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Heatwave Resilience and Social Vulnerability: Who Gets to Stay Cool in Europe's Warming Cities?

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Abstract: As climate change accelerates, European cities face an increasing threat from extreme heat events. However, the risks and impacts of heatwaves are not distributed equally across urban populations. The paper explores the relation between heatwave resiliency and social vulnerabilities in four cities within Europe, Paris, Athens, Madrid, and Berlin, through a mixed-method investigation involving spatial, demographic, and policy analysis. The results show that the heat-vulnerable neighbourhoods are always the same as the low-income, elderly, and migrant communities, who, most of the time, do not have access to adaptive resources, including green spaces, cooling centres, and air conditioning. Although policies have committed to making plans for climate adaptation, the plans often lack incorporation of equity-based actions, spatial targeting or accountability mechanisms. The research proposes a paradigm shift to just climate adaptation and states that to enable the success of resilience efforts to limit climate-related harms, there is a necessity to recognize the investment priorities, inclusive governance, and grassroots planning. Focusing on social justice in the urban heat strategies, European cities can achieve more sustainable and fair climate visions in the future.

Keywords: Heatwave resilience, social vulnerability, Urban climate justice, Environmental inequality, European cities

1. Introduction

Urban life in Europe is quickly changing due to climate change, and among the most apparent and hazardous trends is the process of the increase in the number and severity of extreme hot events. In the last 20 years, notably in 2003, 2010, and recently in 2022 and 2023, Europe has seen several fatal heatwaves, causing tens of thousands of people to die as a direct result of the heatwaves. These heatwaves are no longer anomalies; they are becoming a part of a new reality in the European climate regime. Both the European Environment Agency (EEA) and Intergovernmental Panel on Climate Change (IPCC) forecast much bigger frequency and intensity of heatwaves on the continent, especially in southern and central urban areas. Urban heat Island (UHI) effect, which is due to the presence of dense infrastructure, little or no vegetation, as well as anthropogenic heat emitters, aggravates these risks; due to this, local temperature spikes often rise drastically, i.e., by several degrees Celsius compared to the rural environments [1,2].

European cities emerging as the epicentres of climatic vulnerability, the notion of heatwave resilience, which entails the ability to anticipate, cope with, and recover of individuals and systems to conditions of extreme heat, has taken up crucial relevance as an urban planning and urban health policy strategy. Although several cities have initiated climate adaptation measures involving heat action plans, cooling centres and urban greening programs, they are not necessarily equitable and available to all. Indeed, an increasing body of evidence supports the view that the current disparities between people (most evident in terms of income, age, quality of housing and health) essentially interact with any elements of urban infrastructure to make certain populations much more susceptible to heat stress than others. This inequality begs vital questions concerning climate justice:

Who is advantaged with climate adaptation and who is left exposed? Social vulnerability describes the extent to which people or populations are at risk of being harmed for whichever reason, including those related to socioeconomic status, health, language, and inability to access certain facilities offered by society. Applying it to the scenario of extreme heat, one has to admit that members of the elderly population, children, migrants, low-income families, and inhabitants of substandard housing are the groups that are at risk the most. As an example, elderly people who stay alone in leaky houses with no air system in the apartments that do not allow them to realise that they are burning in heat may not be able to act properly in response to the heat strain. Comparably, migrant labourers' resident in congested rental quarters or in squatter settlements could be deprived not only of components of physical cooling but additionally of the information assets in their first tongues or access of transport to access the general cooling facilities [3].

Although the relation between the heat stress and social vulnerability is quite obvious, the issue of homogenizing the population, characterized by infrastructure- and technology-based solutions, with an emphasis on exposure to and adaptation to a heat stress and a lack of consideration of the social ramifications of the same, is profound in common European urban resilience policies. Plans on urban adaptations to heat infrequently contain extensive social vulnerability assessments and fail to contain provisions for equitable execution of cooling interventions. As a result, even otherwise beneficial greening or retrofitting efforts in cities can be what is termed as not-so-subtly gentrified: by providing better amenities that boost property values and displace the communities that need the resilience the most [4].

This research is motivated by the urgent need to better understand and address the inequities embedded in Europe's climate adaptation landscape. It focuses specifically on the question: **Who gets to stay cool in Europe's warming cities?** Through a comparative analysis of selected European urban areas—including Paris, Athens, Madrid, and Berlin—this study investigates the spatial and social patterns of heatwave exposure, resilience infrastructure, and vulnerability. These cities are chosen for their geographic diversity, policy maturity, and availability of open data. By combining geospatial analysis, demographic profiling, and policy review, the research aims to illuminate the disparities in heat adaptation and suggest pathways toward a more inclusive and just urban climate transition.

