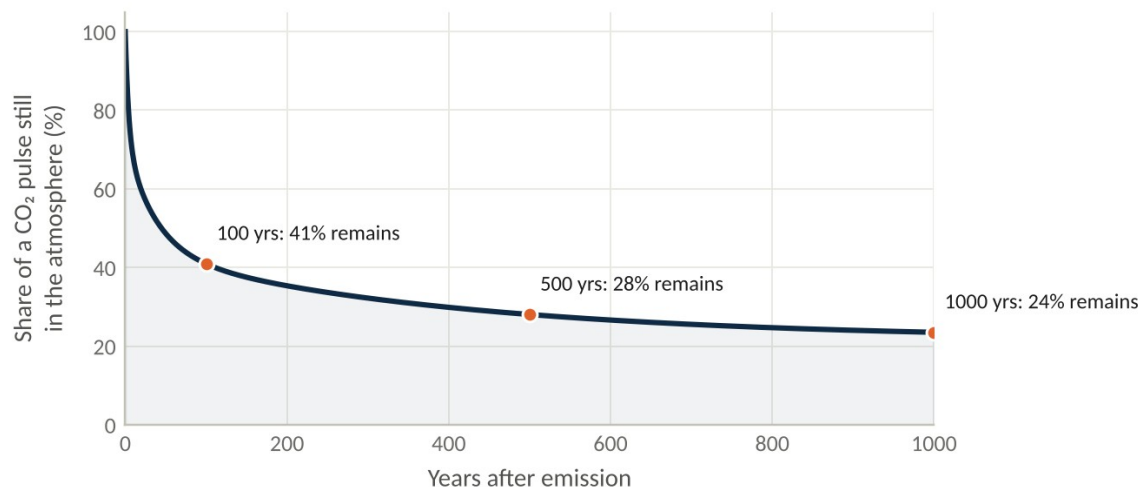
Most climate projections stop at 2100. The year is a convention, not a boundary. The children born in Lagos, Kinshasa and Patna in the 2090s will live into the 2170s, and their great-grandchildren into the twenty-third century. The question of whether conditions will improve, stabilise or keep worsening after 2100 matters a great deal for the populations at the centre of this report. The physical science gives a clear and sobering answer.

Carbon dioxide does not go away

Carbon dioxide is unlike most pollutants. It is not broken down in the atmosphere. It is gradually redistributed into the ocean and land biosphere, and finally removed by slow geological processes over many thousands of years. A multi-model study by [Joos et al. \(2013\)](#) characterised how a pulse of CO₂ decays. About 40% remains in the atmosphere after a century, nearly 30% after 500 years, and about a quarter after 1,000 years. [Archer et al. \(2009\)](#) concluded that a substantial fraction of fossil carbon will continue to affect climate for tens of thousands of years.

Figure 18 Carbon dioxide persists for millennia

Fraction of a pulse of CO₂ emissions remaining in the atmosphere over time, using the multi-model mean impulse response function of Joos et al. (2013) for present-day conditions.



Source: Joos et al. (2013), *Atmospheric Chemistry and Physics*. Chart: H Heuristics.

Warming stops, but does not reverse

When net CO₂ emissions reach zero, global temperatures are expected to stop rising more or less straight away. The IPCC assesses the "zero emissions commitment" as close to zero. They are not expected to fall back, however. As the ocean slowly absorbs CO₂, it also slowly releases stored heat, and the two effects approximately cancel. [Solomon et al. \(2009\)](#) showed that warming caused by CO₂ is **largely irreversible for at least 1,000 years** after emissions stop.

The implication for this report is direct. **The level of warming the world reaches at net zero is, without large-scale carbon removal, the level that humanity will live with for many centuries.** If the world stabilises at

2.7°C, the late-century conditions described in Sections 4 to 6 are not a peak to be endured and then left behind. They are the new baseline climate of the regions that will hold most of humanity. Returning to cooler conditions would require removing hundreds of billions of tonnes of CO₂ from the atmosphere, which is far beyond any capacity that exists today.

Some changes keep growing for centuries

Some parts of the climate system respond so slowly that they keep changing long after temperatures stabilise.

