Too hot to grow

The economic costs of extreme heat

28 May 2026

Allianz Research

Content

Executive Summary

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- **Extreme heat is emerging as a structural economic risk, with Europe highly exposed.** Heat stress events have multiplied sevenfold since the 1980s while the average death toll per event has risen fivefold. That share partly reflects measurement: vital registration and excess-mortality surveillance are far more developed in Europe than in much of Africa and South Asia, where heat deaths go largely uncounted. But genuine structural vulnerability is also at work – ageing populations, dense urban building stock designed to retain warmth and severely underdeveloped cooling infrastructure, with air-conditioning penetration averaging 19% across Europe against roughly 90% in the US.

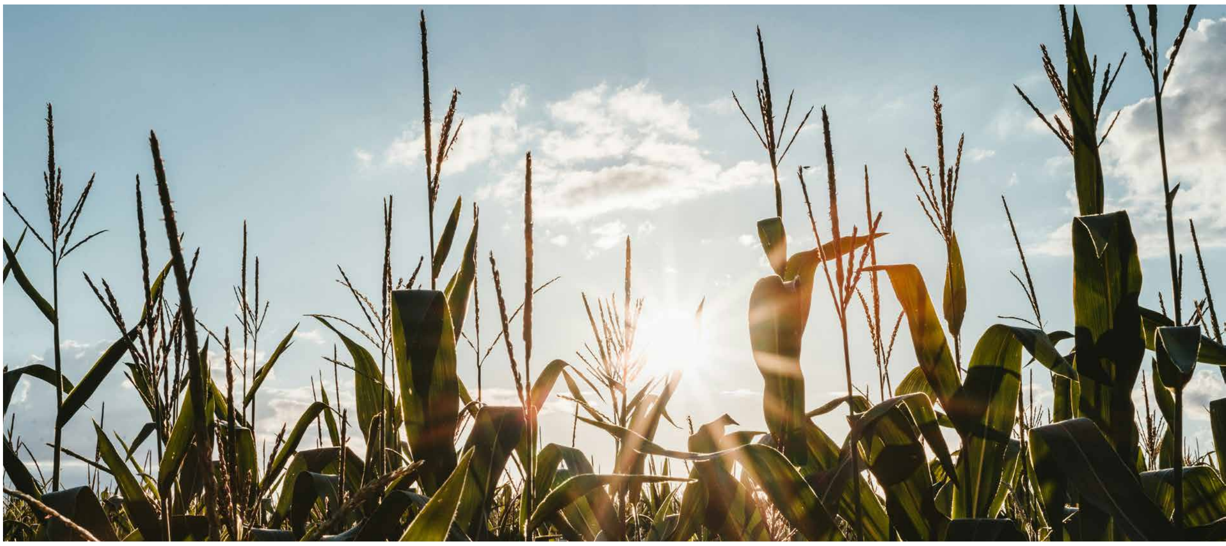
- **The economic transmission of heat stress is non-linear, with a critical threshold around 30°C beyond which productivity losses intensify sharply.** Below this level, warming reduces heating costs and is associated with modest productivity gains. Above this level, the relationship reverses and both channels worsen with each additional degree. The dominant effect operates through labor: output per hour declines by approximately USD1.3 (constant PPP, ~3% of mean hourly output in our 2014-2024 sample) for every degree across the 30-35°C range. Wage adjustments follow productivity with a lag, so the short-run cost falls disproportionately on firm profitability before gradually transmitting to household income and consumption. A second, smaller channel runs through energy: consumption rises by around 1.2% per degree, raising firms' input costs at exactly the temperatures where labor productivity is falling.

- **To gauge the macroeconomic stakes, we construct a stress scenario in which the five hottest years observed in each country between 2014 and 2024 are replayed in ascending order over 2026–2030 – the fifth-hottest year in 2026, the fourth in 2027 and so on, culminating in the country's hottest year on record in 2030.** Under this trajectory, cumulative implied GDP losses (2026 – 2030) could reach 5–7% for the most exposed economies: USD240bn for France, USD354bn for Japan, USD147bn for Italy, USD131bn for Germany and USD120bn for Spain. More consequentially for long-run growth, in such a scenario the decline in fixed capital formation systematically exceeds consumption losses, reaching 8% on average across affected countries: As heat compresses expected returns on capital, investment falls, reducing future productive capacity in a self-reinforcing drag. Moreover, stagflationary dynamics should be expected, with rising prices alongside rising unemployment, placing monetary authorities in a binding trade-off that is especially acute in the Eurozone, where a single policy rate must serve economies with sharply diverging climate exposures.

- **The fiscal consequences fall most heavily on the economies least able to absorb them.** The loss of economic output due to heat reduces tax revenues: Estimated annual losses would reach 1.8% in France, 1.3% in Italy and Spain and 0.7% in Germany – partly because progressive tax systems mean revenues tend to fall faster than output itself, amplifying the fiscal drag beyond the headline GDP loss. Simultaneously inflation-indexed transfers, healthcare costs and emergency infrastructure repair raises public expenditure. Fiscal balances deteriorate by around 0.5% of GDP annually on average. Italy and Spain risk breaching the Maastricht deficit ceiling (again) once heat-related pressures are incorporated. France, already carrying a projected deficit of –4.9% of GDP, faces additional heat-related pressure of 2.2%.

- **Insured losses remain a small fraction of total damages, reflecting a structural mismatch between what heat destroys and what conventional insurance was designed to cover.** In 2022, total climatological losses in Europe reached EUR46bn while the insured share rose only marginally. Most heat damage accumulates through excess mortality, lost working hours, healthcare-system pressure and infrastructure stress – channels that indemnity contracts are not designed to handle. This makes extreme heat harder to insure than other climate risks because losses are widespread and are often indirect – like lower productivity or health impacts – making them difficult to measure and price. Closing the protection gap is therefore as much a product-design challenge as a capacity one, and the insurance toolkit is already evolving in response: parametric instruments that pay out on objective temperature or duration thresholds, public–private risk-sharing arrangements for systemic exposures and dedicated public backstops where private capacity cannot reasonably reach.

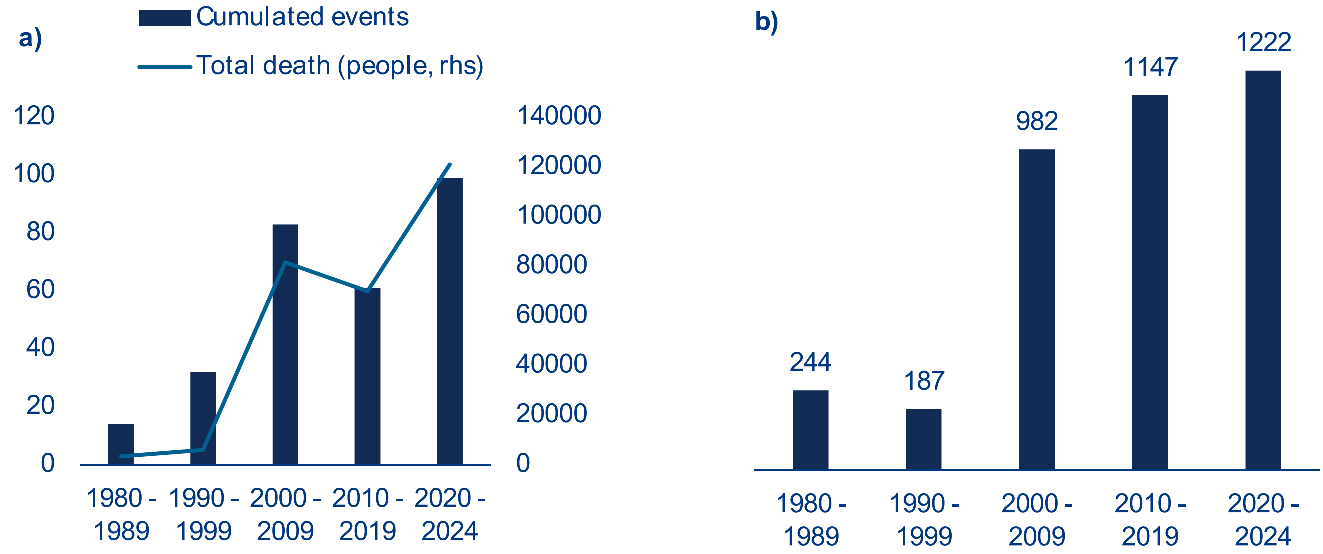
- **Heat-adaptation policy in Europe is built mainly to compensate for losses rather than prevent them.** Following the multi-actor frame of IPCC, closing the gap in Europe requires coordinated action on four fronts: labor regulation, buildings, public finance and households. A workable occupational regime needs binding temperature thresholds, automatic work restrictions when those thresholds are crossed, paid compensation for lost hours and coverage that reaches fixed-term, seasonal and platform workers. No major European economy has all four, and the gap is concentrated on the last: protections were designed around standard contracts and leave the workers most exposed to heat largely outside the regime. Prevention itself is also underused, with shifted hours, partial mechanization and indoor cooling still rare. For buildings, four pieces have to fit together: overheating standards in new construction, mandatory passive cooling in renovation, cooling access for vulnerable households as a social entitlement and grid-adequacy planning that accounts for coincident summer cooling demand and the thermal derating of generators. The revised EU Energy Performance of Buildings Directive delivers the first; the gap is the other three, where indoor temperatures, mortality and peak electricity demand are actually held down. On fiscal architecture, every major European economy has a national adaptation strategy but almost none has translated it into a multi-year budget envelope, so the response defaults to ad-hoc emergency packages – and each episode quietly consumes the fiscal space that ex-ante adaptation would have used to lower the next. The missing layer is households. EU households hold almost EUR40trn in financial assets, including a very large stock of deposits, while much of Europe's housing stock remains poorly adapted to hotter summers. Mobilizing even a small, well-targeted share – through incentives for retrofit, passive cooling and affordable parametric cover – could close part of the gap that public budgets alone cannot reach. But this is not a private-finance solution: the households most exposed are often not those with the greatest liquid savings, so public guarantees, subsidies and distributional safeguards are what turn household wealth into resilience rather than into inequality.



The economic transmission of heat stress

From one decade to another, the data are recording more frequent and more lethal heat stress events. Between 1980 and 1989, only 14 heat-wave events[1] were catalogued globally; the figure more than doubled in the 1990s, jumped to 83 in the 2000s and has already reached 99 in the truncated 2020–2024 period, meaning five years have nearly matched what entire decades produced two cycles earlier (Figure 1a). Mortality has followed an even steeper trajectory: from around 3,400 deaths in the 1980s to more than 121,000 in the first half of the 2020s alone. The most analytically significant metric is the average death toll per event, which has risen fivefold from 244 in the 1980s to 1,222 in 2020–2024. This decoupling between event frequency and per-event lethality indicates that the intensity and duration of individual episodes are increasing faster than societies can adapt (Figure 1b).

