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Urban Heat Inequality: Social Stratification, Policy Responses, and Health Implications

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ABSTRACT

Climate change and rapid urbanization have significantly intensified urban heat exposure, creating unequal health risks across socially stratified populations. This review critically examines the mechanisms through which social inequality influences urban heat exposure and evaluates policy interventions aimed at reducing heat-related health disparities. The analysis integrates evidence on urban heat island dynamics, socioeconomic determinants, neighborhood characteristics, housing quality, occupational exposure, and access to environmental resources such as urban green space. Particular attention is given to vulnerable populations that experience disproportionately high rates of heat-related morbidity and mortality due to limited adaptive capacity and unequal access to cooling infrastructure. The review further assesses governance approaches, including equitable urban planning, housing policy, public health preparedness, stakeholder engagement, and climate adaptation strategies that seek to reduce environmental and social inequalities simultaneously. Comparative evidence from cities in North America, Europe, and the Global South demonstrates that successful heat mitigation depends not only on technological or environmental interventions but also on inclusive governance and socially responsive policymaking. The review identifies persistent research gaps regarding causal mechanisms, equity-focused evaluation metrics, and long-term policy effectiveness. It concludes that future urban climate adaptation must integrate environmental sustainability with social justice principles to reduce heat vulnerability, improve health outcomes, and strengthen resilience among disadvantaged urban communities.

Keywords: Urban Heat Inequality, Urban Heat Island (UHI), Social Stratification, Climate Change Adaptation and Heat-Related Health Inequalities

INTRODUCTION

Climate change is severely intensifying environmental heat in cities worldwide. As the planet warms, urban centres with significant social stratification and inequality are projected to experience extreme changes beyond official temperature increments reported by climate scientists [1]. In cities, social stratification creates unequal access to cooling resources, raising urgent questions about social inequities of climate-change effects in heat-stratified contexts [2]. Urban heat matters because urban heat islands (UHIs) increase exposure to extreme heat and exacerbate health-inequality burdens for vulnerable groups experiencing persistent socio-economic disadvantages. In cities and metropolitan regions, heat exposure inequalities emerge differently across spatial, demographic, and temporal dimensions depending on specific social conditions [1]. Patterns of exposure and vulnerability vary systematically across sub-populations facing diverse social and economic stratifications. Urban-heat and heat-exposure extreme levels exceeding those of rural hinterlands affect large metropolitan clusters in developed and developing contexts. High UHI intensities increase linked illness and mortality rates for specific groups with certain socio-economic histories or configurations [2]. Actionable insights into climate-change exposure effects derived from urban research can contribute to broader climate-change-equality agendas and offer distinct perspectives for international climate-change solutions. Heat exposure is a key channel through which climate-change benefits and harms circulate [3]. Therefore, exploring urban heat within developing-country contexts and at the scale of metropolitan regions, neighbourhoods, and city-wide geographies promises distinctive, relevant, and actionable knowledge [4]. Urban research can illuminate how countries rich in biodiversity, forests, and agricultural land and thus perceived as less vulnerable to climate change are profoundly reshaped. Many

countries and economies, already beneath a high inter-thematic climate-change burden, confront even higher exposure risks due to a complex array of inter-scalar, inter-subject, and inter-public-policy interactions. Understanding how the simultaneous content, process, actors, and subject formations co-vary across circumstances and surfaces can deeply inform general public policy and development dialogues [1]. Urban systems, serving as critical material-and-imaginary infrastructures of a broad range of contemporary activities, stand at the intersection of these trajectories and can therefore highlight pivotal linkage points and fragile public-policy junctures [2]. Urban populations account for 56% of the world; this proportion is projected to reach 68% by 2050, involving an estimated 2.5 billion additional people migrating to cities, especially in the Global South [1].