Table 5 Long-term commitments of twenty-first-century warming

System	Commitment	Implication
Global temperature	Roughly constant for 1,000+ years after net-zero CO ₂	Late-century heat in the tropics becomes the long-run baseline
Sea level	About 2–3 m over 2,000 years at 1.5°C; 2–6 m at 2°C; 19–22 m at 5°C (IPCC AR6)	Deltas and coastal megacities face continuing loss for centuries
Ice sheets	Partial loss of Greenland and West Antarctica may become self-sustaining above about 1.5–2°C	Multi-metre sea-level rise locked in for future generations
Deep ocean	Warming, acidification and oxygen loss continue for centuries to millennia	Fisheries and coastal food security decline further
Permafrost and carbon feedbacks	Continued release of CO ₂ and methane	Adds warming that must be offset by additional removals

Sources: IPCC AR6 WGI Summary for Policymakers (B.5); Solomon et al. (2009); Clark et al. (2016); Armstrong McKay et al. (2022).

[Clark et al. \(2016\)](#) examined the consequences of twenty-first-century policy over a 10,000-year horizon. They concluded that emissions this century will commit the planet to climate and sea-level changes that last for many millennia, and that the regions now home to about a fifth of the world's population could eventually be submerged. [Armstrong McKay et al. \(2022\)](#) assessed that several climate tipping points, including the collapse of the Greenland and West Antarctic ice sheets, could be triggered within the Paris Agreement range of 1.5–2°C.

Will it get better, stabilise or get worse?

A central question for this report is whether conditions in the heat-exposed regions will keep worsening, or stabilise at unsafe levels, over the coming centuries. On the physical side the answer has three parts:

- 1. Until net-zero is reached, it gets worse.** Every year of continued emissions adds to warming. The trajectory of heat exposure in Sections 4 to 6 keeps rising until emissions stop.
- 2. After net-zero, temperatures stabilise at their peak level for centuries.** Without large-scale carbon removal, there is no natural "recovery" on any timescale that matters for human societies.
- 3. Some impacts, especially sea-level rise, keep worsening for centuries** even after temperatures stabilise.

On the human side the outlook is open. The same physical climate can be lived in very differently depending on wealth, technology, institutions and choices. Over the next century and beyond, populations may stabilise or decline in today's high-growth regions too, as fertility falls everywhere. Cooling technology, urban design and health systems can improve dramatically. A world of 2.7°C need not be a world of permanently rising suffering, *if* the investments described in Section 16 are made. A world of 3.6°C or more would push larger areas beyond the limits of what any adaptation can sustain. The long tail of the physical climate makes the

next three decades of emissions policy the most consequential in human history for the habitability of the places where most people will live.

The warming reached at net-zero is the warming humanity will keep. The choices of the next thirty years set the climate for the next thousand.

SECTION 14

Life in 2100: Portraits of the Middle Half of Humanity

What will daily life be like for the typical person at the end of this century? Statistics can describe exposure. They cannot describe experience. This section draws on the projections in this report to sketch five composite portraits of people in the middle half of humanity in 2100. They are **illustrative scenarios, not forecasts**. Each is built from the projected climate, demography and development conditions of a real place under the SSP2-4.5 pathway, and each shows a range of outcomes that depends on the choices made between now and then.

WHO IS THE MEDIAN HUMAN OF 2100?

On current projections, the person at the middle of humanity in 2100 is around forty years old, as likely to be a woman as a man, and lives in a city in Sub-Saharan Africa or South Asia, in a country that is low or lower-middle income today. The mean annual temperature where this person lives is about 26°C. They experience around two months a year with a heat index above 35°C and, depending on exactly where they live, anything from a few days to several weeks above 41°C. Unless their country follows China's path on air quality, they breathe air several times dirtier than the WHO guideline. Whether they have reliable electricity, a cool home, safe work and a functioning clinic is the single most important unknown in this report.

Kano, northern Nigeria: Amina, 34, market trader

Kano's metropolitan population, about 4–5 million today, could be several times larger by 2100 as Nigeria approaches half a billion people. The mean annual temperature in northern Nigeria rises towards 29°C. In the hottest months before the rains, from March to May, daytime highs regularly exceed 42°C, and humidity rising with the monsoon's arrival pushes the heat index into the danger zone. Nights stay above 30°C for weeks at a time.