Figure 1: Increasing exposure to heat stress: a) Evolution of number of events and total death (1980 – 2024); b) Average number of death per heat stress event (1980 – 2024)



Sources: EM-DAT, Allianz Research

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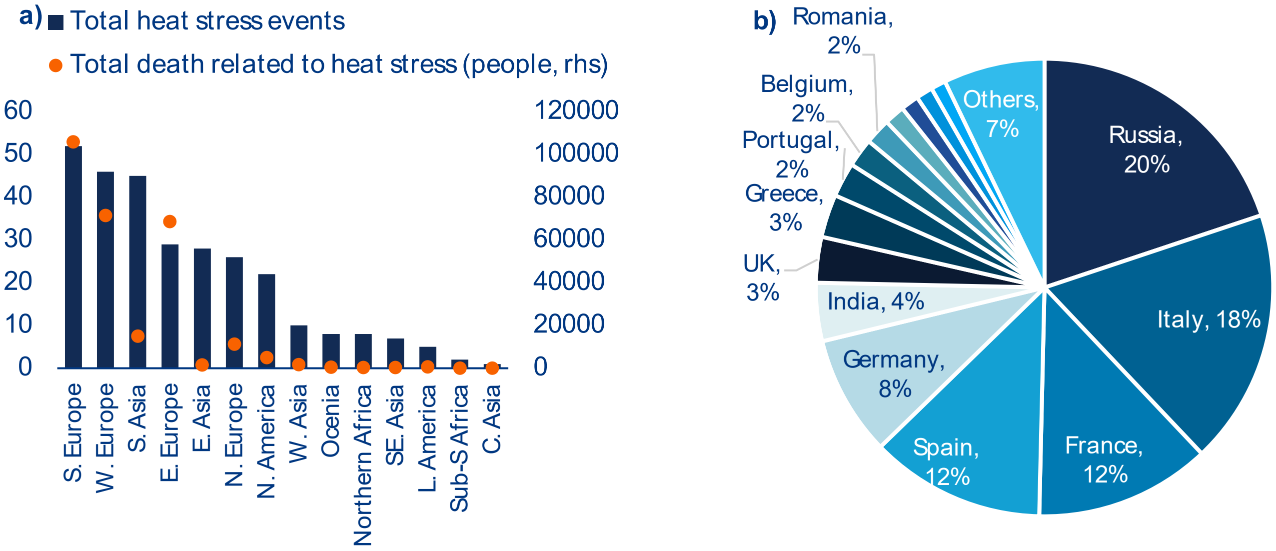
[1] EM-DAT defines a heat wave as a period of abnormally hot and/or humid weather lasting typically two or more days, with location-specific thresholds. Only events with ≥10 deaths, ≥100 people affected, a declared emergency, or an international assistance call are catalogued.

The cross-sectional distribution of heat stress events and mortality adds a second layer of insight, showing that exposure and impacts do not fully align geographically (Figure 2a). At the regional level, Southern and Western Europe concentrate the highest number of recorded events (52 and 46 respectively), closely followed by South Asia (45). Yet, this apparent convergence in frequency masks a profound divergence in outcomes. Southern Europe alone accounts for more than 105,000 deaths, while Western and Eastern Europe contribute a further 71,000 and 68,500 respectively. By contrast, South Asia, despite a comparable number of events, records fewer than 15,000 deaths over the same period. This asymmetry becomes even more pronounced when examined at the country level. A limited set of European countries dominates the global mortality profile: Russia (20%), Italy (18%), France (12%), Spain (12%) and Germany (8%) together account for 68% of total deaths. The concentration is too strong to be explained by hazard occurrence alone. Recent valuations suggest that heat-related mortality in European cities already entails welfare losses of EUR192–314 per adult per year, on par with air pollution, with avoided mortality alone worth more than EUR150bn annually.[2] This is only one channel of impact. On the productivity side, heatwaves cost 0.3–0.5% of European GDP in anomalously hot years such as 2003, 2010, 2015 and 2018, and more than 1% in the most exposed southern regions. Losses are projected to rise fivefold by 2060 in the absence of further mitigation or adaptation.[3]

The pattern in Figure 2b needs to be read carefully: EM-DAT counts reflect reporting practices as much as biophysical exposure. In hot regions such as the Gulf, India and interior Australia, populations have adapted over time through acclimatization, building design and work practices, so many high-temperature episodes do not register as disaster events, even though heat continues to kill outdoor workers, the poor and the elderly. Europe sits at the opposite end, combining ageing populations with impaired thermoregulation, dense historic urban form, uneven air-conditioning access and stronger vital registration. The European mortality concentration therefore reflects exposure meeting structural vulnerability and more complete death recording, not exceptional hazard frequency.

Figure 2: Global distribution of heat stress events: a) Number of events and total death across regions (1980 – 2024); b) Heat stress related death by country (1980 – 2024)



Sources: EM-DAT, Allianz Research

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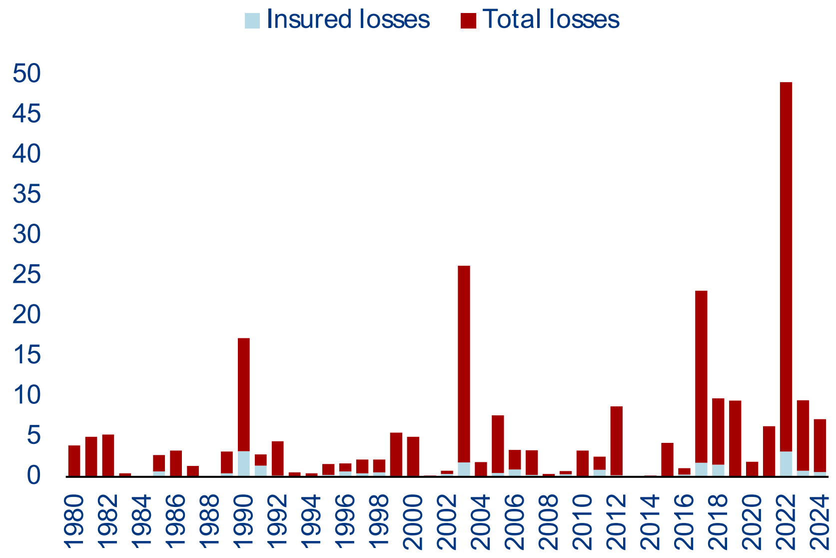
[2] Economic valuation of temperature-related mortality attributed to urban heat islands in European cities | Nature Communications

[3] Current and projected regional economic impacts of heatwaves in Europe | Nature Communications

Insured and uninsured losses tell a parallel story. Total losses from climatological hazards in Europe have risen across 1980–2024, with sharp peaks in 2003 and 2022, while the insured share has stayed limited (Figure 3). In 2022, total losses reached around EUR46bn, of which insurance covered only a small fraction. The gap is not simply a matter of market lag; it also reflects what heat actually damages. Compared with storms or floods, extreme heat less often shows up as direct damage to insured assets. Most of its cost appears through excess mortality, lost working hours, healthcare-system pressure and the disruption that follows when grids, railways and water systems are pushed past their design limits. The more conventionally insurable parts, such as direct property damage, heat-amplified wildfire losses, some crop and equipment failures etc., make up only part of the total. EEA data for 1980–2022[4] show that only around 10% of economic losses from heatwaves, droughts, wildfires and other climatological events in Europe were insured, against more than a third for storms, hail and wind. These figures cover direct asset damage only and exclude mortality, healthcare costs and lost productivity.

Heat is also hard to insure through standard indemnity contracts. Heatwaves can be defined meteorologically, but turning a temperature episode into a compensable loss is diffuse, lagged and hard to attribute. Losses tend to be highly correlated across large regional portfolios, which limits diversification. And the largest impacts – deaths, morbidity, lost output, public-service stress – are not the kind of damage private indemnity contracts were written for. Heat therefore sits at the boundary of conventional insurability: some asset-based losses can be transferred, but the largest welfare and productivity costs are hard to transfer at scale. Closing the gap will require new instruments, such as parametric cover, public–private risk-sharing and dedicated public backstops, without which much of the cost will keep falling on households, firms and public budgets.

Figure 3: Climatological (including heat waves) insured and uninsured losses in Europe (1980 – 2024)



Sources: EEA, Allianz Research

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[4] Economic losses from weather- and climate-related extremes in Europe | Indicators | European Environment Agency (EEA)

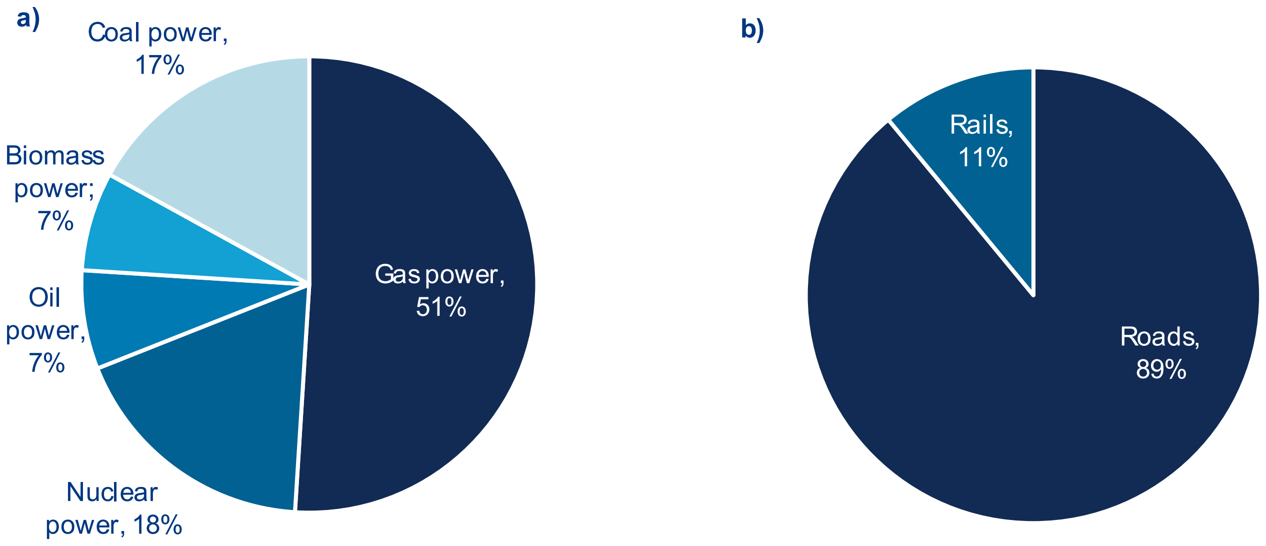
Heat translates into measurable macroeconomic cost through two channels: additional energy demand and lower labor productivity.[5] Both relationships are sharply nonlinear, with a critical threshold around 30°C beyond which damages intensify. The remainder of this section estimates the magnitude of each channel using panel regressions covering 35–49 countries over three decades, and quantifies what those estimates imply when each country experiences its recent peak-heat conditions relative to a 1991–2010 climatological baseline. The output of these two channels feeds directly into the global macroeconomic scenario presented in Section 2.

Energy demand

The relationship between temperature and energy demand is inherently non-linear, and the structure of Europe's power mix amplifies the risk on both demand and supply sides. At moderate temperatures, milder conditions reduce space-heating needs and consumption falls; above a threshold, cooling dominates and consumption rises sharply, producing a convex U-shaped response (Auffhammer and Mansur, 2014)[6]. The supply side magnifies the demand-side pressure. A large share of European generation capacity exposed to heat stress relies on thermoelectric technologies – gas (51%), nuclear (18%) and coal (17%) – all of which depend on water availability and cooling efficiency. Elevated air and river temperatures directly constrain these systems, forcing output reductions precisely when cooling-driven electricity demand surges (Figure 4a).

Recent episodes illustrate the systemic nature of the resulting grid stress, and analogous pressures affect transport infrastructure. During the August 2020 California heatwave, electricity demand peaked near 47,000 MW while generation capacity was simultaneously constrained, producing the first rolling blackouts in nearly two decades. During the 2019 French heatwave, nuclear output was reduced due to cooling constraints, tightening supply and triggering sharp electricity-price spikes. Heat also degrades transmission networks, lowering the carrying capacity of generators, transformers and power lines, while even non-thermal renewables, in particular solar PV, experience efficiency losses at high temperatures. Transport infrastructure faces analogous physical pressures: road networks account for nearly 89% of heat-exposed transport assets and rail for 11% (Figure 4b), with asphalt softening and rutting under sustained heat and rail tracks prone to thermal expansion, illustrated by the UK in July 2022, when temperatures first exceeded 40°C and rail operators imposed strict speed limits or suspended services entirely.