Conceptual Framework

Extreme heat ranks as the deadliest weather-related hazard in the United States, with yearly fatalities surpassing those caused by tornadoes, hurricanes, and flooding combined [3]. Rising global temperatures and high-emission climate scenarios portend an increase in the frequency, duration, and intensity of extreme heat events, amplifying the need for adaptation. Modern cities, containing over half the global population, have undergone unregulated growth, particularly in the Global South [4]. Urbanization tends to exacerbate extreme heat risk, with the rise of urban heat islands exacerbating the heat burden per square kilometer compared to natural landscapes. Urban heat has emerged as an important vector for health and well-being, motivating extensive study of urban heat exposure in relation to health [5]. Rapid urbanization during the late 20th century increased extreme heat exposure in cities, rendering urban heat a pressing health equity concern. Urban heat inequality denotes differential exposure to urban heat across space or varying population groups [6]. Emerging evidence identifies significant disparities in urban heat exposure among different neighborhoods and demographic groups. Comprehending the dimensions and origins of urban heat inequality is critical for effective mitigation [6]. Existing studies employ differing definitions, jurisdictions, and metrics, leading to diverse interpretations and confusion. Addressing these gaps, this study adopts a socio-spatial lens to examine heat exposure in relation to socio-economic stratification and its health effects. Urban, social, and health attributes associated with urban heat exposure constitute the analytic focus, with the city serving as the principal unit for analysis and census tracts as spatial units for data analysis [1].

Definitions of Urban Heat and Inequality

Urban heat is a specific result of unnatural temperature increases in cities, driven by the urban heat island (UHI) phenomenon. Urban areas can reach temperatures of 11 to 20 degrees Fahrenheit (6 to 11 degrees Celsius) higher than their surrounding rural regions due to the UHI effect [1]. Land use types, built environment characteristics, color of building materials, and nearby vegetation influence UHI intensity. Baseline temperature metrics serve to identify heat fluctuations, while descriptors of heat exposure indicate the effect of urban heat on residents [2]. Socially stratified populations can be differentially exposed to urban heat because of these distinctions in land use and development [3]. Urban heat is defined as the excess temperature difference between a designated urban site and a nearby rural area. Three metrics characterize urban heat UHI magnitude, spatiotemporal UHI, and urban-rural temperature difference; UHI magnitude is the principal metric [4]. Equity-oriented studies should focus on regulating the urban heat experienced by residents and how these exposure patterns differ among demographic and socioeconomic groups. An inequity indicator measures variation in exposure, either as a proportionate share of upper-tail exposure or as the magnitude of the exposure gap itself [5].

Theories of Social Stratification in Urban Environments

Urban environments are inherently unequal. Cities concentrate wealth, resources, and power, resulting in significant disparities in health risks, health itself, and the related socio-ecological vulnerabilities among their residents [6]. The elite live in high-value areas where their health is prioritized and subsidized through extensive investments in the built and natural environments, while the poor are consigned to low-value areas where their health is negatively affected, along with little to no support for their health needs [1]. Social stratification, unequal access to resources is more pronounced in unequal political economies. Under capitalism, the commodification of protection has produced spatial patterns of social stratification, with differential exposure to economic shocks shaping differential vulnerability to other, environmental shocks [7]. At the city scale, the nearness, or exposure, of disadvantaged groups to industrial sites, hazardous substances, and degrading infrastructures condition their health [8]. At the neighborhood scale, a focus on social equity leads to the prioritization of access to urban greenery and emphasize the mediating role of neighborhood resources in the unequal exposure to environmental hazards or degradation [2].

Empirical Evidence of Urban Heat Inequality

High maximum land surface temperature (LST) values reliably identify hot spots across a wide range of urban areas [1]. In Southwestern U.S. cities, the hottest urban locations attain average summer LSTs surpassing 50°C in some instances, while the coolest areas remain lower than 40°C. Geostatistical analyses of non-contiguous neighborhoods and census tracts reveal low-moderate coefficient of determination (R^2) values, indicating LST surrogates alone cannot fully explain urban warming [2]. Hotter neighborhoods in Global South cities are often situated near major pollution sources. Emissions from industrial facilities, road traffic, and waste burning,

combined with poorly organized urbanization, hamper the thermal quality of urbanized areas [3]. Analysis of countries from the Global North demonstrates diverse patterning of inter-neighbourhood temperature differentials across different administrative strata. U.S. cities exhibit a thermal inequity where middle-income neighborhoods display greater LST exposure than both low- and high-income locales [4].

Spatial Patterns and Hot Spot Analysis

Urban areas have largely emerged as the epicenter of human-induced climate disruption and are projected to be among the most intensely affected areas by the projected global warming in the coming decades [5]. It is becoming increasingly evident that cities are not only experiencing challenges related to comprehensive ground-level air quality or particulate matter but is also facing acute concerns surrounding climate change adaptation. Such rising concerns have made attention toward the spatial distribution of urban heat and its unequal distribution among cities of varying demographics inevitable [6]. The exposure to such heat varies significantly among social groups and the populations residing in less privileged neighborhoods remain at a higher risk of exposure to such environmental nuisances [7]. Available empirics have revealed distinct spatial patterns of average heat exposure and certain processes driving the emergence of such patterns in large metropolitan areas of U.S. cities [3]. Takes into account for a significant portion of the developed regions in the world, exposition to urban heat raises even more among underprivileged and vulnerable population groups, which intensifies the pre-existing urban heat challenge [1].