In the "trapped" version of 2100, Amina's family lives in a two-room concrete house with a metal roof. The grid supplies power for a few hours a day, and the fan stops when the power stops. She opens her stall at 5 a.m. and closes it at 10, losing half her trading day during the hot season. Her mother, aged 68, was hospitalised twice last year with heat-related kidney problems. Her eldest son has gone to Lagos for construction work, and his remittances keep the household afloat. *In the "resilient" version*, Amina's district has a rooftop-solar mini-grid, and her market has been rebuilt with shade structures, cooling stations and free water. A municipal heat alert system sends SMS warnings, and the health post keeps a cool room for older people. The heat is the same. The harm is very different.

Patna, Bihar, India: Ravi, 52, construction supervisor

Bihar is one of India's most populous and poorest states and sits in the heart of the Indo-Gangetic Plain. By 2100 India's population has begun to decline, but Bihar's remains very large, and Patna has grown into a sprawling metropolis. In the pre-monsoon and monsoon months the combination of 40°C-plus temperatures and high humidity produces heat-index values above 41°C on most days for two months or more, and in bad

years for three. The air in winter, laden with smoke from crop burning, vehicles and brick kilns, is among the most polluted in the world.

In the trapped version, construction work stops between 11 a.m. and 4 p.m. by state order, but the informal crews Ravi oversees cannot afford to stop, and two of his workers collapsed from heat stroke this season. His family's air conditioner runs on a strained grid that blacks out at peak demand. In the resilient version, India has followed through on its cooling action plan: efficient, affordable air conditioners and fans, cool-roof programmes in low-income housing, and enforced heat-protection labour codes with paid "heat leave". Coal has largely left the grid, and with it much of the winter smog. Heat remains a fact of life, but no longer a regular killer.

Kinshasa, DR Congo: Grace, 19, student

Kinshasa could be one of the largest cities on Earth by 2100, with a population of perhaps 50–80 million. The city lies near the equator, where temperatures are high but steady. Climate change adds about 2°C to its mean annual temperature and greatly increases the number of humid, oppressive days and nights. Flooding along the Congo River and its tributaries intensifies.

In the trapped version, Grace's school has no cooling, and her concentration fades by midday for much of the year. She lives in an informal settlement on a flood-prone hillside, and malaria and dengue are constant threats. Without a reliable job market in the formal economy, her prospects depend on informal trading and the remittances of relatives abroad. In the resilient version, the Democratic Republic of the Congo has used its vast hydropower potential and mineral wealth to build a grid, invested in planned urban expansion and secondary schools designed for passive cooling, and has a growing technology and services economy. Grace studies engineering at a university whose campus is shaded and cooled.

Dhaka, Bangladesh: Nasrin, 61, garment-factory retiree

Bangladesh is among the most heat- and climate-exposed countries in the world. By late century its average resident faces about 68 days a year with a heat index above 41°C under SSP2-4.5, and over 110 under SSP3-7.0. Sea-level rise and salinisation have pushed millions from the southern coastal districts into Dhaka, already one of the densest cities on Earth.

In the trapped version, Nasrin lives in a crowded flat with her son's family. The building traps heat, the electricity is unreliable, and she spends the worst afternoons in the stairwell, where there is a slight draught. Older women like her are the group most likely to die in Dhaka's heatwaves, and many deaths are never recorded. In the resilient version, Bangladesh's world-leading disaster preparedness, which has already cut cyclone deaths dramatically, has been extended to heat. There are community cooling centres, door-to-door checks on older people during heat alerts, and an electricity system that prioritises power for homes and clinics during peak heat.

Niamey, Niger: Ibrahim, 27, solar technician

Niger's population is projected to grow from 27 million to about 91 million by 2100. Niamey lies where the Sahel meets the Sahara. By the 2090s its mean annual temperature exceeds 31°C, well outside the historical human climate niche, and the hottest months bring weeks above a heat index of 41°C. Rainfall is erratic, and the River Niger's flow is more variable.

In the trapped version, Ibrahim's family has left their village after successive harvests failed. Insecurity in the countryside limits movement, and borders to the north are closed. He works in the informal economy and sleeps on the roof to escape the heat inside. In the resilient version, the Sahel's extraordinary solar resource has become the basis of an export industry. Ibrahim installs and maintains solar-powered cold chains, irrigation pumps and cooling systems across the region. His income lets his parents live in a well-insulated house with a solar-powered air cooler, and regional free movement gives him the option to work in coastal West Africa.