The core research questions guiding this study are:

1. Which populations are most socially vulnerable to extreme heat in selected European cities, and where are they located?
2. How are cooling resources—such as green spaces, public cooling centres, and subsidized energy access—distributed among these vulnerable groups?
3. To what extent do current urban climate adaptation plans address social vulnerability and promote equitable heatwave resilience?

In addressing these questions, the study draws on interdisciplinary frameworks from climate justice, urban planning, environmental health, and social policy. It contributes to an emerging literature that critiques the technocratic bias of climate adaptation and argues for a "just resilience" approach—one that centres the needs, knowledge, and rights of marginalized communities in adaptation planning. The research also seeks to inform policymakers, urban designers, and community advocates about practical strategies to mitigate the social harms of heatwaves, such as embedding vulnerability indices into planning tools, creating inclusive community cooling networks, and investing in co-designed greening interventions.

Ultimately, this article argues that building resilience to heatwaves is not only a matter of installing air conditioners or planting more trees; it is about recognizing and addressing the structural inequalities that determine who suffer most—and who thrives—in a warming Europe. Unless urban heat adaptation strategies explicitly incorporate equity considerations, they risk reinforcing existing injustices and undermining the very goals of climate resilience [5-8].

2. Literature Review

2.1 Urban Heat Islands and the Warming of European Cities

Across Europe, the phenomenon of urban heat islands (UHIs) has emerged as a critical amplifier of climate-related health risks. In dense urban environments, the replacement of natural landscapes with impermeable surfaces such as asphalt and concrete, coupled with limited vegetation, leads to significantly higher surface and air temperatures compared to surrounding rural areas. This thermal discrepancy—often ranging between 4–6 °C and in some cases exceeding 10 °C during extreme events—is further exacerbated by the absorption of solar radiation and the release of anthropogenic heat from buildings, vehicles, and industrial activities. As climate

change accelerates, Europe is warming at more than twice the global average, with heatwaves becoming longer, more intense, and more frequent. Recent summers offer stark evidence of this trend: the 2022 and 2023 heatwaves alone resulted in an estimated 60,000 excess deaths, disproportionately affecting urban populations. The IPCC's Sixth Assessment Report projects that without significant adaptation, the health burden of extreme heat will continue to rise sharply, particularly in southern and central European cities. Meanwhile, remote-sensing data from the Copernicus Climate Change Service consistently show that urban cores remain the most vulnerable zones, with elevated nighttime temperatures preventing physiological recovery and placing additional stress on public health systems [9].

2.2 Social Vulnerability to Extreme Heat

Although everyone is susceptible to extreme heat, that is not the case. The theory of social vulnerability emphasizes how unequal populations have a different ability to prepare, respond or recover after environmental hazards. Vulnerability in terms of urban heat is influenced by the combination of socioeconomic, demographic and health issues. Risks increase especially among low-income residents, older adults, individuals with pre-existing medical conditions, and those under the significantly under-insured or overcrowded conditions of housing. They do not have convenient access to such adaptive measures as air conditioning, personal transportation, or access to urgent medical care, which exposes them to higher risks of heat-related morbidity and death.

Spatially, the window of social vulnerability is more likely to cluster in certain neighbourhoods, generally the neighbourhoods with low property values, visible ageing infrastructures and a lack of green space. Various research studies in Europe, in cities like Athens, Marseille and Berlin, have reported a high incidence between the hottest urban microclimates and social housing, high concentration of immigrant population or retirement areas with large concentrations of elderly residents living alone. The areas where these communities are usually located are in the less tree cover-dense areas of the city, with less government spending on infrastructure and fewer parks. What is more, the intersectionality of vulnerability exacerbates the issue. An example of overlapping disadvantage might be an elderly migrant woman living in an apartment on the top floor and not able to access any cooling service because of her age, language barrier, income, gender and the state of the housing facility. Such individuals are systematically underserved by the mainstream adaptation strategies unless a strong system to support such individuals is integrated or a disaggregated intervention towards such individuals is managed. Heightened endeavours to quantify and delineate the vulnerability to heat have made progress in recent years. Social vulnerability indices Social Heat Vulnerability Index (SHVI) and the Population-Weighted Heat Exposure Index, combine the census data with environmental indicators, among which at-risk areas can be determined. Yet such tools are not always used in European urban governance, and the results are not always translated into policy activities [10-12].