Figure 4: Exposure of critical European infrastructure to heat stress : a) Energy infrastructure; b) Transport infrastructure



Sources: Forzieri et al. (2018)[7], Allianz Research

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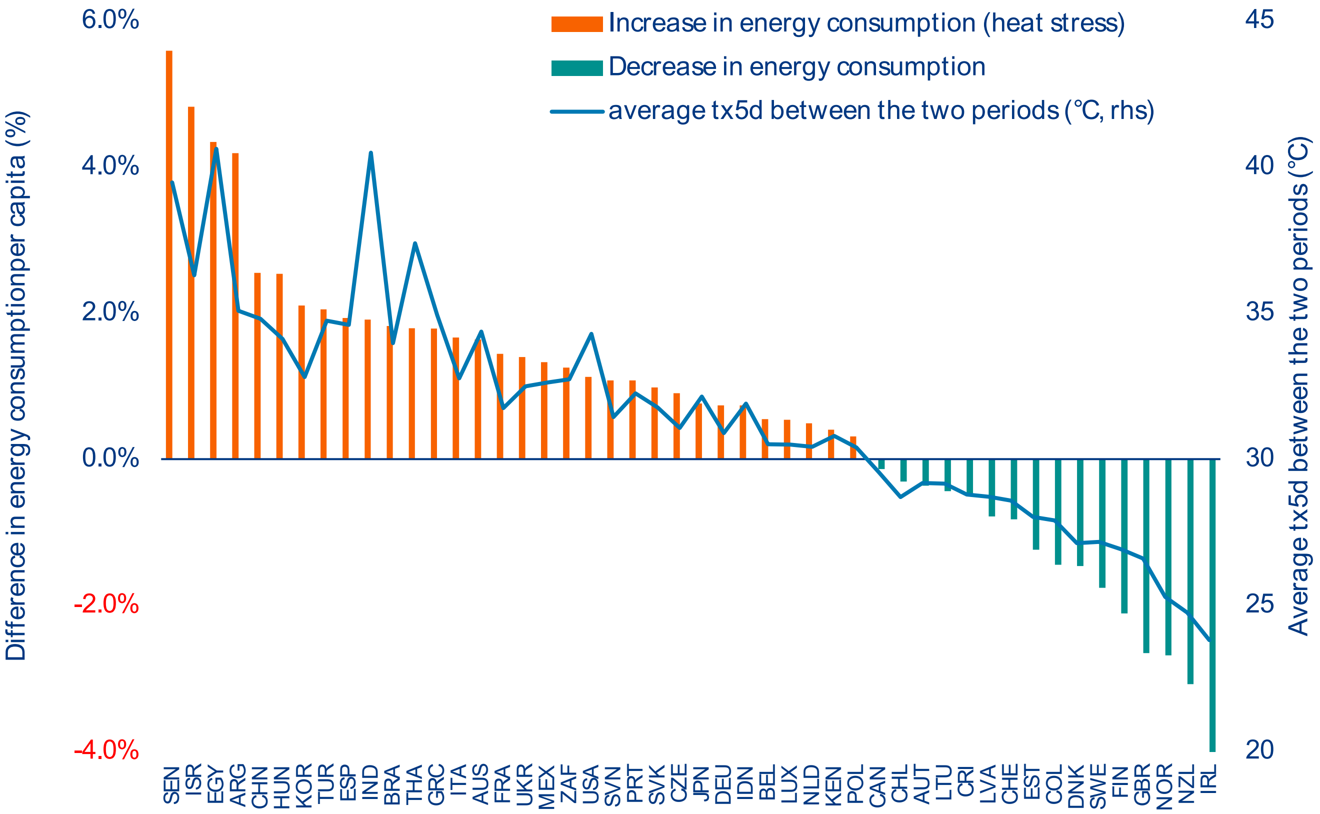
[5] What to watch I July 01, 2025 | Allianz
[6] Measuring climatic impacts on energy consumption: A review of the empirical literature - ScienceDirect
[7] Escalating impacts of climate extremes on critical infrastructures in Europe - ScienceDirect

Our empirical results confirm the non-linear structure and identify a threshold close to 30°C (Appendix 1). Using the Tx5d indicator, which is the mean daily maximum temperature over the hottest five consecutive days of the year, on an unbalanced panel of 49 countries over 1991–2023, the estimated marginal effect of heat stress on per capita energy consumption is sign-switching and temperature-dependent. At 25°C, a one-unit increase in Tx5d is associated with an approximately 0.6% decline in per capita energy consumption. At 35°C, the relationship reverses: the same marginal increase implies a 1.2% rise. The twofold differential illustrates how disproportionately energy-system stress intensifies once thermal thresholds are crossed.

The country-level counterfactual reveals a sharply asymmetric pattern, with heat already operating as a structural driver of energy demand across much of the G20 (Figure 5). Comparing per capita energy consumption during each country's most intense post-2014 heat episode (maximum Tx5d) with its 1991–2010 baseline average, countries already operating at high temperature levels (Senegal, Egypt, China, South Korea, Spain and Brazil) register increases above 4–5%, pushed further into the convex segment of the response. Almost all G20 economies in the tropics see rising energy demand across sectors, while only Europe and Oceania post aggregate reductions, driven by lower residential heating needs in cooler latitudes. The cooling gains are structurally fragile and likely to erode as temperatures continue to rise.

Figure 5: Per capita energy demand under peak heat stress (maximum Tx5d after 2014) vs. the 1991–2010 average baseline

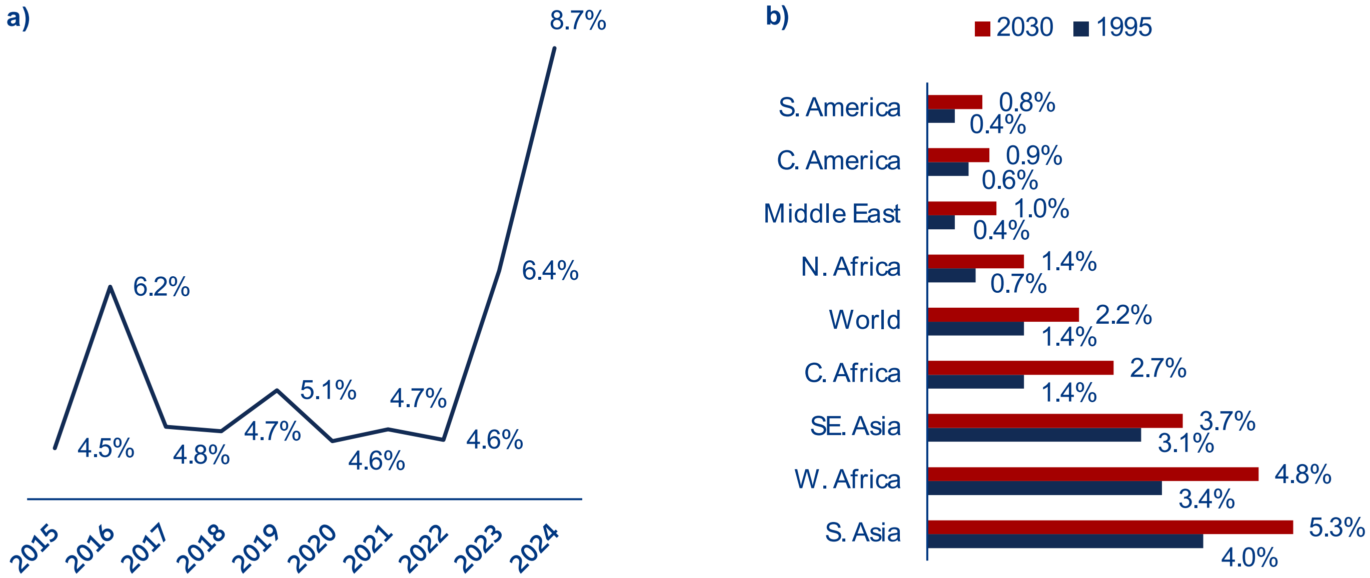


Sources: China National Customs, Allianz Research

Labor productivity and wages

Heat stress reduces labor output through physiological, cognitive and sleep-related channels that extend well beyond outdoor work (Figure 6). At the worker level, sustained exposure above the thermoneutral zone induces cardiovascular strain, dehydration and cognitive impairment, with field studies consistently documenting productivity losses across sectors (Ebi et al., 2021)[8]. The share of global working hours lost to heat stress is projected to rise from 1.4% in 1995 to 2.2% by 2030, with much higher impacts in already-warm regions – 5.3% in South Asia, 4.8% in West Africa – and a near doubling even in traditionally less exposed regions (Figure 6b). Indoor workers are not insulated: night-time temperatures, which are rising faster than daytime averages in many regions, increased total sleep time lost by around 6% over 2020–2024 relative to the 1986–2005 baseline, reaching a record 8.7% in 2024, with up to 12 additional hours of sleep loss per person per year in the most affected locations (Figure 6a). Degraded sleep duration and quality has measurable next-day consequences for cognition, cardiovascular health and decision-making, transmitting heat impacts to indoor as well as outdoor labor.

Figure 6: Heat stress and productivity : a) Loss of sleeping time for the period 2015 – 2024, compared to a baseline 1986 – 2005 (%); b) Decline in working hours (%)



Sources: The Lancet Countdown (2025), ILO (2019), Allianz Research

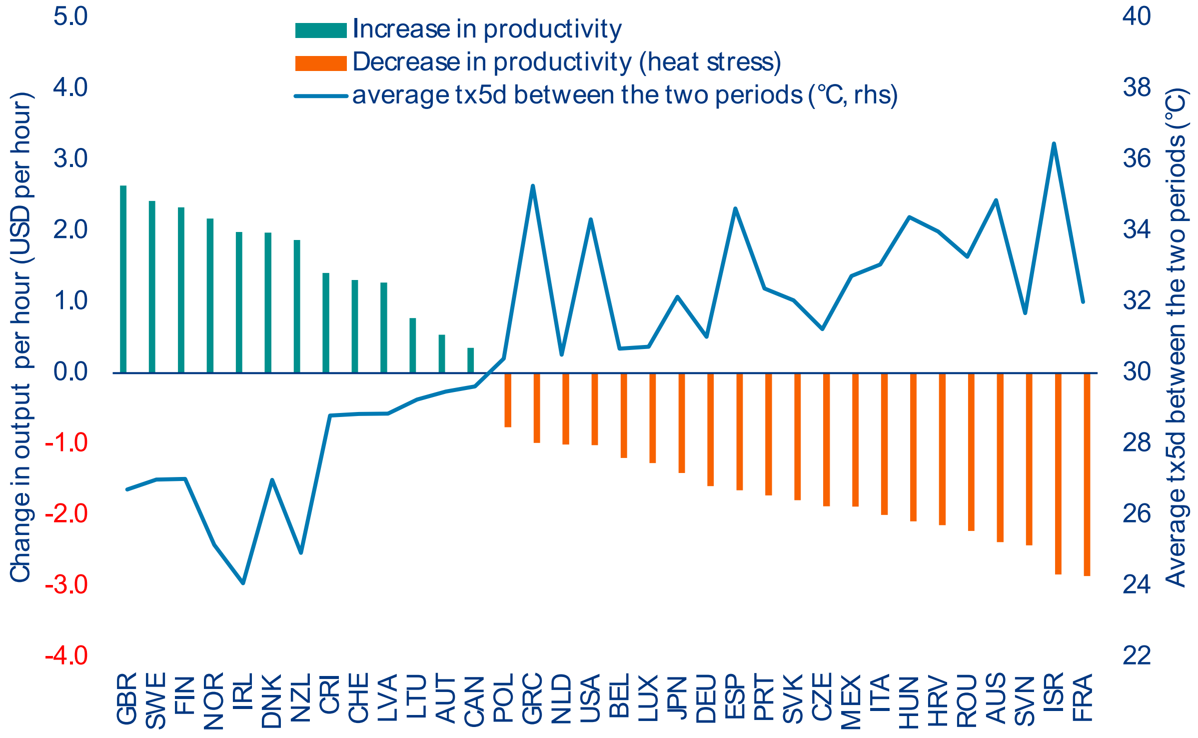
Our regressions on output per hour reveal a clear threshold effect at 30°C, consistent with the empirical consensus (Appendix 2). Estimated on a panel of 35 countries over 1997–2023, the coefficient on Tx5d below 30°C is positive and marginally significant (+0.59), consistent with mild productivity gains at moderate temperatures in temperate economies. Above 30°C, the interaction coefficient turns negative and statistically significant (–1.30), implying that each additional degree of heat beyond the threshold reduces output per hour by approximately USD1.30 (constant PPP, representing 3% of average output per hour in our sample between 2014 and 2024). Applied to the country-level counterfactual, where each country experiencing its maximum Tx5d observed over 2014–2024, against its 1991–2010 average, France, Slovenia, Australia and Italy emerge as the most affected, with output per hour declining by up to USD 1–3 in the most exposed cases. The UK, Finland, Ireland, New Zealand and Canada, all below the 30°C threshold, exhibit modest productivity gains (Figure 7a).

