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Major Cause of Heatwaves in Europe and Policy Recommendations

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Abstract. Heatwaves in Europe have become increasingly frequent, long-lasting and intense, significantly and negatively influencing public health, infrastructure, and ecosystems. The major cause is anthropogenic climate change and atmospheric circulation changes. Government measures now include expanded heat-health warning systems, early alert networks, targeted public outreach to vulnerable populations, and urban cooling initiatives. This paper, through a literature review, analyzes the climatological causes of recent extreme heatwave events, reviews their impacts, evaluates current policy, and identifies critical defects. Finally, this paper proposes evidence-based policy recommendations, including nature-based cooling, infrastructure retrofits, enhanced health planning, and continued emissions reduction to improve Europe's preparation for future heatwaves. These measures can also be applied in a broader context of global heatwave issues and promote the improvement of environmental management.

Keywords: Heatwave, Europe, Environmental policies, Climate change

1. Introduction

Heatwaves in Europe have been an increasingly popular topic in recent years, posing a significant threat to the socio-economy and local people's lives. Europe used to be cool in the past, but in the last few decades, Europe has warmed faster than most regions globally, and summer heat extremes have increased significantly in the last few decades. For instance, in 2003, Europe faced an unprecedented heatwave, which caused roughly 70,000 excess deaths [1]. Recent summers have continued to break heatwave records: the summer of 2022 became Europe's hottest on record and was linked to an estimated 61,000 heat-related deaths across 35 European countries [2]. Previous studies confirm that anthropogenic global warming has greatly amplified these events. Thus, the frequency of extreme heatwave events has changed from rare to common.

Heatwaves arise from the combination of a warmed baseline climate and other natural variables. Persistent high-pressure "blocking" anticyclones in Europe eliminate clouds and rainfall, allowing intense solar heating. Recent research highlights a characteristic "double jet" stream pattern that traps heat over Western Europe [3]. Positive feedback loops further amplify heat: prolonged hot and dry conditions dry soils and vegetation, which reduces reflective and evaporative cooling and makes the surface temperature higher. To sum up, Europe has become a heatwave hotspot and global

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climate focus, since European summer heat extremes rise significantly higher than average global warming.

This essay provides a comprehensive, multi-disciplinary review of European heatwaves in recent decades. It examines the climate science and meteorological drivers behind heatwaves, and analyzes their societal and environmental impacts across health, infrastructure, the economy, and agriculture. Also, it evaluates existing policy measures at the European Union (EU), national, and local levels, identifying shortcomings in these responses. Now, at the same time, the 2025 summer is impending, so this essay offers clear policy recommendations to improve heatwave preparedness, response, and mitigation to overcome this summer.

2. Climate science of European heatwaves

Anthropogenic warming has intensified European heat. Global mean temperature is now about 1.2 ℃ above pre-industrial levels, which raises the baseline from which extremes draw. Superimposed on this are atmospheric circulation changes: Europe's summers often feature "quasi-stationary high-pressure ridges". These blocks suppress cooling and allow heat to accumulate. Studies find that such blocking anticyclones are a primary driver of European hot extremes. Moreover, a special "double jet" pattern (a split in the jet stream) has grown more frequent and persistent over the last decades. A study showed that Western Europe's heatwave frequency and intensity have increased 3 to 4 times faster than the rest of the hemisphere [3].

In addition to atmospheric dynamics, positive land feedback loops magnify heatwaves. Heat dries soils and plants, causing surface temperatures to spike beyond what radiative forcing alone would produce, which is strongest in southern/central Europe. Warm anomalies in the adjacent oceans, such as the Mediterranean and the North Atlantic, also help sustain high-pressure over land. Altogether, these factors explain why Europe warms disproportionately in summer compared to other regions.

3. Impacts of European heatwave

European heatwaves have serious impacts across society and ecosystems, which may affect public health, a country or region's infrastructure, economy and labor force development, and agriculture, forestry, and even the whole environment.

3.1. Public health

Heatwaves cause dramatic mortality and illness. Excessive heat can trigger heat stroke, dehydration, and worsen cardiovascular and respiratory conditions [4]. Vulnerable populations include the elderly, infants, pregnant women, outdoor workers, and those with chronic diseases. European data indicate that on the order of 95% of all fatalities from weather or climate-related events (1980 to 2023) were due to heatwaves. For example, the 2003 heatwave alone claimed about 70,000 lives, and the 2022 summer led to about 61,000 deaths [1]. Moreover, health services are strained. During recent heat events, hospital admissions rose about 20% or more, and emergency department visits spiked, which is uncommon in summer in the past. The disease burden is unevenly distributed, heavily affecting urbanized areas and socially disadvantaged groups [4].