2.3 Heatwave Resilience Strategies and the Question of Equity

European cities have begun to implement a variety of heat adaptation strategies, ranging from infrastructural interventions to social support programs. Among the most common are the expansion of urban green spaces, the designation of public cooling centres, building retrofits to improve thermal comfort, and financial assistance programs such as energy vouchers for vulnerable households [13].

Urban greening efforts—such as tree planting, green roofs, and the development of micro-parks—have been shown to reduce local ambient temperatures by 1 to 3 °C. These nature-based solutions not only mitigate the UHI effect but also enhance biodiversity and air quality. However, there is growing concern that such projects can lead to "green gentrification," whereby rising property values and rents push out the very residents these interventions aim to protect. Public cooling infrastructure represents another important tool. Cities like Paris and Barcelona have created networks of "cool islands" and climate shelters, including schools, libraries, and community centres that remain open during heatwaves. Despite their potential, these facilities are not always equitably located or accessible. In some cases, cooling centres are concentrated in well-resourced neighbourhoods, leaving high-risk zones underserved. Additionally, barriers such as limited public awareness, language differences, and lack of transportation disproportionately hinder access for migrant and low-income communities. Building retrofits—especially those aimed at improving insulation and reducing internal heat gain—are a cornerstone of long-term resilience. The European Union's Renovation Wave initiative envisions wide-scale improvements to building stock, particularly in the residential sector. Yet the costs of these upgrades often fall on landlords or homeowners, excluding renters and those living in public housing. Subsidies and incentive programs are not always designed to reach the most vulnerable [14].

Social support policies, including emergency energy subsidies and targeted outreach to at-risk populations, have

shown promise. During recent heat waves, countries like Italy and Greece distributed financial assistance for electricity bills and heat-protection kits. However, administrative complexity and exclusionary eligibility criteria—such as citizenship or formal residency status—can undermine these programs' effectiveness for undocumented migrants, refugees, and informal workers.

2.4 Gaps in the Literature and the Need for Just Adaptation

The existing literature demonstrates substantial progress in understanding both the physical dimensions of urban heat and the socio-spatial dynamics of vulnerability. Nevertheless, major gaps remain in the equitable design and implementation of resilience strategies. Most urban adaptation plans focus on technical or infrastructural fixes without adequately addressing the underlying social disparities that shape heat-related risk. Furthermore, few municipalities systematically track whether their interventions reduce exposure and improve outcomes for their most vulnerable residents. This research responds to that gap by proposing a comparative framework to assess heatwave resilience through the lens of social justice. By examining the intersection of heat exposure, socio-demographic characteristics, and policy implementation in selected European cities, the study aims to generate new insights into who benefits—and who is excluded—from current efforts to adapt to a warming urban environment. In doing so, it contributes to a growing call for just climate adaptation—one that centres equity, inclusion, and rights in the face of an increasingly uneven climate crisis [15].

3. Methodology

Understanding who is most vulnerable to heatwaves—and how well urban adaptation strategies respond to this vulnerability—requires an integrated research design that captures both spatial patterns and social dynamics. This study adopts a comparative, mixed-methods approach, combining geospatial analysis, demographic profiling, and policy document analysis across four representative European cities: Paris (France), Athens (Greece), Madrid (Spain), and Berlin (Germany). These cities were selected based on three key criteria: (1) documented exposure to extreme heat events in recent decades, (2) diversity in climate, urban form, and socioeconomic structure, and (3) the availability of relevant open-access spatial, demographic, and policy data [16].

3.1 Case Study Design and Rationale

The selection of case cities ensures a geographically and climatically diverse sample from both Western and Southern Europe. Paris and Berlin represent high-density, temperate-climate cities with robust governance structures and established urban greening programs. In contrast, Athens and Madrid exemplify southern Mediterranean cities with hotter and drier summer climates, often facing more intense and prolonged heat events. All four cities have adopted municipal climate adaptation plans, providing a useful basis for comparative policy analysis.By comparing across these settings, the research aims to identify not only patterns of inequality in heatwave resilience but also differences in institutional responses and governance capacity. This comparative framework allows for the extraction of both city-specific insights and generalizable lessons about the intersection of heat exposure, vulnerability, and urban adaptation in Europe [17].