The wage response materializes with a lag, reflecting institutional rigidities in labor markets (Appendix 3). Using a one-year lag specification on a panel of 33 countries over 1995–2023, the relationship follows an inverted U-shape: below 30°C, higher heat stress in year t is associated with a modest acceleration of wage growth in year t+1 (approximately +0.2% at 25°C); above 30°C, the relationship reverses (approximately –0.2% at 35°C). The lag is consistent with the combination of collective-bargaining frictions, nominal wage rigidities and minimum-wage floors, all of which delay the transmission of productivity losses into labor compensation. The counterfactual maps the same threshold logic onto observed peak heat: Israel, Bulgaria, Australia, Hungary, Romania and Spain register wage declines of approximately 0.7–1.3%, while Ireland, Norway, the UK, Sweden and Finland post wage gains of 0.3–0.7% (Figure 7b).

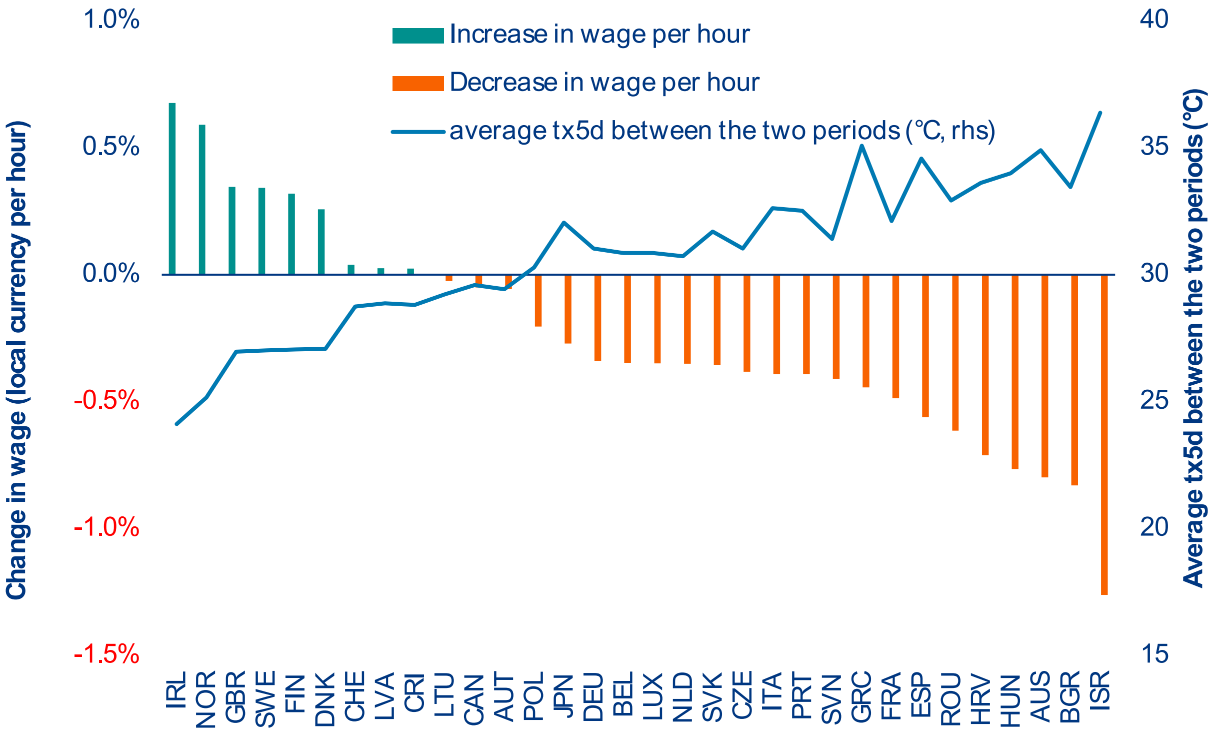
The distributional implication is structurally important and motivates the macroeconomic scenario that follows. In the short run, the cost of heat stress falls disproportionately on firm profitability as wage rigidities prevent compensation from adjusting in line with productivity. Over time, however, that wedge closes: real wages decline, household purchasing power erodes and consumption weakens, precisely in the economies already most exposed to rising temperatures. The two channels estimated in this section, additional energy demand and lower labor productivity, transmitted partially and with a lag into wages, are the inputs to the global macroeconomic simulation in the next section, which quantifies the general-equilibrium consequences in terms of GDP, prices, employment and fiscal balances.

Figure 7: The change in labor productivity under peak heat stress (maximum Tx5d post-2014) relative to the 1991–2010 baseline, measured as (a) output per hour in USD and (b) wage per hour (%).

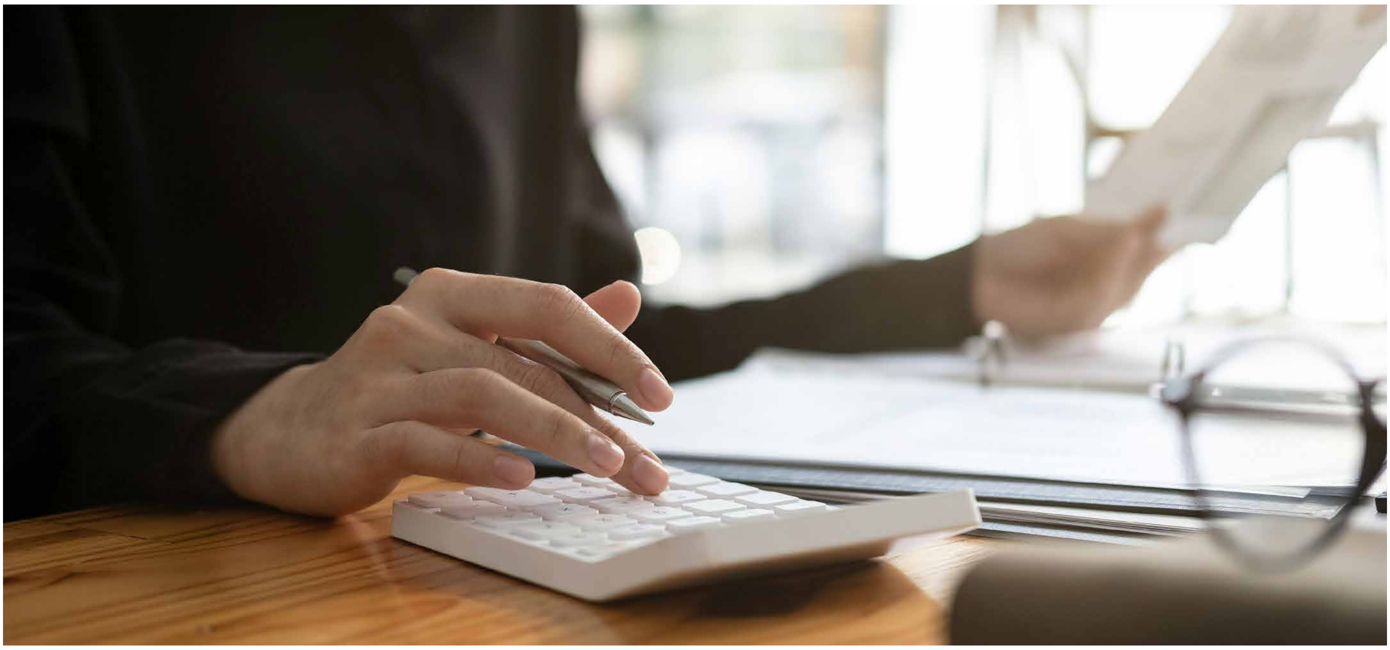
a)



b)



Source: Allianz Research



The macroeconomic implications of heat stress

To quantify the macroeconomic cost of these effects, we translate the empirical estimates into a structural scenario using the Oxford Economics Global Economic Model. The counterfactual exercises described above provide country-specific measures of the productivity and energy demand impact of heat stress, but they remain partial-equilibrium estimates, as they capture the direct effect of temperature on each variable in isolation, without accounting for the general-equilibrium feedbacks that propagate through the broader economy. As the recent climate-macroeconomics literature has increasingly recognized, reduced-form empirical estimates of climate damages, while essential for identification, cannot capture the full macroeconomic cost because they omit the general-equilibrium feedbacks, through trade, prices, investment and fiscal balances, that amplify the initial shock.[9]

To capture these interdependencies, we impose three simultaneous shocks on the model, each calibrated directly from our regression results. The first is a shock to potential output[10], reflecting the estimated decline in output per hour worked under extreme heat conditions. Entering the productivity loss through potential output ensures that the shock operates on the supply side of the economy, reducing the economy's productive capacity. The second shock targets wages and salaries per employee[11], capturing the lagged and partial transmission of productivity losses to labor compensation that our analysis identifies. The exogenous wage shock therefore captures the residual labor market adjustment that our regressions document beyond the model's endogenous response. The third shock targets energy demand[12], reflecting the additional per capita energy consumption induced by heat stress. This channel translates higher cooling needs into increased household and firm expenditure, higher energy imports for net-importing economies and upward pressure on consumer prices.

To assess the macroeconomic cost of heat stress, we construct a counterfactual scenario and compare it against a baseline projection. The baseline simulates economic outcomes over the period 2026–2030 under climatological normal conditions, defined as the average Tx5d per country observed over the 1991–2010 reference period. This baseline represents the economic trajectory each country would follow if heat stress remained at its historical norm. Against this baseline, we impose a stress scenario in which each country experiences,

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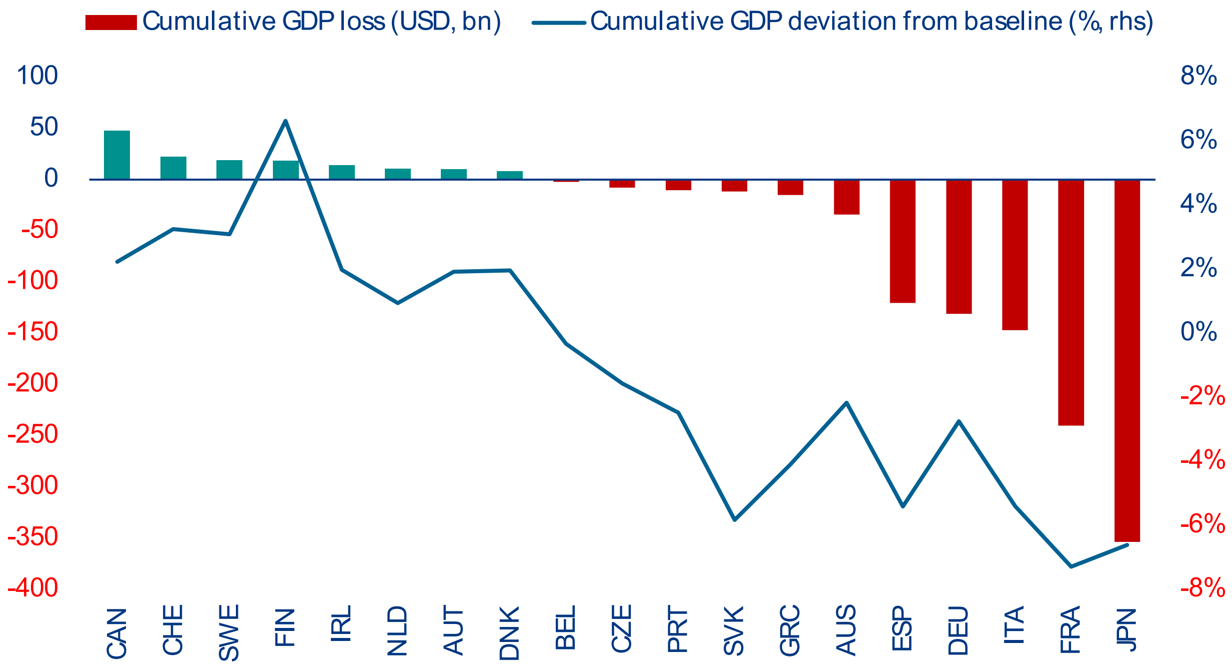
[9] Climate Change through the Lens of Macroeconomic Modeling | NBER
[10] YHAT in Oxford Economics
[11] PEWFP in Oxford economics
[12] DENERGY in Oxford economics

consecutively from 2026 to 2030, five years with the most important heat waves recorded during the 2014–2024 period, ranked by Tx5d. This is not a climate scenario based analysis but a historically grounded exercise: it asks what the macroeconomic consequences would be if the extreme heat conditions already observed in the recent past were to recur over a sustained five-year window.