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3.2. Infrastructure

Extreme heat can damage infrastructure. Many transport and energy systems were built under cooler design norms. In heat, steel railway tracks expand and can buckle, so there must be speed restrictions or temporary closures, which reduce the efficiency of transportation. For instance, in the UK (which has relatively mild summers), about 20% of national infrastructure is estimated to be at risk of overheating as temperatures rise [5]. Steel rails in Europe can become about 20°C hotter than the air. Without space to expand, they deform and require days of repairing. Similarly, road asphalt and airport runways can soften and deform under extreme heat. Electrical networks operate near capacity in summer; overhead power lines sag and electrical resistance increases, which can reduce electricity transmission efficiency. In some heatwave events, grid operators have warned of blackouts if demand for cooling exceeds supply capacity. Water systems are also affected. Heat and drought can lower river flows and reservoir levels, threatening drinking water and hydropower generation [5]. To sum up, transportation, energy, and water systems face increased failure risks and performance losses during heatwaves.

3.3. Economy and labor

Heatwaves impose large economic costs through direct damages and reduced productivity. High temperatures slow labor, especially in outdoor work such as construction, agriculture and delivery services. A recent analysis of four major European heatwave years (2003, 2010, 2015, 2018) estimated that heatwave-related productivity losses were about 0.3 to 0.5% of EU GDP in those years [6]. Losses were uneven: southern Europe (e.g., Spain, Italy, Greece) faced the highest GDP impacts (approaching 1% in some regions) due to already-high baseline temperatures [3]. These estimates include lost work hours and reduced output from heat stress. Also, economic impacts can be from direct damages: heat can warp machinery, boost wildfires, and spoil perishable goods [7]. Tourism is mixed: some short-term tourism (beaches, pools) may see a small uptick, but overall, extreme heat reduces outdoor economic activity. Insurance claims that heat-driven losses (crop damage, wildfire, etc.) have risen. In conclusion, heatwaves reduce GDP growth and increase economic volatility.

3.4. Agriculture, forestry, and environment

Heatwaves, usually accompanied by drought, cause severe agricultural losses and environmental damage. Heat and water stress can reduce crop yields. Studies showed that European crop losses from combined heat/drought have roughly tripled over the last half-century. Staple cereals (wheat, maize, barley) are most affected, since much of Europe's grains are rain-fed [4]. For example, the 2018 heat/drought slashed the EU's grain harvest by about 8% relative to the 2013 to 2017 average [8]. This translated into livestock feed shortages and grain price spikes (welfare effects). Heat also stresses viticulture and horticulture (grape crops, fruits, vegetables), and can disrupt planting/harvest schedules. Forests suffer increased fire risk: 2022 saw catastrophic wildfires in France, Spain, and southern Germany, burning hundreds of thousands of hectares [7]. Even when not ignited by lightning, dry heat waves weaken trees and wildlife, contributing to ecosystem degradation and biodiversity loss [8].

In general, all these impacts negatively influence society. Reduced agricultural harvests push up food prices and strain supply chains, which disrupt previous nutrition and trade balances. Infrastructure outages interrupt businesses, compounding losses. Overall, Europe has already

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incurred hundreds of billions of euros in damage from climate extremes (1980 to 2023) due to heatwaves. Vulnerable groups disproportionately bear these costs, raising equity concerns.

4. Current measures and their shortcomings

European governments have begun to address heatwave risks at multiple scales. Strategies vary widely, and some are problematic.

4.1. Current policies

The EU's 2021 Adaptation Strategy sets a broad framework to build climate resilience by 2050. It emphasizes "smarter, swifter, and more systemic" adaptation, including nature-based solutions and data platforms. In practice, the EU's latest climate risk assessment explicitly flags extreme heat, drought, and wildfires as critical threats to health and food systems [7]. EU initiatives like the Climate-ADAPT platform share best practices (e.g., heat action plans, urban cooling projects) and support risk evaluation. The EU also funds research and infrastructure through programs (Horizon Europe, Cohesion Fund) that can include heat resilience components. However, the Adaptation Strategy does not mandate binding measures, so much implementation depends on Member States [9].