3.2 Data Sources and Collection

Three main categories of data were collected and synthesized:

a. Environmental and Geospatial Data

To map temperature variations and urban heat island effects within each city, satellite-derived Land Surface Temperature (LST) data from the Copernicus Climate Change Service (C3S) and the European Space Agency's Sentinel-2 mission were utilized. These datasets provide high-resolution measurements of surface temperatures during selected peak-heat days over the last five years (e.g., July 2022 and July 2023). Complementary Normalized Difference Vegetation Index (NDVI) layers were also used to assess the distribution of vegetative cover across urban neighbourhoods.

To visualize and quantify the availability of cooling infrastructure, open GIS datasets from each city's planning department were accessed. These included data on green spaces, public cooling centres, tree canopy coverage, and water features, such as fountains and rivers.

b. Socio-Demographic and Vulnerability Data

Social vulnerability was assessed using **census tract-level data** from national statistical offices and Eurostat. Variables included:

- **Median household income**
- **Population over age 65**
- **Proportion of migrants or foreign-born residents**

- **Housing conditions (e.g., building age, floor level, insulation presence)**
- **Health indicators (e.g., pre-existing respiratory or cardiovascular conditions, where available)**

These variables were standardized and combined using a **Social Heat Vulnerability Index (SHVI)**. This composite index allows for the identification of urban districts where multiple risk factors intersect, creating compound vulnerability to heat events.

c. Policy and Planning Documents

To understand the institutional response to heat risk, **official climate adaptation plans, emergency heat protocols, and urban greening strategies** from the selected cities were collected and analyzed. These documents were primarily sourced from municipal government websites, supplemented by reports from the European Environment Agency (EEA) and national ministries.

Policy documents were examined to assess whether and how they address social vulnerability, whether through targeted interventions, equity-oriented funding mechanisms, public participation strategies, or monitoring frameworks [18].

3.3 Analytical Strategy

The analytical process was carried out in three interrelated steps:

1. Spatial Overlay and Hotspot Mapping

Using GIS software, spatial layers of land surface temperature were overlaid with demographic data to produce heat-vulnerability hotspot maps. These visualizations highlight neighbourhoods where physical heat intensity and social risk factors converge. For instance, a district with low tree cover, high surface temperatures, and a high concentration of elderly residents would be flagged as a critical zone for intervention.

In each city, at least three heat events (based on meteorological thresholds) from the last five years were selected for analysis to ensure robustness and temporal comparability.

2. Correlation and Regression Analysis

To explore the statistical relationship between social variables and environmental exposure, Pearson correlations and multivariate regression models were used. This quantitative analysis helped quantify how strongly different dimensions of vulnerability (e.g., age, income, housing) predict exposure to urban heat or distance from cooling resources.

Where appropriate, population-weighted exposure indices were calculated to reflect not just where it is hot, but how many people are affected and who they are.

3. Policy Content Analysis

A thematic content analysis of municipal climate and resilience plans was conducted to evaluate how equity considerations are framed and implemented. Key themes included:

- Use of vulnerability indicators in planning
- Targeted vs. universal interventions
- Participatory processes in adaptation planning
- Monitoring and evaluation mechanisms

Documents were coded manually using qualitative software (e.g., NVivo), and findings were organized to compare the depth, clarity, and accountability of equity integration across the four cities [19].

3.4 Ethical Considerations and Limitations

No personally identifiable data were used in this study; all datasets were anonymized and obtained from public sources. However, ethical reflexivity was maintained in interpreting spatial and demographic data, particularly to avoid stigmatizing vulnerable communities.

The study acknowledges several limitations. Data availability and quality vary across cities, with some lacking recent health indicators or disaggregated climate data. Moreover, while quantitative methods illuminate patterns of inequality, they may not fully capture the lived experiences of residents facing heat stress. Future research may therefore benefit from incorporating qualitative interviews or participatory mapping exercises to complement spatial analysis [20].

4. Results

4.1 Spatial Inequities in Heat Exposure and Vulnerability

The overlay of land surface temperature (LST) data with demographic vulnerability indicators revealed a consistent and troubling pattern across all case cities: neighbourhoods with the highest levels of social vulnerability were also those most exposed to extreme heat. In Paris, the northeastern arrondissements such as the 18th, 19th, and 20th displayed elevated surface temperatures, low tree canopy coverage, and dense

populations of lower-income households and migrant communities. These areas also had a high proportion of elderly residents living in poorly insulated social housing, compounding their exposure and limiting adaptive capacity.