The results reveal a clear divide across economies (Figure 8). Countries where average Tx5d remains below the 30°C threshold under the stress scenario – Canada, Switzerland, Sweden and Ireland – experience cumulative GDP gains of 1% to 3% relative to the historical climate baseline, leading to absolute gains ranging from USD10bn to USD47bn.[13] These gains reflect the net balance of reduced heating costs and marginally improved working conditions, benefits that are structurally fragile and likely to erode as temperatures continue to rise. Beyond this group, the transition into net losses is sharp. France, Japan, Slovakia, Spain and Italy register the highest cumulative GDP losses of 5% to 7% below baseline, reflecting the direct productivity drag that our shocks impose. The largest absolute losses, however, are concentrated in the biggest economies in the sample: Spain (USD120bn), Germany (USD131bn), Italy (USD147bn), France (USD240bn) and Japan (USD354bn).

Figure 8: Cumulative GDP loss from sustained extreme heat stress (2026–2030) relative to historical climate baseline



Sources: Oxford economics, Allianz Research

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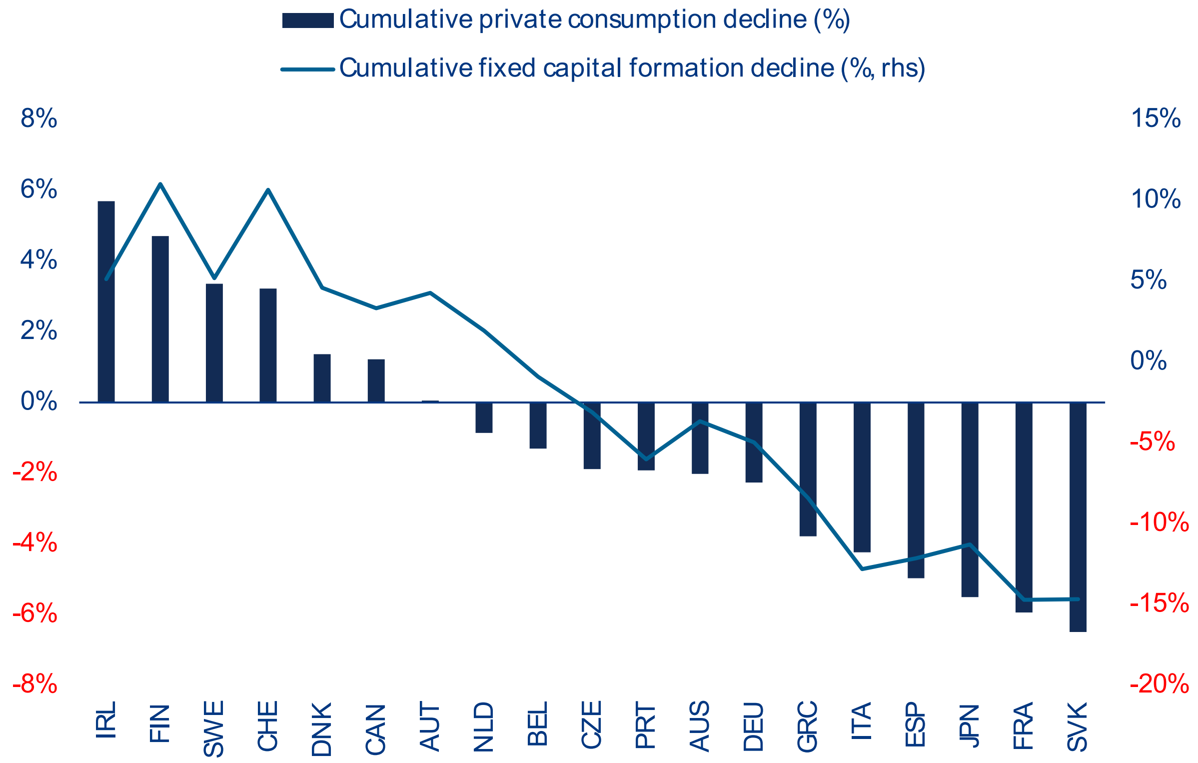
[13] Finland is an outlier, with a potential cumulative GDP gain of 7% under sustained extreme heat stress

Decomposing the GDP impact into its demand-side components reveals that the macroeconomic cost of heat stress operates through two reinforcing channels: weaker household consumption and lower investment leading to a long-run decline in fixed capital formation (Figure 9). In countries where moderate warming produces net economic benefits – Ireland, Finland, Sweden, Switzerland and Denmark – both private consumption and fixed capital formation rise relative to baseline, with investment gains generally exceeding consumption gains. The pattern inverts sharply for heat-exposed economies, and here the most striking feature of the results is the systematic amplification through investment. In virtually every country where the heat stress scenario produces economic losses, the decline in fixed capital formation exceeds the decline in private consumption, often by a wide margin. Portugal sees a consumption decline of 1.9% but an investment decline of 6.0%. Italy registers consumption losses of 4.2% against an investment collapse of 12.8%. France and the Slovak Republic, the two most affected economies, experience investment declines of 14.7% alongside consumption losses of 5.9% and 6.5% respectively. This wedge between the consumption and investment response reflects a powerful amplification mechanism: as heat stress reduces potential output and compresses firm margins, the expected return on new capital falls, discouraging investment. Lower investment in turn reduces future productive capacity, reinforcing the initial productivity shock and creating a self-reinforcing drag on the economy's growth trajectory. This asymmetry between the investment and consumption response is consistent with Casey et al. (2022)[14], who show that standard climate-economy models systematically understate investment damages because climate change disproportionately affects capital-intensive sectors exposed to outdoor heat.

The consumption response, while smaller in percentage terms, is nonetheless consequential. It captures the combined effect of lower real wages, which our wage shock imposes directly, and higher energy expenditure, which erodes household purchasing power. In the most affected economies, cumulative consumption declines of 4% to 6.5% compared to the baseline, representing a material reduction in living standards over a five-year horizon, with implications for domestic demand, retail activity and ultimately tax revenues.

Figure 9: Impact of sustained extreme heat stress on private consumption and fixed capital formation, 2026–2030 (cumulative deviation from baseline)



Sources: Oxford economics, Allianz Research

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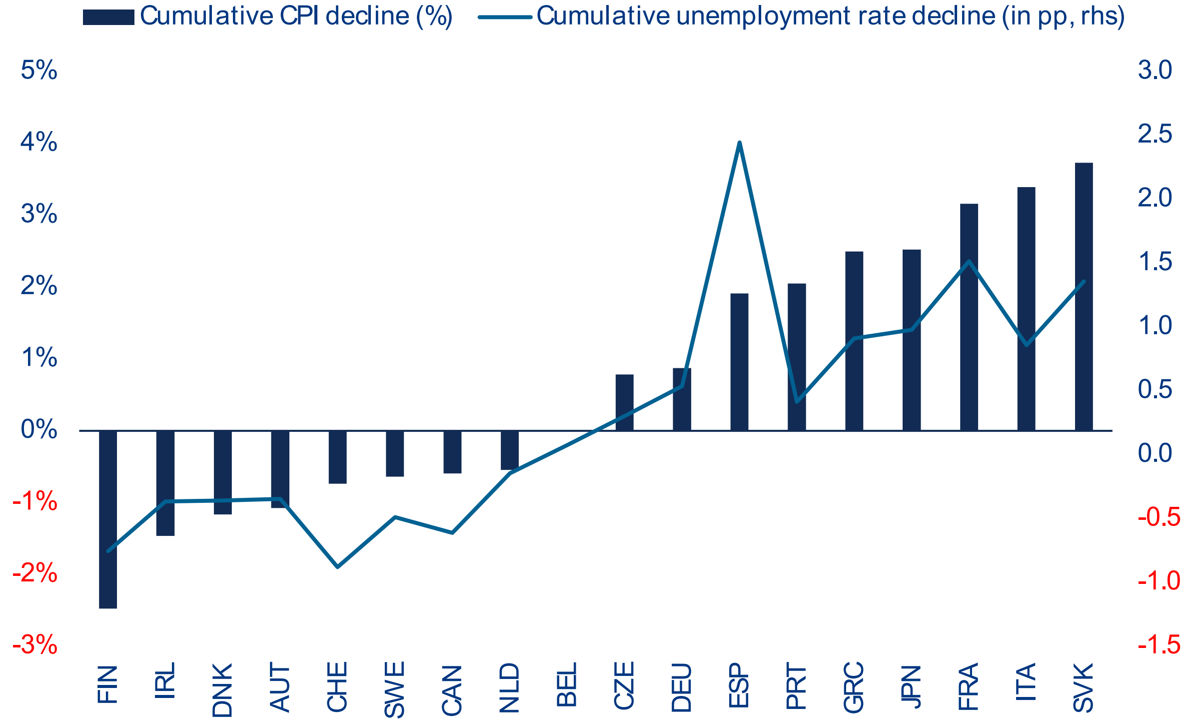
[14] Understanding climate damages: Consumption versus investment - ScienceDirect

The joint behavior of consumer prices (CPI) and the unemployment rate under the stress scenario reveals the stagflationary nature of the heat stress shock, a finding with direct implications for monetary and fiscal policy. In cooler economies – Finland, Ireland, Denmark, Austria and Switzerland – both indicators improve relative to the baseline: prices fall by 0.5% to 2.5% cumulatively, while unemployment declines by 0.14 to 0.88pp. In these countries, the modest productivity gains associated with below-threshold heat stress expand supply, easing price pressures and strengthening labor demand simultaneously.

The picture reverses as heat exposure rises. For hotter countries in our samples – the Czech republic, Germany, Spain, Portugal, Greece, Japan, France, Italy and Slovakia – both prices and unemployment move in the same adverse direction, which is a defining characteristic of a negative supply-side disturbance. Spain registers a cumulative CPI increase of 1.9% alongside a 2.45pp rise in unemployment. France, Italy and Slovakia experience price increases of 3.2% to 3.7% combined with unemployment increases of 0.86pp to 1.51pp. This co-movement of rising inflation and rising unemployment is the hallmark of stagflation, and it stands in sharp contrast to the pattern produced by a standard demand shock, where the two variables move in opposite directions along the Phillips curve. In the New Keynesian framework, Blanchard and Galí (2007)[15] show that such a trade-off arises when real imperfections, such as wage rigidities, prevent the economy from adjusting smoothly to supply-side shocks. The heat stress shock in our simulation operates through precisely this type of supply-side channel: reduced potential output pushes up unit costs and prices, while simultaneously contracting wages and salaries.