The same heat can be lived in very differently. The gap between the trapped and resilient versions of 2100 is the gap this report asks the world to close.

SECTION 15

Three Pathways for the Late Century

The future of the heat-exposed regions depends on the interaction of two broad sets of choices. The first is **how much the world warms**, which is decided mainly by emissions in the major economies over the next three decades. The second is **how well the most exposed populations are protected**, which is decided by development, finance, governance and technology diffusion. Combining these gives three stylised pathways for the late twenty-first century.

Table 6 Three pathways for the middle half of humanity in 2100

Dimension	Pathway A: The Heat Trap	Pathway B: Managed Hardship	Pathway C: Resilient Convergence
Warming by 2100	3.5–4°C (SSP3-7.0-like)	About 2.7°C (SSP2-4.5-like)	1.5–2°C (SSP1-2.6-like)
People with 30+ days/yr heat index >41°C	About 3.6 billion	About 2.2 billion	About 1.3 billion
People living at mean annual temperature ≥29°C	About 2.5 billion	About 1.5 billion	About 0.7 billion
Development in Africa and South Asia	Stalled convergence; fragmented trade; high debt	Uneven growth; some regions converge, others fall behind	Rapid convergence led by clean energy and urban productivity
Access to cooling and electricity	Large gaps persist; grids fail at peak demand	Expanding but unequal; poorest households excluded	Near-universal access to efficient cooling and reliable power
Air quality	Little improvement; coal locked in	Partial improvement in major cities	WHO interim targets met across most of Asia and Africa
Health systems	Overwhelmed; heat deaths largely uncounted	Heat action plans in major cities; rural gaps	Climate-resilient primary care; heat deaths rare and tracked
Mobility	Closed borders; large trapped populations	Mostly internal migration into informal settlements	Planned urbanisation, regional free movement and labour pathways
Human outcome	Chronic suffering and high mortality for hundreds of millions; rising instability	Heavy, persistent hardship for the poorest; adaptation limits reached in hottest areas	Hardship managed for most; physical limits reached only in localised extreme events

Exposure estimates from H Heuristics analysis (SSP1-2.6, SSP2-4.5 and SSP3-7.0, 2100). Other dimensions are qualitative scenario narratives.

Pathway A: The Heat Trap

Warming reaches 3.5–4°C as emissions fail to fall in large economies and geopolitical fragmentation slows technology transfer. Development in Sub-Saharan Africa stalls under the combined weight of heat-related productivity losses, debt, conflict and declining aid. More than a third of humanity faces a month or more of danger-level heat every year, and a quarter lives in climates outside the historical human niche. Adaptation reaches its limits across large parts of the Sahel, northern India, Pakistan and the Gulf. Mortality, displacement and conflict rise, and the gap between the climate-protected minority and the exposed majority becomes the defining inequality of the century. This pathway is not the most likely. It is plausible enough to plan against.

Pathway B: Managed Hardship

This is roughly where current policies point. Warming reaches about 2.7°C. Emerging economies grow, but unevenly. India, Indonesia and parts of East and West Africa converge on middle-income living standards and

build significant cooling and health infrastructure. The Sahel, Central Africa and the poorest parts of South Asia fall behind. More than 2 billion people face a month or more of dangerous heat a year. Most survive it, but at great cost in health, income, education and dignity. Heat becomes a chronic background stress, like malaria in the twentieth century: a constant drain on human potential that falls hardest on the poorest.

Pathway C: Resilient Convergence

The world limits warming to below 2°C through rapid decarbonisation, enabled by the falling cost of clean energy. Solar PV costs fell by about 90% between 2010 and 2023 ([IRENA](#)). Climate and development finance flow at scale. Africa's abundant solar resource underpins universal electricity access and an efficient cooling revolution. Cities are planned for heat, with shade, green space, cool roofs and ventilation corridors. Clean air is achieved alongside clean energy. Exposure to dangerous heat still roughly doubles from today, because some warming is already locked in, but it falls on populations that are far better protected. This is the only pathway in which the demographic shift of the twenty-first century becomes primarily a story of human flourishing.