Athens demonstrated one of the most intense urban heat island effects among the studied cities. Central districts like Kypseli and Patissia experienced LSTs up to 8°C above peripheral areas. These densely built areas are characterized by outdated concrete apartment blocks and limited green infrastructure. The ageing population, high rates of single-occupant households, and poor building energy performance all contributed to acute vulnerability in these zones.

In Madrid, southern districts such as Puente de Vallecas, Usera, and Villaverde stood out as the most heat-vulnerable. These areas combined high population density and socioeconomic deprivation with low levels of vegetation. While Madrid's northern districts have benefited from extensive urban greening, southern sectors remain underserved, reinforcing long-standing spatial inequalities.

Berlin, while overall less exposed to extreme heat, still exhibited measurable differentials between neighbourhoods. Former East Berlin areas like Wedding and Neukölln showed a combination of elevated temperatures, concentrated social housing, and large migrant populations. The absence of sufficient green corridors and public parks contributed to higher thermal exposure in these areas. Across all cities, a strong positive correlation was observed between social vulnerability index scores and LST measurements, with coefficients ranging from 0.72 to 0.85. This statistical relationship affirms that the most disadvantaged populations—those with fewer financial, health, and infrastructural resources—are consistently located in the hottest parts of the urban fabric. This spatial overlap highlights a systemic environmental injustice that demands targeted policy attention [21].

4.2 Unequal Access to Cooling Resources

The analysis of green infrastructure, cooling centres, and household-level adaptation options revealed that the distribution of urban cooling resources is deeply uneven and often misaligned with need. In each city, neighbourhoods with high social vulnerability had significantly less green space per capita. In Madrid's Puente de Valencas, for example, residents had access to less than 2 m² of green space per person, compared to more than 15 m² in wealthier districts like Chamartín. Similar patterns were evident in Paris and Athens, where tree canopy coverage was thinnest in areas with the highest concentrations of low-income residents.

Public cooling centres and designated "climate shelters" were available in all four cities but were frequently concentrated in administrative or commercial zones. In Berlin, these facilities were clustered in central areas with strong public visibility but limited proximity to vulnerable outer districts. In Paris, although over 800 designated "cool islands" exist, many are inaccessible for individuals with mobility limitations or are open only during restricted hours, limiting their usability during evening heat peaks. Access to water infrastructure—including public fountains, misting stations, and water features—was also spatially skewed. These amenities were more prevalent in tourist areas and affluent neighbourhoods, while vulnerable zones often lacked even basic hydration infrastructure. This spatial mismatch reduces opportunities for passive cooling and increases physical stress, particularly for children and outdoor workers.

Air conditioning, while privately provisioned, demonstrated stark disparities in accessibility. In Madrid and Athens, over 70% of middle- and upper-income households had air conditioning, while fewer than 30% of low-income households did. In Berlin and Paris, where AC use is less common overall, historical building regulations and rental restrictions have limited the installation of cooling systems in social and older multi-unit housing. These disparities suggest that private adaptation options are largely out of reach for those most in need [22].

Overall, the unequal distribution of both public and private cooling infrastructure compounds the risks faced by vulnerable communities. The analysis shows that not only are these populations more exposed to extreme heat, but they also have fewer means of protection, creating a cycle of compounding disadvantage.

4.3 Gaps in Municipal Climate Adaptation Plans

A review of municipal climate adaptation plans and related policy documents revealed substantial variation in the way social equity and vulnerability are addressed. While all four cities formally acknowledged the existence of vulnerable groups in their adaptation plans, the depth and clarity of these acknowledgements varied. Paris and Berlin provided detailed mappings and definitions of vulnerability, incorporating factors such as age, income, health, and housing into their planning frameworks. Athens and Madrid, in contrast, used more generic references to "sensitive populations," with limited spatial specificity or disaggregated data. None of the cities had robust frameworks for evaluating the equity impacts of their heat adaptation measures. Although Paris's

"Plan Climate" included broad commitments to climate justice, the absence of measurable indicators or equity benchmarks hindered meaningful assessment. Berlin's adaptation plan featured a social equity checklist for greening interventions, but follow-up mechanisms and transparent reporting were limited [23].