The result of such heat stress scenario is a policy environment in which conventional stabilization tools face a binding tradeoff: tightening monetary policy to contain inflation would deepen the employment losses, while loosening policy to support the labor market would accommodate further price increases. This dilemma is especially acute in the Eurozone context, where a single monetary policy must simultaneously address economies experiencing positive supply effects from moderate warming, such as Finland and Austria, and economies facing stagflationary pressures from extreme heat, such as Germany, France, Italy and Spain, a form of climate-induced macroeconomic divergence that existing policy frameworks are not designed to manage.

Figure 10: Consumer prices and labor market response to sustained extreme heat stress, 2026–2030 (cumulative deviation from baseline)



Sources: World Bank, Microsoft, Allianz Research

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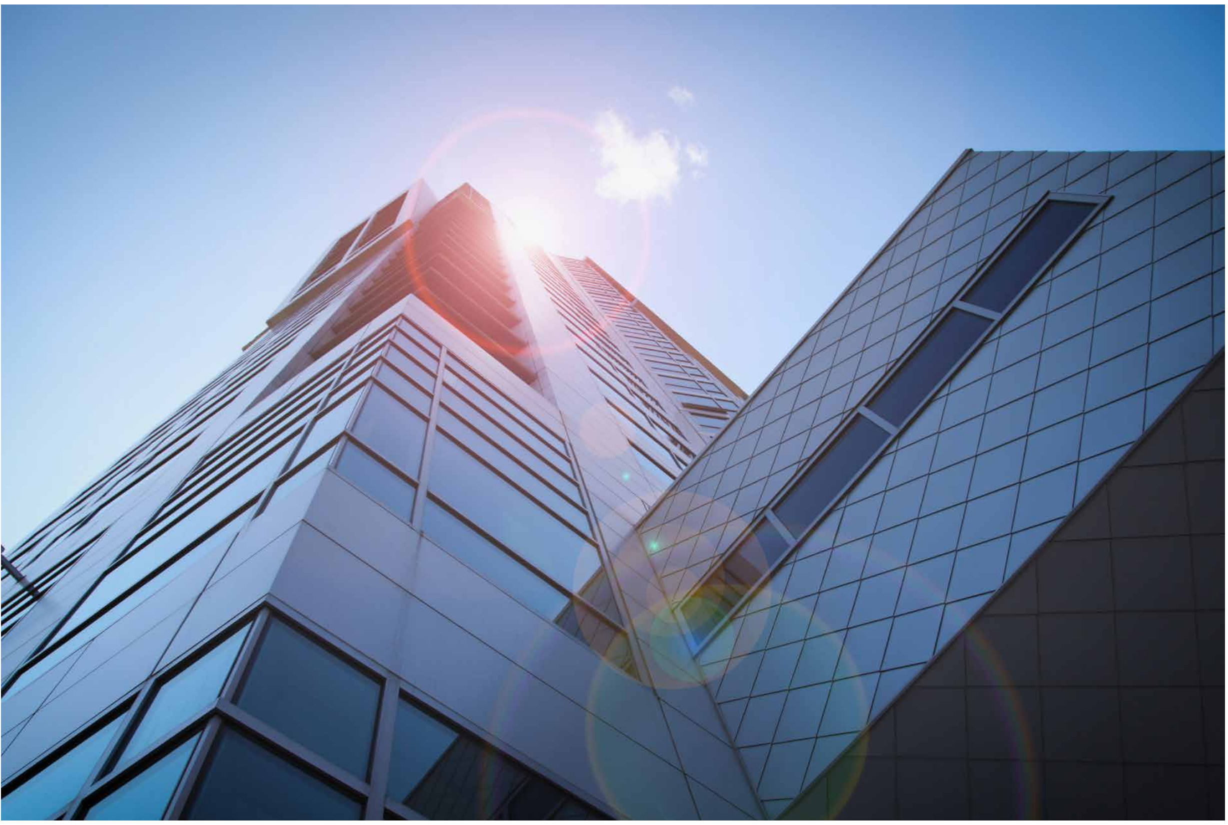
[15] Real Wage Rigidities and the New Keynesian Model - BLANCHARD - 2007 - Journal of Money, Credit and Banking - Wiley Online Library



The fiscal burden

Even though it already receives about 50% of climate-related investments, extreme heat puts a strain on public finances by cutting revenues and raising adaption costs. Heat reduces GDP and productivity, which lowers tax collection, while also disrupting supply chains and energy systems, which further weakens revenues. Estimated annual revenue losses are -1.8% in France, -1.3% in Italy and Spain, -1.0% in Greece and -0.7% in Germany – higher than estimated GDP losses because progressive tax systems mean revenues tend to fall faster than output itself, amplifying the fiscal drag beyond the headline GDP loss. At the same time, public spending rises. Governments face higher inflation-linked costs (e.g. wages, pensions and social benefits) as well as heat-specific expenditures (e.g. healthcare, energy subsidies, disaster response, infrastructure repair and social protection). Demand for emergency investments in cooling infrastructure also increases. In Europe, heat-related spending accounts for around 50% of climate-related public expenditure (2.1% of GDP), but this figure varies widely: 40% in Austria, 51% in Germany, 58% in France, 63% in Spain and 65% in Italy. Flooding accounts for about 35%, with the remainder going to wildfires, drought and other areas like biodiversity. As a percentage of GDP, heat-related spending ranges from 2.2% in Italy to 1.6% in France, 1.3% in Spain, 1.1% in Germany and 0.5% in Ireland (Figure 11). Adaptation to heatwaves accounts for a significant proportion of more than a quarter of heat-related budgets, primarily for cooling and urban greening measures. However, overall investment in heat resilience is still lacking to provide for a heat proof society.[16]

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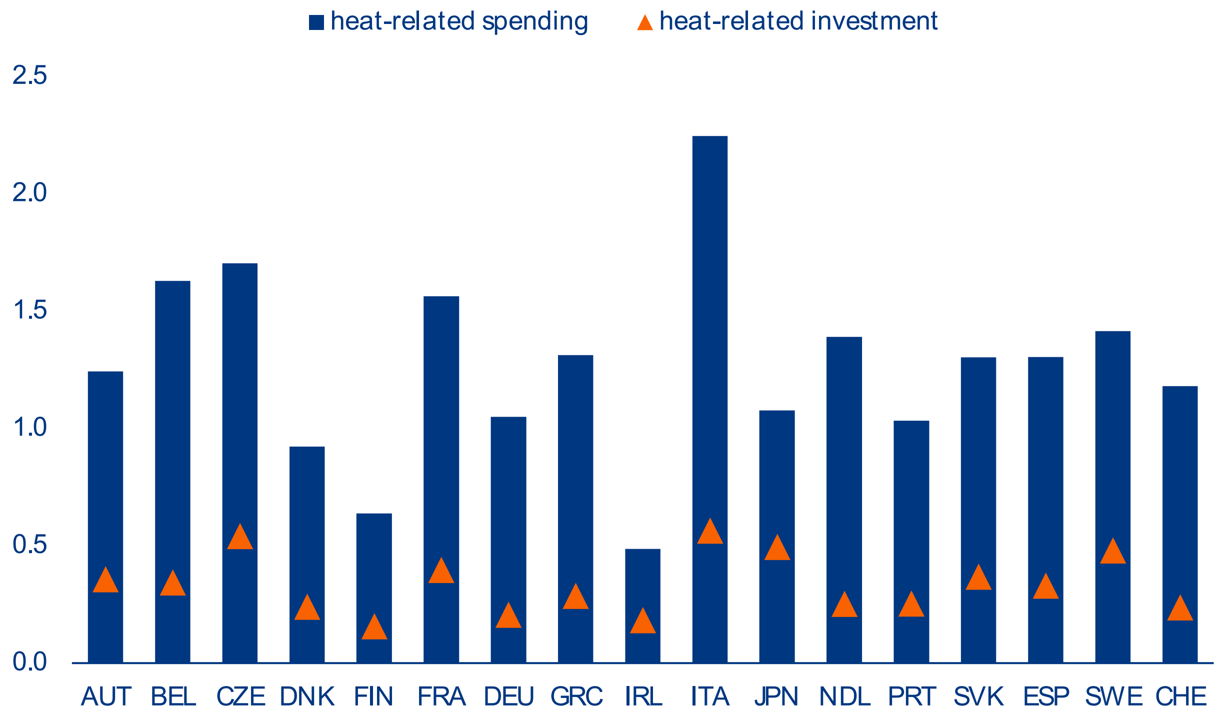
[16] From invisible to investible: An investment taxonomy for climate adaptation | Allianz

Figure 11: Heat-related spending and investment, in % of GDP 2023



Sources: OECD, Allianz Research

On average, the fiscal balances of European countries could deteriorate by around 0.5% of GDP annually due to heat stress, creating a structural tension between the fiscal damage caused by heat and the investment required to adapt to it. A rapidly growing literature has established that climatic risks impose economically significant costs on public finances[17], operating through both the erosion of tax revenues as climate damages reduce economic output and the increase in public expenditure as governments face rising costs for existing commitments and new demands for adaptation. Our results confirm both channels operating simultaneously. On the revenue side, the productivity and wage shocks documented in our simulations translate directly into lower tax receipts: economies producing less and paying lower real wages generate less income tax, social security contributions and value-added tax revenue. On the expenditure side, the stagflationary character of the heat shock through rising prices combined with contracting output, inflates the cost of government programs indexed to prices or wages. The share of public spending subject to such indexation varies considerably across our sample, from approximately 20% in Ireland to 58% in Finland, creating heterogeneous fiscal exposure to the same inflationary impulse.

We identify three groups of countries based on the interaction between heat-related fiscal pressure and existing budgetary constraints. The first group comprises countries where this tension is most acute: heat-related fiscal pressure is significant and public finances are already strained exceeding the Maastricht deficit criterion of –3%. France is the most exposed case. Heat stress could worsen an already high expected fiscal deficit of –4.9% (average 2025-2030) by an additional 2.2% of GDP. At this level, fiscal space for discretionary adaptation spending is severely compromised. Germany, with an estimated deficit of –3.6% and additional heat-related pressure of 0.9%, faces a tighter version of the same constraint. Italy's fiscal deficit of -3.1% could worsen by an additional 1.9% of GDP while Belgium, where 0.2% of additional pressure meet a deficit of –4.0%, completes this group

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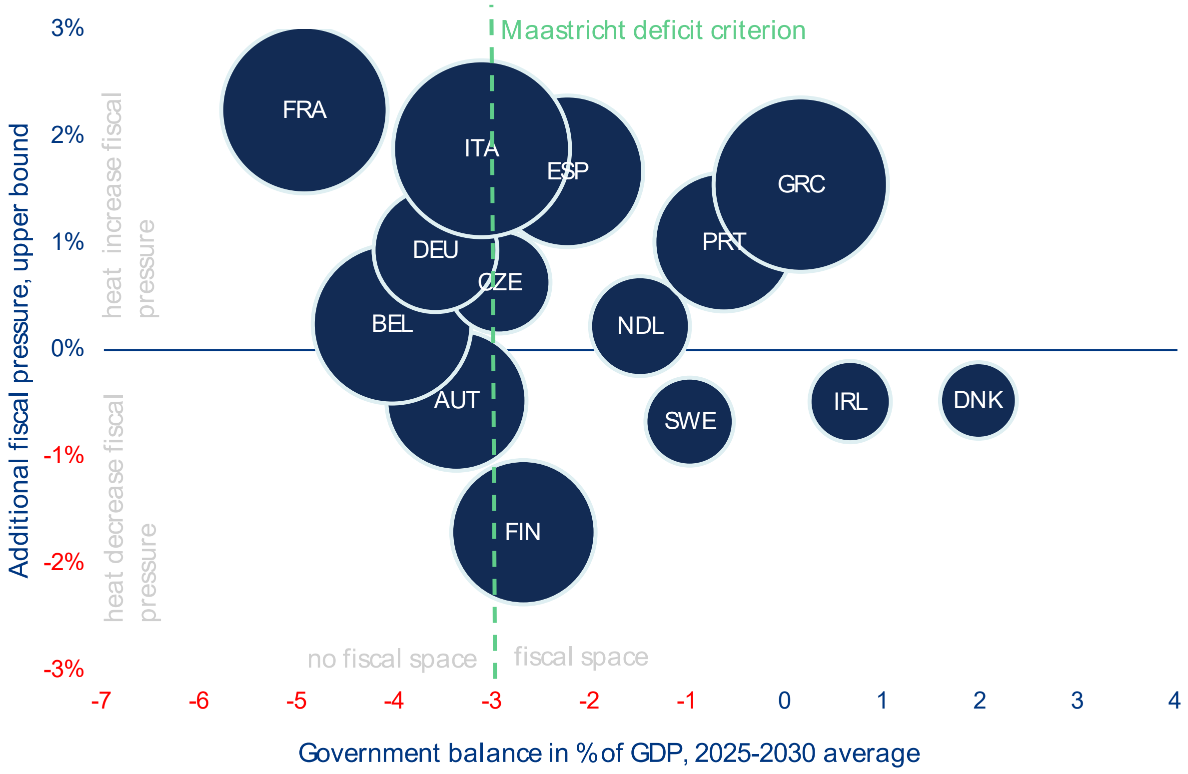
[17] Climate Change Impacts on Public Finances Around the World | Annual Reviews

in the upper quadrant (Figure 12). For these economies, the fiscal damage from heat is actively eroding the budgetary room from which the adaptation response must be financed. Considering in addition the projected debt burden of a country also makes clear that the heat-related fiscal pressure on countries like France (121% of GDP on average between 2025 and 2030, bubble size), Italy (136% of GDP) or Belgium (109% of GDP) is more worrying than for countries like Germany with a projected debt burden of about 66%.