THE DECISIVE DECADE

The pathways diverge mainly after 2050, but the choices that set them are made before 2040. These include peaking and rapidly cutting global emissions, financing energy access and cooling in Africa and South Asia, building health and urban systems for heat, and setting the rules for mobility. Infrastructure built in the 2020s and 2030s, including power plants, buildings, roads and city layouts, will still be standing in 2100. The children who will be the middle of humanity in 2100 are being born now.

SECTION 16

An Agenda for Action

The heat trap is foreseeable, and it is not inevitable. This section sets out twelve priorities, organised under six commitments. Together they form an agenda for governments, multilateral institutions, philanthropy, business and civil society.

THE RETURN ON ACTION

Investments in heat resilience are among the highest-return investments in global development. Early warning systems are estimated to return many times their cost in avoided losses. Clean air delivers large health gains within years. Efficient cooling saves energy and money. Each degree of warming avoided spares hundreds of millions of people from dangerous heat. The barrier is not cost or technology. It is attention, and the political will that follows from it. This report exists to supply the first, in the hope that it will help create the second.

Table 7 Who must act: priorities by actor

Actor	Highest-leverage actions
High-emitting governments	Accelerate decarbonisation; deliver and exceed the US\$300bn finance goal with a large grant-based adaptation share; open labour mobility pathways
Governments of exposed countries	Heat action plans in every city; cooling and clean-air strategies; heat-resilient building codes; worker protections; death registration
Multilateral development banks	Lower the cost of capital for clean energy; scale adaptation lending with grant elements; climate-resilient debt clauses
Cities and municipalities	Cool roofs, shade and green space; cooling centres; heat-health alerts; upgrading of informal settlements
Philanthropy and research	Fund heat-health surveillance, wet-bulb and heat-mortality research in Africa and South Asia; support data and early-warning systems
Business and employers	Heat-safe working conditions across supply chains; efficient cooling products for low-income markets; investment in African clean energy
Civil society and media	Make heat deaths visible; elevate the voices of affected communities; hold decision-makers accountable for the long tail of emissions

Source: H Heuristics synthesis.

Commitment 1: Keep warming as low as possible

Mitigation is the largest single lever. The difference between SSP1-2.6 and SSP3-7.0 is about **2.3 billion people** who would or would not face a month or more of dangerous heat each year by 2100.

- 1. Accelerate emissions cuts in the major economies**, which account for most current emissions, and **cut methane** quickly. Methane is the fastest lever on near-term warming, and its main sources, in fossil fuel operations, agriculture and waste, have low-cost solutions.
- 2. Finance clean energy in emerging economies at affordable cost.** The cost of capital for solar and wind in much of Africa is two to three times higher than in Europe. Concessional finance, guarantees and currency-risk instruments can unlock clean power that serves mitigation, development and cooling all at once.

Commitment 2: Make cooling a basic public good

3. **Treat access to safe cooling as a basic need**, like water and sanitation. That means universal electricity access, efficient fans and air conditioners, the phase-down of super-polluting refrigerants under the [Kigali Amendment](#) to the Montreal Protocol (which could avoid up to 0.4°C of warming this century), and minimum efficiency standards that halve the energy needed for each unit of cooling.
4. **Build cool cities and cool homes**. This includes cool and reflective roofs for informal housing, shade trees and urban green space, ventilation corridors, passive building design, and building codes enforced for the climates of 2050, not of 1950.

Commitment 3: Treat clean air as climate adaptation

5. **Adopt and enforce national clean-air plans** aligned with WHO interim targets, building on China's demonstration that PM2.5 can fall by around 40% within a decade. Priorities include phasing out coal near population centres, cleaner transport, controls on brick kilns and industry, and alternatives to crop-residue burning.
6. **Achieve universal clean cooking** for the 2.1 billion people without it. This is one of the most cost-effective health interventions available, and it cuts household air pollution that compounds heat stress.