Demographic and Socioeconomic Correlates

Heat exposure disparities associated with demographic and socioeconomic characteristics shape a policy-relevant dimension of urban heat inequality [3]. These disparities often reflect a legacy of structural racism, exploitation, and disinvestment; yet, their analysis may be complicated by concepts such as "toxic neighborhoods" and "neighborhood opportunity structures" that emphasize the uneven distribution of resources across space [1]. Studies of the spatial patterning of sociodemographic disparities in extreme heat exposure across the contiguous United States demonstrate that, at the national level, race/ethnicity and poverty contribute to greater exposure, although geographic context mediates their influence [3]. Local analyses in metropolitan areas further highlight the importance of housing tenure, composition, and type; urban-rural context; and the presence of land-use and climate-adaptation policies [2]. Although measures of heat exposure may vary in coverage and granularity, titles alone permit survey-level questions that elucidate the influence of demographic and socioeconomic characteristics on exposure [4].

Temporal Dynamics and Climate Trends

Over the last two decades, various initiatives have sought to mitigate climate change through improved development policies and templates. Substantial changes to the underlying emission regimes, however, have not yet occurred [5]. As a result, the developing cities of Asia, Africa, and Latin America, along with their higher climatic temperatures, have undergone a rapid urbanization as well as a quest for social equity. Overall metropolitan populations in these cities rose from the local 677 million in 1910 to almost 5 billion or about 55 % of the global total in 2020, with a steep increase among those of more than 10 million in them[6]. Urbanization presently nets regions with higher rural-to-urban migration rates, including either the least or lower income countries, such as Africa and Central America (e.g., Mexico). Detailed dialogues exist on the fragility of attempting to replicate the historical experience of cities in Europe and North America within today's metropolitan growth and, subsequently modify the architectural and environmental characteristics of their urban systems to achieve widely separated heat-mitigation targets [7]. Climate change, economic growth, population movements, political regrets, ecological disaster, and urbanization among other forces presently either support or interfere with the continual establishment of inclusive, productive, enjoyable, and resilient cities[8]. Metrics and models exist that locate, emphasize, and quantify the deep-rooted impacts that metropolitan changes exert on climatologies and on the urban heat island [1]. Models and mesures on climate resilience and adaptation, such as LEED and the associated economic incentives, are still seldom put into practice along the American continent and much of the world [2]. Furthering monographic and comparative studies examines the emergence of excessive heat threats in particular regions of the planet (e.g., China), and their interactions with urban planning systems that had earlier relaxed. Models, injunctions, and ordinances that should stem from rigorous health-evaluative frameworks acquire greater support [3]. Use of high-density, high-rise, multi-use, mixed urban-growth models receive great interest and early testing has indicated unanticipated perceptions on urban-heat-island and econometric evidence on land rents show that climates interact with econometric phenomena in comparative urbanization (Becker etc)[4].

Mechanisms Linking Social Stratification to Heat Exposure

Social stratification contributes to urban heat inequality through differential access to resources, housing quality, neighborhood conditions, and occupational exposures [5]. These pathways are exacerbated by the COVID-19 pandemic, which restricts mobility and intensifies pre-existing disparities [6]. Cities are home to over half of the global population and account for three-quarters of energy consumption, making urban heat one of the central challenges for sustainable development [7]. Warming temperatures and intensified heat waves considerably affect

human health, especially among vulnerable populations. The urban heat island (UHI) effect amplifies temperatures in cities compared to rural areas, which poses significant risks to urban dwellers [8].