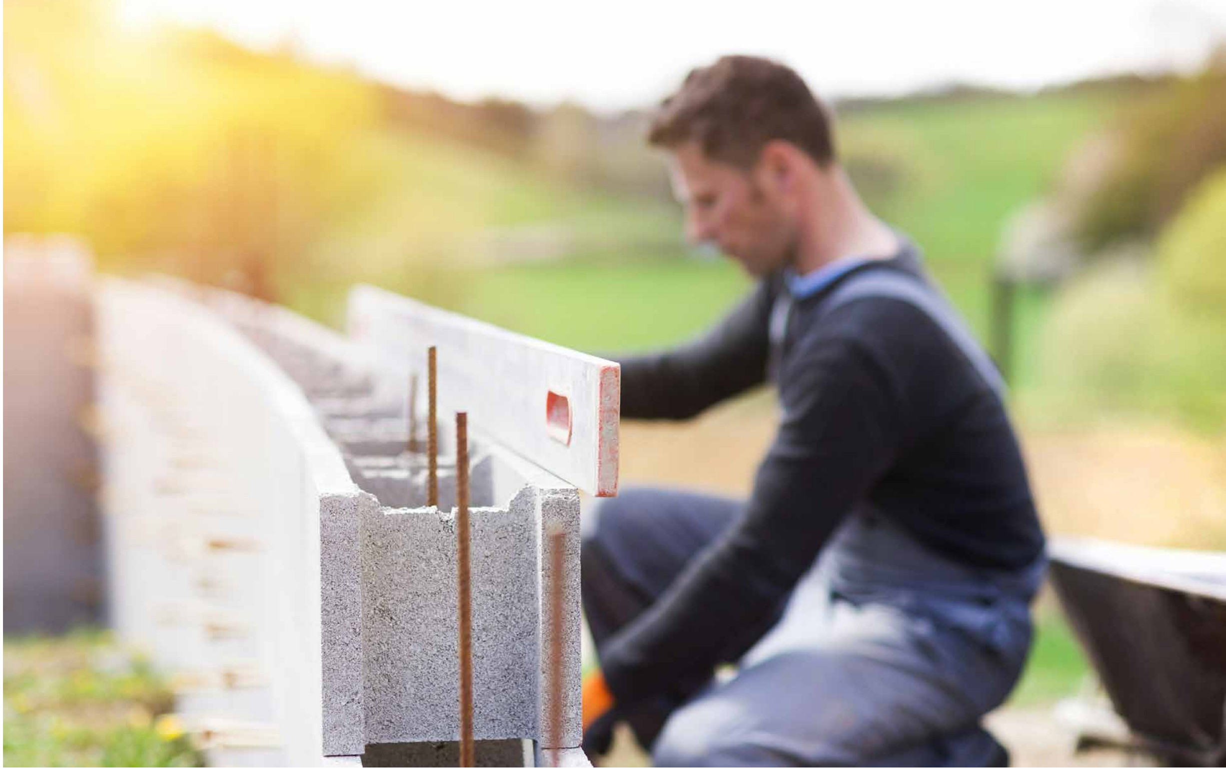
The second group includes countries where the fiscal deficit still provides some room but where heat-related pressures from lower growth, higher inflation and adaptation investment needs are large enough to threaten the Maastricht threshold. Italy and Spain, with estimated deficits of –2.8% and –2.4% respectively, could clearly breach the –3% criterion once heat-related pressures of 1.9% and 1.7% of GDP are factored in. The Czech Republic faces a similar dynamic, with 0.6% of heat pressure meeting a deficit hovering just above –3%. Other countries in this group, such as Greece (1.5% of heat pressure), Portugal (1.0%) and the Netherlands (0.2%), have more fiscal room and are thus less immediately constrained, but the trajectory might point toward increasing pressure.

The third group, which contains cooler regions such as the Nordic countries, may experience an improvement in their fiscal positions as moderate warming boosts economic activity through reduced heating costs and marginally improved working conditions. For these countries, the fiscal space created by a temporarily favorable climate position should be used for preventive adaptation investment, including updating building codes, establishing heat-health action plans, introducing workplace heat protocols, before the temperature distribution shifts further. Preventive action taken now, when fiscal conditions permit, yields substantially higher returns than remedial action taken later under fiscal constraint.

Figure 12: Average fiscal pressure due to heat in % of GDP (annually between 2026 and 2030) and government balance in % of GDP (2025-2030 average)



Sources: OECD, COFAS, Oxford economics, Allianz Research. Note: Bubble size indicates the projected debt burden by country 2025-2030 on average. These figures take into account the average change in inflation due to heat between 2026 and 2030, the share of indexed spending by country and heat-specific expenditure as a share of total climate-related public expenditure



From exposure to resilience: the three-pillar adaptation plan

Pillar 1. Protecting workers and productivity

The labor-productivity exposure shows that above 30°C, each additional degree of Tx5d reduces output per worker-hour by approximately USD1.30. Globally, without a tailored adaptation strategy, working hours lost to heat stress are projected to rise from 1.4% in 1995 to 2.2% by 2030 (ILO 2019). Four regulatory mechanisms shape how much of this will be mitigated: quantitative temperature thresholds, automatic work-restriction or suspension triggers, compensation for hours lost and contractual extension to fixed-term, seasonal, self-employed and platform workers.

No major European economy currently pulls all four, and the open cells cluster on the dimensions most relevant to outdoor and non-standard workers (Table 1). Spain comes closest, combining binding indoor thresholds (Royal Decree 486/1997) with up to four days of paid adverse-weather leave (Royal Decree-Law 8/2024), though the indoor focus and standard-contract design leave outdoor and non-standard workers partially exposed. France introduced procedural employer obligations from July 2025 but stopped short of quantitative thresholds or compensation. Germany's ASR A3.5 sets graduated thresholds at 26°C, 30°C and 35°C with a recognized compliance route under workplace-safety law, but does not by itself trigger automatic work restrictions. Finland regulates exposure time above 28°C through binding work-rest limits. The UK and Ireland rely on general workplace-safety duties.

Table 1: Coverage matrix — occupational heat-stress regulation across selected economies, scored on four mechanism dimensions.

Country / Economy	Quantitative threshold	Automatic work restriction / suspension trigger	Compensation for lost time	Extension to non-standard workers
Spain	● indoor	◐ adverse-weather trigger	● RDL 8/2024	◐ standard contract bias
France	○	◐ procedural only	○	○
Germany	● ASR A3.5 graduated	○ compliance route only	○	○
Finland	● 28°C / 33°C	● work-rest limits	○	○
Italy	○	◐ protocols	◐ wage support for heat stoppages	○
UK & Ireland	○	○	○	○
Slovenia	◐ indoor reported	○	○	○
Australia	○ no national heat-specific mechanism	○	○	○

Legend: ● fully covered, ◐ partial or conditional, ○ not covered

Source: Allianz Research

Read in this format, the gap is not that most countries are silent, it is that no country closes all four cells, and the open cells concentrate where exposure is highest. Of the four economies most affected in the output-per-worker-hour counterfactual (France, Italy, Slovenia and Australia) none appears to combine comprehensive binding heat thresholds, automatic work-restriction rules and broad compensation coverage. France has recently strengthened procedural obligations; Italy provides some wage-support channels during extreme heat, recognized for temperatures above 35°C and, in some cases, below it depending on perceived temperature and work conditions; Australia relies mainly on general work-health-and-safety duties rather than a national heat threshold and Slovenia's coverage should be treated separately depending on whether the analysis focuses on indoor thresholds or outdoor exposure. Several EU countries have no explicit heat-specific workplace provision. The most consistent open cell across all groups is contractual: compensation provisions, where they exist, are built around standard employment relationships; they may cover fixed-term and seasonal employees in principle, but access is weaker in practice, while self-employed and platform workers are often excluded or only indirectly covered. The cost of adaptation therefore falls disproportionately on the workers least able to bear it.

Pillar 2. Cooling buildings and stabilizing the grid

The exposure is two-sided and must be addressed simultaneously: poorly adapted buildings on the demand side, where indoor temperatures rise and cooling demand and heat mortality follow, and thermoelectric generation on the supply side, which derates under heat stress precisely when cooling demand peaks. Four regulatory levers shape how much of this is mitigated: overheating thresholds in building codes, mandatory passive cooling in renovation, cooling access as social policy and summer adequacy planning that models coincident cooling demand and supply derating. No major European economy currently pulls all four, and the gaps cluster on renovation, social-policy access and adequacy planning (Table 2). The revised EPBD (Directive 2024/1275), with a transposition deadline of 29 May 2026, brings overheating and passive cooling into the energy-performance framework but is silent on cooling access and grid resilience. At the national level, France's RE2020 is the most advanced overheating regime, integrating a degree-hour indicator calibrated on a 2003-heatwave reference; England's Approved Document O and the Netherlands' TOjuli indicator play comparable new-build roles. Spain and Germany sit a tier below – Spain capping cooling energy demand without a dedicated overheating definition and Germany addressing summer thermal protection through DIN 4108-2 rather than a dedicated regime.

Table 2: Coverage matrix — building heat resilience and summer peak-demand management across selected economies, scored on four mechanism dimensions.

Country / Economy	Quantitative overheating threshold (new build)	Mandatory passive cooling in renovation	Cooling access as social policy	Heat-adjusted summer adequacy & distribution planning
EU EPBD 2024/1275 (from May 2026)	◐ EPC reflection, passive cooling in min. standards	◐ depends on transposition	○ out of scope	○ out of scope
France	● RE2020 DH indicator	◐ new-build focus	○	◐ RTE summer adequacy assessment
Germany	◐ DIN 4108-2 (indirect)	○	○	○ winter-oriented
Spain	◐ cooling-energy cap (CTE)	◐ partial	○	○ no documented mechanism
United Kingdom (England)	● Approved Doc O	○ new-build only	○	○ winter-peak focus
Italy	○ no dedicated national overheating indicator	○	○	○
Netherlands	● TOjuli indicator	◐ partial	○	○
Legend: ● fully covered, ◐ partial or conditional, ○ not covered				

Source: Allianz Research

Read in this format, the gap is twofold: cooling access remains far less institutionalized than winter heating support, and even the strongest national codes apply mainly to new build rather than to the existing stock where most exposure sits. The forthcoming EU floor in May 2026 will raise the minimum on overheating and passive cooling but does not address cooling access or grid resilience, and its bite depends entirely on transposition. The most consistent open cell is cooling access: no major European economy has developed a systematic summer counterpart to the winter heating-support architecture, and the gap falls on the groups that drive the European mortality concentration – older people, low-income households and tenants in the least-insulated dwellings. A workable national plan therefore rests on closing the four open cells together: binding overheating thresholds extended from new build to deep renovation; mandatory passive cooling triggered by a transparent renovation threshold; cooling access as a coordinated package – passive retrofits and efficient-appliance subsidies first, targeted bill support and medically prioritized access second, paired with a regulated right-to-install subject to structural and heritage constraints and heat-adjusted summer adequacy planning that explicitly models coincident cooling demand and supply derating, paired with residential demand response.