Commitment 4: Build heat-ready health and labour systems

7. **Implement heat action plans and early warning systems in every major city and district** of the exposed regions. These include heat-health alerts, cooling centres, outreach to older and isolated people, and hospital preparedness. Ahmedabad's Heat Action Plan, the first in South Asia, was associated with a substantial fall in heat-related deaths ([Hess et al., 2018](#)). The UN's [Early Warnings for All](#) initiative aims to cover everyone on Earth by 2027.
8. **Count heat deaths**. Strengthen death registration and heat-mortality surveillance in Africa and South Asia so that the toll is visible, attributable and actionable.
9. **Protect workers**. Enforce heat-stress standards that set rest breaks, shade, water and work-hour limits based on heat index or wet-bulb globe temperature, including in informal and agricultural work. Pair them with **heat insurance and social protection** that compensate lost income, so that workers can afford to stop. Parametric heat insurance pilots for women informal workers in India point the way.

Commitment 5: Close the adaptation finance gap

10. **Scale adaptation finance towards the US\$187–359 billion a year that developing countries need**, mostly as grants and highly concessional finance. Prioritise heat, cooling and health, which today receive a very small share of adaptation funding. Climate-resilient debt clauses and new levies on aviation, shipping and fossil-fuel windfalls can help.
11. **Capitalise the loss-and-damage fund at scale** to support communities facing impacts beyond the limits of adaptation.

Commitment 6: Open safe pathways for mobility

12. **Plan for movement instead of resisting it**. This means planned urban expansion with serviced land ahead of migration, regional free-movement agreements, labour mobility partnerships between ageing and young economies, portable social protection, and legal frameworks for the planned relocation of communities from places that become uninhabitable.

SECTION 17

Conclusion: Recalibrating the Sense of Direction

At the start of this series we asked where the century, and humanity, is headed. Part I described a world of convergence and contraction: Asia rising, Europe and East Asia ageing, Africa growing, and a polycrisis of climate, pollution, poverty and conflict overlapping all of it. This report has followed one of those threads to its end, and the picture it reveals should reshape how we think about the century.

The future of humanity is tropical, young today, urban, and exposed. By 2100 most people will live in Sub-Saharan Africa and South Asia, in climates hotter than almost any in which large human populations have lived before. The average person's home climate will be about 6°C warmer than in 1950. Roughly two-thirds of that shift comes from where people are born, and one-third from the warming of the places they are born in. Between 1.3 and 3.6 billion people, depending on our choices, will face a month or more of danger-level heat every year. Most of them will also breathe heavily polluted air, earn their living outdoors, and depend on fragile power grids and health systems.

That is the heat trap. Its defining feature is not a single catastrophe but a structural mismatch between where humanity is growing and where the conditions for safe, dignified, productive life are being eroded fastest. And because carbon dioxide persists for millennia, the warming reached when emissions finally stop will define the climate of these regions for many generations.

Three conclusions follow.

First, the crisis deserves to be recognised as one of the central humanitarian challenges of the century, on the scale of the great public health campaigns of the twentieth. It is currently fragmented across climate, development, health and migration policy, and largely invisible in the places where it is most acute.

Second, mitigation and adaptation are not alternatives. Mitigation determines how much heat there will be. Adaptation and development determine how much harm it causes. Both are needed, and both are needed now. The gap between the pathways in this report is measured in billions of people.

Third, there is real reason for hope. The technologies to protect people from heat, including efficient cooling, solar power, cool buildings, early warning and heat-resilient health care, exist and are getting cheaper. China has shown how quickly air can be cleaned. Ahmedabad has shown how heat action plans save lives, and Bangladesh has shown how preparedness can transform disaster mortality. The demographic dividend of Africa's young population, if matched with investment, can become a driver of global prosperity rather than a story of suffering.

The direction of the century is set by physics and demography, and the experience of living it will be set by choices. The people who will form the middle of humanity in 2100 are being born now. Whether they inherit a heat trap or a liveable future is still, for a short while longer, up to us.

*The question is not whether humanity's future lies in the global South. It does.
The question is whether we will build a world in which that future is liveable.*

APPENDIX A

Methodology and Data Notes

This appendix describes the original analysis behind the figures labelled "H Heuristics analysis". All data sources are public.