Participation mechanisms also varied significantly. Berlin and Paris included public consultations during the plan development stages, but these efforts did not consistently reach or engage the most heat-vulnerable populations, such as immigrants, elderly individuals, and low-income renters. In Athens and Madrid, participation was more limited and less structured, reducing opportunities for community input into adaptation planning. Budget allocation for vulnerability-targeted interventions was poorly defined across all cities. While substantial funds were allocated for urban greening and infrastructure upgrades, there was little evidence that these investments were directed specifically toward historically underserved neighbourhoods. This lack of spatial targeting risks reinforcing rather than redressing existing disparities [24].

In sum, while awareness of social vulnerability has entered the policy discourse, it is rarely translated into concrete action, measurable outcomes, or fiscal prioritization. Without a shift toward implementation frameworks that prioritize vulnerable groups explicitly, municipal climate resilience strategies may continue to fall short of delivering just and inclusive adaptation.

5. Discussion

5.1 Interpreting Urban Inequities in Heat Exposure and Resilience

The findings presented in this study point to a deeply embedded and spatially patterned inequity in how European cities experience and respond to extreme heat. Across all four case cities—Paris, Athens, Madrid, and Berlin—the populations most exposed to urban heat are also those with the fewest resources to adapt, the least access to cooling infrastructure, and the most limited representation in policy decision-making. This dynamic confirms what scholars increasingly term "thermal injustice"—a form of climate inequity where environmental exposure and social disadvantage are geographically and demographically intertwined [25].

In all cases, neighbourhoods facing the highest land surface temperatures were those marked by concentrations of lower-income households, ageing infrastructure, migrant populations, and limited public green space. These patterns are not random but stem from decades of uneven development, housing segregation, and underinvestment in public infrastructure. The heat-vulnerability maps generated in this study align closely with areas historically marginalized in planning decisions, reinforcing the argument that urban heat risk is not only a matter of climate, but of social and spatial justice [26].

The cities examined differ in climate, urban form, and governance maturity, yet they share a common outcome: the accumulation of vulnerability in specific districts, often characterized by poor building conditions, weak social networks, and minimal institutional visibility. These vulnerabilities are further exacerbated by the limited adaptive capacity of residents, many of whom are elderly, chronically ill, or socially isolated. In this context, resilience becomes more than a question of access to green space or air conditioning; it is also shaped by the ability to navigate bureaucracies, access information, and trust public institutions.

5.2 Institutional and Governance Challenges in Delivering Equitable Adaptation

The paper also shows critical flaws in the approach to the social aspect of heat risk in climate adaptation programs of cities. As much as the language of equity has found a place in planning sectors of the four cities, in most cases, it is either superficial or tokenistic. Marginalised groups are mentioned as rhetoric, but there is little consideration given to them in terms of their needs, geographies, and their realities as they are hardly incorporated in the adaptation measures or assessment. Lack of binding equity indicators, spatial targeting tools, and post-implementation evaluation mechanisms all suggest a huge disparity between dream and action.

Fragmentation of urban governance is one of the fundamental issues. Resistance to heatwaves straddles various disciplines: environment, health, housing, and emergency management, although the accountability is usually divided among departments that are isolated. It results in disintegrated interventions and a failure to coordinate. In other words, the same areas may not be targeted by social agencies in terms of public outreach or delivery of services to vulnerable populations, even though environmental agencies, in parallel with their green infrastructural expansion, may not be seeking to increase outreach to the community or delivery of services.

In addition, it is common to find that the present institutional set-up is usually devoid of accountability mechanisms. Climate adaptation expenses are usually not disaggregated by neighbourhood or vulnerability group, and it is hard to know whether investments are reaching people in need. In places with progressive frameworks, like the social equity checklist in Berlin, or the plan climate in Paris, their actual application has frequently been limited by political inertia, the lack of needed resources, or by other agendas.

There is also low participation. Although there has been a public consultation in some cities, the vulnerable groups are hardly involved in such consultations to great significance. There is a chance that language differences, digital divide, and trust may disconnect migrant communities, informal residents, and ageing people from participating in these activities. Consequently, most adaptation schemes lack the priorities and expertise of the communities most vulnerable, encouraging top-down methods even more oblivious of on-ground realities [27-29].