Pillar 3. Income protection and adaptation finance

Pillar 3 addresses the income-transmission channel of heat risk: when productivity losses become wage losses, the burden falls unevenly across workers, households and public budgets. The wage compression documented in previous sections lands first on outdoor workers, fixed-term, seasonal and platform workers and lower-income households. Existing stabilizers, such as unemployment insurance, short-time work, indexed transfers and energy-poverty support, absorb part of the shock, but with a structural twist: the same indexation and triggering that protect household purchasing power also raise public expenditure or compress tax receipts, lifting the fiscal cost of each heat episode.

This is the fiscal-stabilizer paradox at the heart of Pillar 3. The more effectively a welfare state cushions households from heat-driven income and price shocks, the more it shifts the climate burden onto public budgets. If that burden is met through ex-post compensation rather than ex-ante adaptation, it consumes the fiscal space needed to lower future exposure. The paradox has two legs: a household-income leg, where existing social protection determines who absorbs the shock, and a fiscal-architecture leg, where public finance determines whether the resulting cost goes into prevention or compensation.

Only Spain (Royal Decree-Law 8/2024 paid adverse-weather leave, including heatwave situations) and partially Italy (CIG/CIGS wage supplementation activated for extreme heat) have operational heat-specific income-protection mechanisms. The remaining major economies – France, Germany, the UK, the Netherlands and most other member states – have general schemes that could in principle absorb heat-driven income loss but require ad-hoc activation each time, with no automatic heat trigger in legislation. Parametric risk-transfer for residual income volatility remains essentially absent at the national level in Europe; the European Commission's Climate Resilience Dialogue (2024) classifies it as an evolving tool requiring further analysis.[18] National adaptation strategies are now in place across all major European economies but remain strategic documents rather than multi-year budget envelopes. At EU level, several frameworks enable national action without amounting to a European income-protection or adaptation-budget regime.

To reduce the gap, income protection, residual risk-transfer, budget planning and investment appraisal have to be redesigned as one fiscal architecture, working on both sides of the problem. Existing social-protection instruments should carry explicit heat triggers conditional on workplace adaptation by employers. Parametric instruments calibrated to occupational heat thresholds can complement social insurance for the residual income volatility it does not absorb, with prioritized access for outdoor and non-standard workers and a public-backstop component for affordability. Multi-year adaptation budget envelopes, set out within medium-term expenditure frameworks, should replace reliance on ex-post emergency packages, paired with climate-risk screening across public investment management and coordinated oversight bringing together the health, housing, environment, energy, transport and labor ministries.

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[18] Climate Resilience Dialogue - Final Report - Zurich Climate Resilience Alliance

Appendix

A1 – The impact of heat stress on energy demand

To empirically assess the relationship between heat stress and energy demand, we construct a panel regression framework that captures how rising heat stress translates into higher energy consumption – primarily through the increased use of cooling technologies such as air conditioning and refrigeration. As climate change drives more frequent and intense heat extremes, this mechanism is expected to become an increasingly important driver of energy demand, with significant implications for grid stability, energy security and the pace of the low-carbon transition.

Our analysis draws on two data sources. Energy consumption data are sourced from the IEA's World Energy Balances 2025, expressed in per capita megajoules (MJ) to allow for cross-country comparability. To capture heat stress, we use the Tx5d indicator from the ERA5 reanalysis dataset, defined as the mean daily maximum temperature over the hottest five consecutive days of a given year. This metric is particularly well-suited to our analysis, as it reflects the kind of sustained heat episodes most likely to trigger a behavioral and technological response in energy use, rather than isolated daily peaks.

The empirical model is estimated on an unbalanced panel covering 49 countries over the period 1991–2023. It provides both broad geographic coverage and sufficient temporal depth to identify meaningful climate-energy relationships. We employ a two-way fixed effects specification, controlling for both country-level heterogeneity and common time trends, with robust standard errors clustered at the regional level to account for potential spatial correlation in residuals. The regression model reads

$$\ln(\mathrm{energy}) = \beta_1 \mathrm{tx5d} + \beta_2 \mathrm{tx5d}^2 + \mathrm{C(ISO3)} + \mathrm{C(Year)}; \mathbf{Eq.}\ 1$$

The relationship between heat stress and energy consumption is nonlinear, following a convex U-shaped curve (Table A1), confirming previous literature results.[19] At moderate temperature levels, energy demand declines as milder conditions reduce the need for space heating and other thermal energy services. This downward trend reverses once temperatures exceed approximately 30°C, a commonly used threshold for heat stress[20], at which point cooling demand begins to dominate, driven primarily by the widespread use of air conditioning.

This non-linearity is reflected in the regression results, which show that the marginal effect of heat stress on energy consumption is both temperature-dependent and sign-switching. At 25°C, the effect is negative: a one-unit increase in the Tx5d indicator is associated with an approximately 0.6% decrease in per capita energy consumption. At 35°C, the relationship reverses: the same marginal increase in heat stress is associated with a 1.2% rise in energy consumption. This twofold difference in magnitude illustrates how the energy implications of heat stress intensify disproportionately at higher temperature levels. A dynamic with important consequences for energy planning and infrastructure resilience in a warming climate.

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[19] Electricity Consumption and Temperature: Evidence from Satellite Data, WP/21/22, February 2021

[20] Keeping cool in a hotter world is using more energy, making efficiency more important than ever – Analysis - IEA

Table A1: Regression results: The impact of heat stress on energy consumption

Variable	Coefficient	p-value
Intercept	10.3390	0.000
tx5d	-0.0514	0.005
$tx5d^2$	0.0009	0.008

Source: Allianz Research

A2 – The impact of heat stress on productivity

The adverse effects of heat stress on labor productivity are well established in the academic literature. Growing evidence from both micro and macro studies shows that exposure to extreme temperatures affects health, labor supply, and labor productivity in the short run.[21] At the physiological level, heat stress affects workers through physiological and behavioral responses, in turn reducing labor supply, productivity and overall labor capacity, with the relationship largely non-linear, declining sharply beyond peak temperature thresholds.[22] Despite considerable heterogeneity across work sectors and study designs, nearly all field studies consistently find a reduction in productivity due to occupational heat exposure.[23]

Building on this evidence, we adopt the same empirical framework used for our energy consumption analysis to derive an econometric estimate of heat stress impacts on productivity. Heat stress is measured using the Tx5d index, as defined previously. For productivity, we draw on two complementary indicators from the OECD database[24], output (gross value added) per hour worked, expressed in USD, and wages per hour worked, which together capture both the economic output and the compensation dimension of labor performance. The models reads as follow

$$\mathrm{GVA}_{\mathrm{per}_{\mathrm{hour}}} = \mathrm{tx5d} + \ \mathrm{tx5d}_{\geq 30} + \mathrm{C(ISO3)} + \mathrm{C(Year)}; \mathbf{Eq.}\ 2$$

$$\Delta \ln(\mathrm{wage}_{\mathrm{per}_{\mathrm{hour}}}) = \mathrm{tx5d}_{(\mathrm{t}-1)} + \ \mathrm{tx5d}_{(\mathrm{t}-1)}{}^{2} + \mathrm{C(ISO3)} + \mathrm{C(Year)}; \mathbf{Eq.}\ 3$$

Equations 2 and 3 depart from the baseline specification of Equation 1 in two important ways, each motivated by the distinct channels through which heat stress affects labor productivity. Equation 2 models gross value added per hour as a function of both the Tx5d index and an interaction term, Tx5d when heat stress exceeds 30°C, to account for the non-linear intensification of heat impacts at higher temperature levels. Equation 3, which models the log change in wages per hour, follows the same structure as the energy consumption model (Equation 1), but introduces a one-year lag specification for both the linear and quadratic Tx5d terms. This lagged structure reflects the hypothesis that wage adjustments to heat stress occur with a delay, as labor market responses, such as renegotiated contracts or sectoral reallocation, tend to materialize more slowly than changes in physical output.[25]

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[21] Reflections—Temperature Stress and the Direct Impact of Climate Change: A Review of an Emerging Literature | Review of Environmental Economics and Policy: Vol 10, No 2

[22] Heat stress and the labour force | Nature Reviews Earth & Environment

[23] Frontiers | Occupational heat stress, heat-related effects and the related social and economic loss: a scoping literature review

[24] OECD Data Explorer • Productivity database

[25] Economic impact of labor productivity losses induced by heat stress: an agent-based macroeconomic approach | Climatic Change | Springer Nature Link

The output per hour regression (Eq. 2) is estimated on a panel of 35 countries over the period 1997–2023 (Table A2). The results reveal a clear threshold effect consistent with the non-linear relationship hypothesized in our framework. Below 30°C, the coefficient on Tx5d is positive and marginally significant at the 10% level (0.59), suggesting that moderate heat is associated with a slight increase in output per hour – potentially reflecting seasonal productivity gains in temperate economies. Above 30°C, however, the picture changes markedly: the coefficient on the interaction term is negative and statistically significant at the 5% level (–1.30), indicating that each additional degree beyond this threshold is associated with a reduction in output per hour of approximately 1.30 USD. These findings underscore the non-linearity of heat's impact on labor productivity, where the results point to 30°C as a critical inflection point beyond which heat stress begins to impose measurable economic costs on labor output.

Table A2: Regression results: The impact of heat stress on output per hour

Variable	Coefficient	p-value
Intercept	13.7401	0.142
tx5d	0.5900	0.072
$\mathrm{tx5d}_{\geq 30}$	-1.3039	0.042

Source: Allianz Research

The wage regression (Eq. 3) is estimated on a panel of 33 countries over the period 1995–2023 (Table A3). The results are broadly consistent with those obtained for output per hour, with a turning point again emerging around 30°C. The use of a one-year lag structure reflects the hypothesis – supported by the data – that labor compensation adjusts to heat stress with a delay, as wage-setting mechanisms respond more slowly to productivity shocks than output itself.

The relationship between heat stress and wage growth follows an inverted U-shape. In the range below 30°C, higher heat stress in year t is associated with a modest acceleration in wage growth in year t+1, consistent with the productivity gains observed at moderate temperatures in the output per hour specification. Above 30°C, this relationship reverses: additional heat stress dampens wage growth the following year, reflecting the transmission of heat-induced productivity losses into labor compensation over time.

The marginal effect of heat stress on wage growth is both temperature-dependent and sign-switching. At 25°C, the effect is positive, with a one-unit increase in Tx5d associated with an approximate 0.2% increase in wage growth. At 35°C, the relationship reverses, with the same marginal increase in heat stress associated with a 0.2% decline in wage growth. While the magnitude of the effect may appear modest, its consistency with the output per hour results and its statistical significance lend confidence to the finding that heat stress above 30°C exerts a meaningful drag on labor compensation, with implications for household income, consumer demand and the broader macroeconomic costs of climate change.

Table A3: Regression results: The impact of heat stress on per hour wage growth

Variable	Coefficient	p-value
Intercept	-0.0756	0.364
$\mathrm{tx5d}_{(t-1)}$	0.0120	0.027
$\mathrm{tx5d}_{(t-1)^2}$	-0.0002	0.013

Source: Allianz Research

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