Data sources

- **Population.** United Nations, *World Population Prospects 2024*: estimates for 1950–2023 and the medium-variant projection for 2024–2100, for 237 countries and territories, accessed via [Our World in Data](#). Births and median age come from the same source.
- **Climate projections.** World Bank [Climate Change Knowledge Portal](#) (CCKP), CMIP6 multi-model ensemble median at 0.25° resolution. Annual climatologies for 1995–2014 (historical), 2040–2059 and 2080–2099 under SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5. Variables used: mean annual temperature (tas), days with maximum temperature above 35°C (hd35), and days with heat index above 35°C, 39°C and 41°C (hi35, hi39, hi41).
- **Observed baseline temperature.** ERA5 reanalysis mean annual temperature climatology, 1991–2020, via the World Bank CCKP.
- **Gridded population and country masks.** [ISIMIP](#) historical gridded population (0.5°, 2021) and fractional country masks (0.5°).
- **Air pollution.** Population-weighted mean annual PM2.5 exposure by country, 1998–2024, from the World Bank and Our World in Data.
- **Poverty.** World Bank Poverty and Inequality Platform, number of people below US\$3.00 a day (2021 PPP) by region, via Our World in Data.
- **Emissions.** Global Carbon Budget fossil and industrial CO₂ by country, via the [Our World in Data CO₂ dataset](#).

Population-weighting of climate

Simple national averages of climate variables are dominated by the largest and often emptiest parts of a country, such as the Tibetan Plateau, the Sahara or Siberia. To measure the climate *people* experience, we sampled each climate field at the centre of every 0.5° population grid cell. We then calculated, for each country, a population-weighted mean using 2021 gridded population multiplied by the fractional country mask. For mean temperature, the baseline is ERA5 (1991–2020) and future values add the CMIP6 change relative to the model's own 1995–2014 baseline (the "delta method"). For heat-index day counts, CMIP6 values are used directly. Where gridded data were unavailable (a few small territories), the national area-average from the CCKP API was used instead. Countries covered by population-weighted values account for more than 99% of world population.

Threshold shares, such as the share of people where mean annual temperature is 29°C or more, are computed at grid-cell level within each country. They are then applied to each country's UN-projected population.

Interpolation in time

Climatologies were assigned to the midpoints of their periods (2005, 2050 and 2090) and interpolated year by year with a monotone piecewise-cubic (PCHIP) function. Values before 2005 are held at the 1995–2014 baseline, and values after 2090 are held at 2080–2099 levels. This is conservative for higher-emission scenarios, in which warming continues after 2090. "2024" values are therefore interpolated model climatology, not observations of that year. "2100" values combine 2080–2099 climatology with 2100 population.

Demography-only counterfactual

To isolate the effect of demographic change, we held each country's climate fixed: ERA5 1991–2020 for temperature and the CMIP6 1995–2014 baseline for heat-index metrics. We then allowed only population to change.

Decomposition

Total exposure E is written as $E = N \times \sum_i s_i c_i$, where N is world population, s_i is country i 's share of world population, and c_i is its population-weighted climate metric. The change from 2024 to 2100 was decomposed into contributions from N (population size), s (population distribution) and c (climate) using an exact Shapley decomposition, averaging over all six orderings of the three factors.

Limitations

- **Within-country distribution is held at 2021 patterns.** Future urbanisation and internal migration will change where people live within countries. Because cities are generally hotter at night than their surroundings through the urban heat island effect, which CMIP6 models do not resolve, our estimates of heat exposure are probably conservative for the urban majority of 2100.
- **Multi-model medians smooth extremes.** Individual models and individual years will produce more extreme outcomes. The heat-index day counts reflect typical conditions in a 20-year period, not the worst years.
- **Heat index is an imperfect measure of physiological stress.** It does not capture wind, solar radiation or metabolic load. Wet-bulb globe temperature or full physiological models give more precise estimates of stress. We use the heat index because consistent global projections are publicly available.
- **Population projections are uncertain,** especially for Sub-Saharan Africa after 2050. Faster fertility decline would reduce the numbers exposed, though not the overall geography (Section 3).
- **Country groupings.** "Sub-Saharan Africa" excludes Algeria, Egypt, Libya, Morocco, Sudan, Tunisia and Western Sahara, following the UN geoscheme. "South Asia" comprises Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan and Sri Lanka. The World Bank's regional groupings, used for poverty, differ slightly.
- **Exposure is not impact.** Our metrics describe hazard and exposure. Actual harm depends on vulnerability and adaptation, which this analysis discusses qualitatively.

Analysis code and derived data are available from H Heuristics on request.

APPENDIX B

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