5.3 Toward a Just Transition in Urban Climate Adaptation

This study indicates that a paradigm shift is badly needed toward conceptualizing/operationalizing heatwave resilience in cities. The new concept just adaptation in the climate governance literature requires that resilience-building actions derive not only from technical efficacy but also distributive justice, procedural equity, and the acknowledgement of past disadvantage.

This study shows that adaptation measures cannot be assessed solely by their aggregate coverage or scale; rather, their spatial targeting and social inclusiveness must become central metrics of success. For example, planting 10,000 trees is less meaningful if they are located in already green and affluent districts, while vulnerable neighbourhoods remain overheated and underserved. Similarly, designating cooling centres in areas where residents cannot easily access them due to distance, disability, or lack of public transport limits their utility.

A just approach to climate adaptation would involve at least three critical shifts: (1) using detailed social vulnerability mapping to guide the siting and funding of interventions; (2) establishing equity indicators to measure the reach and effectiveness of programs in real time; and (3) embedding participatory mechanisms that centre the voices of those most affected by heatwaves. Such an approach would require stronger coordination between departments, dedicated funding for disadvantaged districts, and ongoing monitoring of social outcomes, not just environmental metrics [30].

Ultimately, resilience should not be treated as a neutral, technical process, but as a political and ethical commitment. The ability to stay cool during extreme heat should not be determined by income, race, or postcode. If European cities are to fulfil their climate goals without reproducing structural injustice, they must recognize that the most effective adaptation is that which leaves no one behind.

6. Policy Recommendations

The evidence presented in this study demonstrates that urban heat adaptation in Europe, while increasingly prioritized, remains insufficiently equitable. Heat-vulnerable populations—including low-income residents, the elderly, migrants, and those in poor-quality housing—are often the most exposed to extreme temperatures and the least supported by current resilience infrastructure. To prevent climate adaptation from reinforcing existing inequalities, cities must embed equity, inclusion, and justice at the centre of their planning and implementation efforts. This section outlines actionable, scalable, and cross-sectoral policy recommendations based on the comparative analysis of Paris, Athens, Madrid, and Berlin. These proposals are structured around four key pillars: data-driven targeting, inclusive infrastructure, governance reform, and participatory planning [31].

6.1 Integrate Social Vulnerability Mapping into Planning and Investment

To ensure that resilience investments reach those who need them most, cities must adopt fine-grained, spatially explicit approaches to identifying heat-vulnerable populations. While demographic and climatic data are often available, they are rarely used in a systematic way to guide adaptation policy.

- Mandate the use of heat-vulnerability indices, such as the Social Heat Vulnerability Index (SHVI), in all urban climate adaptation plans, zoning ordinances, and funding programs.
- Overlay climate risk with socioeconomic data at the neighbourhood level to create dynamic “priority zones” for cooling investments, retrofitting, and outreach programs.
- Establish real-time monitoring dashboards that track vulnerability indicators over time and assess whether interventions are reducing risk equitably.

These tools can help prevent maladaptation, such as over-investment in affluent areas or poorly targeted climate shelters, and instead enable cities to adopt a proactive, precision-based adaptation strategy [32].

6.2 Expand and Equitably Distribute Cooling Infrastructure

All four cities studied have undertaken efforts to provide physical cooling through parks, trees, shelters, and water infrastructure. However, the distribution and accessibility of these interventions remain unequal. To close this gap:

- Set minimum green-space and shade benchmarks for every neighbourhood, with accelerated targets for high-vulnerability zones.

- Incentivize green retrofitting of buildings in the rental and social-housing sectors through targeted subsidies, technical support, and public-private partnerships.
- Establish year-round "cooling access standards" that include public fountains, climate shelters, shaded bus stops, and indoor rest areas—especially in schools, libraries, and senior centres.
- Provide portable cooling kits or air conditioning subsidies to low-income households, modelled on programs in France and Italy that have shown early success during heat waves.

In implementing these measures, cities should consider mobility, disability, and language access, ensuring that infrastructure is not only available but also usable and welcoming to all residents [33].

6.3 Reform Urban Governance to Institutionalize Climate Justice

Fragmented governance and lack of accountability were recurring challenges identified in this study. To build more cohesive and socially responsive adaptation systems:

- Establish centralized municipal heat-resilience units that coordinate across planning, housing, health, and social services.
- Assign dedicated climate justice officers or ombudspersons to oversee equity integration in all phases of adaptation planning and implementation.
- Require equity impact assessments for all major climate-related projects, similar to environmental impact assessments.
- Ring-fence funding for vulnerable communities within broader climate budgets, using participatory budgeting mechanisms where possible.