Housing Quality and Urban Form

In many cities, the uneven distribution of housing quality and urban development contributes to the social stratification of heat exposure by creating 'urban heat islands' (UHI) that disproportionately impact low-income households [1]. Factors such as poor building materials, inadequate insulation, and poorly designed dwelling access can lead to higher indoor temperatures, while the distribution of urban form including skylights, bushes, trees, and other periurban surfaces affects the exterior residential microclimate [2]. Changes in zoning, taxation, policy, and building design that foster urban decentralization and sprawling, low-density settlement further increase exposure [3]. Housing quality measured through indicators such as homeownership rates, air conditioning access, the proportion of dilapidated buildings, property tax delinquency, and the incidence of code violations therefore has a direct effect on both building characteristics and urban form that shape heat exposure [4]. Across urbanized regions, mortality rates associated with high-temperature events are strongly associated with housing quality. The proportion of owner-occupied housing represents the most robust correlation between housing quality and heat-related mortality among seniors [5]. Factors such as property tax delinquency in smaller residential buildings and high rates of building code violations point to neighborhood stability and economic distress that may compromise building maintenance and repair. Consequently, housing instability arising from foreclosures, mortgage delinquency, and economic recession is likely to heighten heating-induced health risks by fostering psychological stress and social dislocation [6]. Programs aimed at urban climate adaptation must therefore address housing deficiencies and instability if they are to foster climate resilience. Improved understanding of the influence of housing and neighborhood conditions on temperature exposure and health risk during extreme heat is essential for advancing urban climate science and policy [4].

Neighborhood Infrastructure and Green Space

Infrastructure and access to green space play a crucial role in shaping heat exposure patterns across urban neighborhoods. Socioeconomic status, color, race, and ethnicity can determine the availability and quality of infrastructure and greenery in a neighborhood [1]. Residence in urbanized areas subjected to environmental degradation via the "heat island" effect, attributed to impervious surface cover, has been shown to be associated with temperature disparities in the heat-retaining materials utilized in urban construction [1]. The distribution of green vegetation, regarded as a valuable commodity, is linked to people's income and may be used as a soft measure to estimate the link between social stratification and environmental variables, such as urban heat exposure [2]. Insufficient availability of ecological assets and various infrastructures fosters additional vulnerability to urban heat [5]. Occupational exposure and engaging in heat-related behaviors have been documented as factors affecting health inequalities, influencing exposure and, consequently, health. In some areas, public accessibility to safe outdoor space tempered by considerations for heat exposure also impacts exposure differentially [3].

Occupational and Behavioral Factors

Urban heat exposure stems from the combination of high-temperature environmental factors and the presence of ambient heat in urban areas, which leads to an increase of temperature inside personal outdoor "microenvironments" in the context of a heat wave [1]. Daily mobility represents an important dimension of social stratification with implications for opportunity access and, consequently, exposure to heat which can be evaluated through time-activity patterns, geographical structure of mobility, and location of activities outside home in function of individual demographic, social, and socioeconomic characteristics [2]. Analysis of heat exposure and social stratification in Pavillion design by Dialesandro et al has pointed three main pathways of the impact of social stratification: access to the home and dwelling quality, neighborhood conditions, and individual lifestyles [3]. Daily mobility and time-activity patterns influence not only the duration of exposure to heat but also the intensity at which exposure occurs [4]. The cumulative impact of social stratification on the correlation between mobility and exposure to heat varies significantly, and in North America it has a limited effect after controlling for relevant spatial expansive accessibility measures [5].

Health Impacts of Urban Heat Inequality

Research on urban heat has consistently documented large and persistent temperature differences between different parts of cities [1]. These disparate temperature profiles have important implications for human health, as heat exposure contributes to a wide variety of morbidity and mortality outcomes [2]. Significant research exists on the relationship between heat and health; findings on relevant population demographics and spatial distributions associated with heat-related impacts are therefore examined to provide a comprehensive understanding of urban heat inequality [3]. Heat-related morbidity and mortality are well-documented concerns in cities with significant summer heat exposure. Urban heat per se is rarely the direct cause of ill health, but rather acts on individuals with high pre-existing vulnerability [4]. Accurate quantification of urban heat health impacts requires good knowledge of factors such as probable lag effects between heat exposure and illness onset,

appropriate estimation of excess heat-mortality rates above and beyond normal levels, and the relative contributions of "standard" risk factors and urban heat itself [5]. Access to health-care facilities and attention to sectors of the population that do not typically utilize formal health services are also critical for ensuring the implementation of effective programs that meet the needs of specific vulnerable groups [6].