Many European countries have adopted heatwave response plans and early-warning systems. For example, in 2024, 21 of 38 assessed countries have formal national Heat-Health Action Plans (HHAPs) or contingency protocols [4]. They include France's Plan Canicule (activated each spring), the UK's Heatwave Plan for England, Portugal's National Contingency Plan for Heatwaves, and Austria's Heat Protection Plan [9]. These plans typically designate lead agencies, define alert thresholds (based on temperature or heat index), and outline coordinated responses (e.g., opening cooling centers, mobilizing emergency services) [4]. At the regional level, many cities participate in the EU Covenant of Mayors and develop Urban Heat Adaptation plans (e.g., Milan's heat action plan, London's cooling strategies) [7]. Early warning systems are increasingly common: national meteorological services and health agencies issue tiered alerts (green, yellow, orange, red) during heatwaves, often tied to public health advice.

Public health authorities have started education and outreach programs. These include media campaigns on staying hydrated and cool, advice on managing vulnerable populations, and communication with healthcare providers. Some countries maintain registries of elderly or at-risk citizens for targeted check-ins during heatwaves [10]. Hospital emergency departments receive heat guidelines. Workplaces and agricultural employers may issue regulations on rest breaks or provide shade and water. International bodies (WHO Europe, ECDC) offer technical guidance for HHAPs [11].

4.2. Limitations

Policy coverage is uneven. There is no EU-wide binding heatwave directive (unlike for flooding or pollution). Policy detail varies greatly: some national plans focus mainly on emergency alerts. Building codes in Europe generally prioritize energy efficiency for cold climates and do not uniformly require cooling features (e.g., solar shading and ventilation standards).

Not all populations are protected. EEA assessments show that many Central and Eastern European countries lack robust HHAPs or heat monitoring systems [4]. In several states, heat adaptation is still nascent or informal. Even in countries with plans, implementation can lag. For

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example, surveys indicate that a significant share of European citizens, including vulnerable groups, live in areas without practical heat shelters or outreach services.

Europe has no unified, real-time system for tracking heat-related health impacts. Excess deaths from heat are estimated retrospectively by statistical models rather than counted directly. As one EEA briefing note states, there is no near-real-time record-keeping system of heat-related deaths at the European level [4].

Built systems remain insufficiently adapted. Most European infrastructure standards were set for a cooler climate. For example, road and rail design tolerances often assume only moderate heat [1]. As a result, heatwaves force ad-hoc measures (speed limits, service reductions) rather than resilience. Urban planning has traditionally favored development over green space, which causes an urban heat island. The Netherlands, for example, has only recently begun updating infrastructure design in anticipation of 40°C summers [8]. Across Europe, physical adaptation is largely reactive, not preventive. The EEA's climate risk report warns that adaptation actions "are not keeping pace with rapidly growing risks" [4].

5. Recommendations for improving heatwave preparedness

The following actions, which are the central focus of this essay for the coming 2025 summer, are recommended to strengthen Europe's resilience to heatwaves.

5.1. Green and nature-based infrastructure

Cities and regions should massively expand green cooling measures. Planting street trees, parks, green roofs/walls, and urban wetlands can passively lower ambient temperatures. This paper recommends updating urban design codes to mandate minimum green space and albedo surfaces in new developments [12]. For example, studies of European cities show that large increases in tree canopy can reduce urban air temperatures by about 0.8°C on average (with up to 6°C locally). Water features (fountains, ponds) should be incorporated for evaporative cooling.

5.2. Strengthen Heat-Health Action Plans (HHAPs)

All EU countries should adopt comprehensive HHAPs and update them regularly [12]. Each plan must assign clear responsibilities, secure funding, and include measurable targets. Key elements include trigger thresholds for action (e.g., alert levels tied to temperature and humidity), activation of health and social services, and designated cooling centers or shelters. Plans should explicitly protect vulnerable groups: for instance, by maintaining registries of the elderly, disabled, or homeless, and by coordinating NGOs for outreach. WHO and EuroHEAT guidelines recommend inter-agency coordination, public education, and emergency response protocols [12]. We urge the EU to support capacity-building: for example, by expanding climate-health training for medical staff and by setting a goal that all Member States have an operational HHAP by 2025. Monitoring and evaluation components must be built in, so that each heat season's data is used to refine future plans.

5.3. Enhance early warning and communication

Meteorological and health services should collaborate on improved heat forecasting. Multi-day forecasts and seasonal outlooks can provide longer lead times. When a heatwave is forecast, multilingual warnings should be broadcast via TV/radio, social media, and SMS alerts. We recommend developing standardized warning levels across Europe (e.g., a common "red alert" criterion) to avoid public confusion. Communication must be clear and actionable: pairing each warning with practical advice (stay hydrated, avoid sun, use cooling centers) and with signposts to resources (public pools, shelters, hotline numbers). Educational campaigns should begin well before summer. Additionally, invest in “smart” alerting (digital apps or wearables) to reach younger and tech-savvy populations.