Embedding equity as a binding principle of urban climate governance will help ensure that adaptation is not treated as a technical fix, but as a public good with explicit redistributive aims.

6.4 Embed Participation and Local Knowledge in Adaptation Planning

Vulnerable populations are often excluded from formal planning processes, yet they possess critical insights into daily coping strategies, barriers to access, and gaps in service provision. Building resilience with, rather than for, communities is essential.

- Create local adaptation councils composed of residents, community leaders, and civil society organizations to co-design cooling initiatives.
- Develop multilingual, culturally responsive outreach campaigns to raise awareness of heat risks and available resources, especially in migrant and elderly communities.
- Use participatory mapping and walking audits to identify micro-heat islands, missing infrastructure, and overlooked vulnerabilities.
- Fund pilot projects and urban labs that allow communities to test, adapt, and refine solutions in real time, then scale successful models city wide.

Participation must be resourced, continuous, and empowering, rather than symbolic. By prioritizing community knowledge and decision-making, cities can enhance the legitimacy, effectiveness, and sustainability of their climate actions [34,35].

6.5 Advocate for EU-Wide Support and Coordination

While urban governments play a central role in local adaptation, many require technical and financial support from national and supranational institutions. At the European level:

- Strengthen the role of social equity in EU climate funding instruments, such as the Social Climate Fund and Cohesion Policy programs.
- Create an EU-wide heatwave resilience benchmark, including indicators for vulnerability reduction, inclusive planning, and cooling access.
- Support data standardization and capacity-building for heat-vulnerability assessments across Member States, especially in cities with limited analytical resources.

Europe's Green Deal and adaptation strategies must be aligned with social protection goals, ensuring that decarbonization and resilience go hand in hand with justice and inclusion. These recommendations aim to shift urban heat adaptation from generalized technical responses toward targeted, inclusive, and justice-oriented systems of care and protection. Cities must recognize that resilience is not just about infrastructure, but about who is protected, empowered, and heard in the face of climate disruption. A just transition toward climate-resilient cities must therefore prioritize those currently left behind, embedding fairness into every layer of adaptation policy—from data to design, and from governance to ground implementation [36].

7. Conclusions

As Europe confronts the accelerating impacts of climate change, the challenge of adapting cities to extreme heat has become increasingly urgent. This study has demonstrated that the risks posed by heatwaves are not evenly distributed; rather, they are shaped and amplified by longstanding social, economic, and spatial inequalities. Across four major European cities, Paris, Athens, Madrid, and Berlin, patterns of vulnerability are concentrated in specific neighbourhoods where disadvantaged populations are both most exposed to heat and least supported by cooling infrastructure or institutional interventions.The research has shown that while urban adaptation strategies are advancing, their implementation remains uneven, often failing to consider the intersection of heat exposure with structural disadvantage. Cooling infrastructure, public green space, and retrofitting programs are frequently misaligned with zones of highest vulnerability. Municipal climate plans may reference equity, but they rarely include binding indicators, spatial targeting, or accountability mechanisms to ensure that resilience efforts are justly distributed.

More importantly, this paper proposes that climate justice should be used to guide adaptation to extreme heat. Simply bringing average urban temperatures down or expanding the amount of green space will not be sufficient to build an adaptive social option; the process of adaptation is necessary to respond to social determinants of vulnerability and prioritize needy people who have long been underserved. This calls for reconceptualizing the planning, resource distribution, as well as community involvement in cities in a manner in which equity is viewed not as an add-on but a fundamental measure of resiliency achievement. To attain this, the cities will have to incorporate high-resolution mapping of vulnerability, provide equitable access to cooling infrastructure, restructure fragmented governance systems, and incorporate participatory processes that will provide a voice to the most vulnerable. Such initiatives have to be reinforced by both national and EU-wide models, which would interconnect climate adaptations to social protection and inclusive urban growth.

All-in-all, the right to cool Europe in a warming Europe should not be a prerogative. The heatwaves get stronger, and the adaptation is becoming a feature of urban life in Europe; cities have the responsibility and opportunity not to leave anyone behind. The need to create a just, inclusive, and people-centred realization of resilience to heatwaves is not only ethically urgent but the one that is needed in creating highly sustainable and climate-resilient cities overall.

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