Heat-Related Morbidity and Mortality

Heat-related morbidity and mortality constitute a significant public health concern, exhibiting disproportionate social stratification across the urban landscape [4]. Elevated temperatures during heat events, particularly those that surpass established norms, exacerbate an array of chronic medical conditions, with lagged health impacts persisting long after peak exposure. Though urban heat is associated with human mortality, empirical attribution to the urban heat-island effect remains complex and multifaceted [5]. Notably, published studies analyzing heat-related morbidity and mortality fail to account for the urban heat-energy-water nexus, rendering a portion of the findings potentially misleading [6]. Key studies, encompassing multiple cities, confirm the strong influence of urban heat exposure on health outcomes, with considerable variation in the degree of stratification observed. Vulnerable groups identified as bearing a disproportionate burden include economically disadvantaged individuals, the elderly, and those with preexisting medical conditions [7]. Nevertheless, the expansive temporal and spatial range of investigations conducted necessitates rigorous testing of the various underlying hypotheses proposed by existing analyses [8].

Vulnerable Populations and Differential Risk

Urban heat exposure exhibits notable disparities across demographic profiles within cities, with over 90% of North American cities experiencing racialized or economic-based heat inequality [3]. Vulnerable populations face heightened risk from environmental hazards such as heat stress, air pollution, and heat waves. Influential studies indicate that these disparities may disproportionately affect low-income residents, younger individuals, and those with chronic conditions or housing insecurity [4]. By drawing from the construct of differential risk, this section identifies vulnerable populations within the urban-heat-inequality framework. Increased risk from heat exposure is observed among individuals lacking access to adequate housing, air conditioning, or healthcare, as well as school-aged children, the elderly, persons with chronic illness, and the physically disabled[5].

Interactions with Chronic Diseases

Heat exposure interacts with chronic diseases to influence health outcomes and, consequently, heat-related mortality. Respiratory diseases such as asthma, chronic obstructive pulmonary disease, and pneumonia have been associated with increased susceptibility to heat [6]. Cardiovascular illness including hypertension, coronary artery disease, arrhythmia, ischemic heart disease, atherosclerosis, and congestive heart failure has received widespread attention given its established link with excessive heat [7]. Other chronic diseases diabetes, neurocognitive impairments, and mental health conditions are also believed to increase vulnerability to heat [8]. Asthma is a chronic respiratory disease affecting 300 million people worldwide and remains a major cause of morbidity and mortality. Extreme heat can exacerbate asthma, leading to poor control, increased symptoms, and higher use of control medications [1]. Cardiovascular diseases are a leading cause of death worldwide, with the burden of heat exposure falling disproportionately on the elderly, the poor, and those with isolated risk factors [2]. Heat is recognized as a factor in the development of cardiovascular diseases, with corollary events such as heart attacks, strokes, and hypertension. Cardiovascular diseases are also among the most significant contributors to heat-related mortality. Inadequate public transportation, increased urbanization, and poor accommodations for developing countries constrain resilience strategies [3].

Policy Landscape and Intervention Strategies

Policies designed to limit urban heat exposure can be organized into three general categories: urban planning and design; housing and social equity; and public health [4]. The first category focuses on retaining or mitigating heat build-up through landscape surfaces and associated infrastructure (e.g., pavements, social infrastructure, walls). Vulnerable areas with limited vegetation or insufficient structural arrangements are at risk of potential overheating, and applying proper legislation can ease exposure levels and guarantee wide access to heat protection policies [5]. The second category acknowledges that inadequate housing options can lead to compromised designs and weakened living standards, both of which increase exposure to urban heat in low-income bracket communities. Legislation promoting affordable housing construction and public investment in basic home improvement can therefore represent an important layer in the policy-making discourse [6]. The third category consists of campaigns seeking to ensure that whenever public alerts about improper living conditions are launched, they reach all vulnerable communities and explain available interventions to remedy health conditions. In parallel with documentation cross-sectional studies of heat exposure, it encompasses at least three fields: overall health equity, productive employment type queries, and the geolocation of vulnerable premises [1]. Urban planning and design strategies focus on physical surfaces and associated infrastructure that retain or amplify heat build-up. Vulnerable areas with limited vegetation cover or insufficient structural arrangements face high risks of overheating. Urban planning can enhance the spatial configuration and extend the role of vegetation cover to maintain lower build-up

levels. Targeted guidance can strengthen the public–private engagement framework by consolidating stakeholder networks using deliverables and mapping of commitments [2]. Proposals call for documenting responses to public campaigns—rack up an incomplete landscape. Housing policies are another core set of strategies, recognising that inadequate housing options lead to compromised designs and reduced living standards that elevate urban heat exposure in low-income neighbourhoods. Locational hot spots are amplified reproduction of wider exposure, underlining the importance of area-level housing arrangements [3]. The lack of affordable housing threatens minimum standards and pushes already-tight budgets. Supply-side measures, such as promotion of precise building arrangements, reinforce the multiplicative effect, signalling a need to broaden the scope and strategy of engagement with low-income populations [1].