5.4. Upgrade infrastructure and building standards

Engineering and construction codes must be revised for the warmer climate. Transport systems should use heat-resilient materials and designs: for example, adopting the steel alloys and rail expansion gaps used in Mediterranean countries. Road construction should favor temperature-resistant asphalt mixes. Energy grids require reinforcement: upgrading power lines with advanced auto-tensioning designs, increasing transformer capacity, and expanding decentralized generation (solar-plus-storage) to reduce load on the system. Buildings should be retrofitted for cooling: installing passive shading (awnings, shutters), adding insulation that blocks heat gain, and promoting white roofs and pavements. New building regulations should require natural ventilation, heat-reflective glass, or mandatory cooling systems where needed. Urban drainage systems should be strengthened to handle compound heat/flood scenarios. These infrastructure upgrades will require financing (public investment, public–private partnerships) and updated technical norms.

5.5. Mainstream adaptation and financing

Heat resilience must be integrated into all relevant policies and funding streams. For instance, EU agricultural policy should incentivize drought-resistant crops and sustainable irrigation practices [5]. The Common Agricultural Policy (CAP) and Rural Development funds can support soil moisture conservation and drought forecasting. Similarly, urban planning and transport grants (e.g., via the Cohesion Fund or Recovery Facility) should include heat risk assessments. We also recommend that EU climate funds allocate specific percentages to adaptation (not just mitigation). Financial regulators and insurers should incorporate climate risk in their models, which would steer private capital toward resilient investments. Possible tools include a European “resilience bond” or targeted subsidies for heatproof housing improvements. Cross-border collaboration (e.g., via the Covenant of Mayors or joint research initiatives) should be encouraged to share best practices and reduce duplication.

5.6. Focusing on equity and vulnerable groups

All adaptation measures must prioritize those most at risk. Policy design should explicitly aim to protect low-income and marginalized populations. For example, urban greening projects should focus on heat-vulnerable neighborhoods, not only city centers. Subsidies or vouchers could help poor families buy cooling fans or retrofit their homes. Social services and NGOs should be funded to conduct door-to-door outreach during heatwaves, checking on isolated seniors or distributing water. Labor regulations should mandate rest breaks, shade, and hydration for outdoor workers, enforced by labor inspections. Special attention is needed for migrants, refugees and homeless people; mobile health units or temporary shelters can provide relief. By centering equity, policies will ensure that no group is left dangerously exposed.

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5.7. Maintaining aggressive mitigation

Finally, heatwave risk will continue to climb with unchecked climate change, so it is imperative to advance emissions reduction simultaneously. Every fraction of a degree avoided reduces heatwave frequency and intensity. For example, at 2°C global warming, events now expected once per decade in Europe would occur 5 to 6 times per decade, whereas at 1.5°C they'd occur about 3 to 4 times [3]. EU and national climate policies (renewable energy expansion, efficiency standards, carbon pricing) should therefore continue with full ambition, following the Paris Agreement. Many adaptation measures have mitigation co-benefits; for example, planting urban trees also absorbs CO_2. A unified climate strategy that links cooling and carbon-reduction goals will be far more effective than tackling either independently.

6. Conclusion

European summers are rapidly becoming hotter due to anthropogenic warming and changing atmospheric circulation. Recent events (e.g., 2003, 2015, 2018 to 2023) have illustrated the severe problems, including lives lost, wide-ranging infrastructure destruction and failure, and severe economic and environmental damages. These impacts are projected to worsen sharply as the planet warms further. Our analysis has shown that while policymakers have begun to address heatwaves, their responses remain uneven and insufficient. Critical gaps in surveillance, planning, and infrastructure leave many communities exposed.

Europe must now treat extreme heat as a chronic climate disaster rather than a short-run unnecessary problem. This means that taking urgent actions is necessary. Equally, Europe must continue aggressive emissions cuts because limiting warming is the ultimate way to reduce future heat risk. The scientific consensus is clear: without such actions, heat-related disasters will become routine and often "catastrophic" in scale. The cost of inaction would far exceed the investment in preparation. In conclusion, the comprehensive climate mitigation and integrated adaptation, which focuses on equity and resilience, is vital for ensuring Europe's health and prosperity.

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