Urban Planning and Heat Mitigation

Urban planning and heat mitigation efforts are aimed at reducing urban temperatures and enhancing cooling, with strategies such as adopting cool surfaces, promoting greening initiatives, and establishing cooling centers [1]. Cool surfaces, including more reflective roofing and pavements, help to decrease heat absorption, while urban greening involving tree canopy expansion, street-side green spaces, park development, and increased vegetation coverage offers shading benefits and evaporative cooling [2]. Mixed outcomes are observed among U.S. cities regarding the implementation of large-scale greening initiatives, though such programs remain promising in the pursuit of climate and heat mitigation [3].

Housing Policy and Social Equity

Social policymakers have identified the equitable provision of shelter as a critical social determinant of health, alongside accessible healthcare and education [6]. Though an absolute commodity, housing quality still exhibits considerable inequality, and investment in shelter promotes individual and community well-being. Formal programs to guarantee equitable shelter and housing conditions are rare, and even the provision of affordable, sanitary, and neat housing remains incomplete in many cities[4]. Affordable housing policies occupy a central place in local governmental urban agendas and contribute significantly to public health[5]. Compliance with urban planning regulations and encouragement of increased density on underutilized land within municipalities promote the creation and preservation of affordable housing by private real estate developers. Purchase assistance and continued rental assistance for low-income households mitigate homelessness and housing stress[6]. Rental control policies, including limits on price increases during lease turnover and restrictions on specified reasons for eviction, restrict the ability of landlords to adjust rents to market rates, thereby protecting tenants from sudden price increases[7]. Grants and low-interest loans remain available for preventive maintenance on buildings designated as affordable housing[8].

Public Health Interventions

Urban planners and policy makers have developed a number of strategies to reduce urban heat and social inequity at the same time, with varying degrees of success[1]. For instance, policies and programs to provide housing assistance, rent control, improved insulation, energy-efficient heating and cooling systems, and green infrastructure such as tree planting and green roofs can partially address both. However, policies that seek to reduce urban heat, such as the construction of additional residential buildings or the removal of certain restrictions on land-use, raise widespread community concern about gentrification, potential displacement of low-income households, and the resultant softening of racial inequity[2]. Broadening the deliberation around urban heat and gentrification to include a focus on access to green infrastructure for low-income households would serve to clarify the concerns of those at risk of displacement and inform a more-targeted discussion[3]. The extensive influence of social stratification on heat exposure provides rich ground for public health intervention. One set of interventions consists of public health alerts based on climatic conditions associated with increased risk of heat-related illness or death. These operationally simple and cost-effective alerts can be enhanced with provision of more detailed information about specific precautions or actions, but must be conveyed by trusted sources with widespread reach in order to meet public needs[4]. Second, programs to improve capacity for vigilance around heat exposure have also been used[5]. Engagement of community actors able to extend outreach into vulnerable areas, such as local officials, business owners, and place-based community-organizing groups, holds promise for improving access to critical information among residents under uneven exposure[6]. Access to funds to assist vulnerable households with paying for mediations can also improve timely adoption of precautionary measures, as median response times to heat warnings vary [7].

Governance, Accountability, and Stakeholder Engagement

Urban heat inequalities are often neglected in climate and policy discussions, despite seriously affecting the wellbeing and livelihoods of urban populations [1]. Unabated, these inequalities may further worsen with increasing global temperatures, intensifying heat exposure among the most vulnerable populations, disproportionately affecting already disadvantaged communities, and increasing the risk of extreme heat events and associated adverse health impacts [3]. Achieving greater equity in the heat exposure associated with climate change is thus a pressing challenge requiring immediate policy engagement[4]. To combat both environmental

and social inequalities, policymakers must strive to promote climate adaptation measures in connection with urbanization and social development. Currently, many government interventions do not sufficiently address these interlinked problems or are not applied equitably. Examining how issues of governance, accountability, and stakeholder engagement shape the distribution of heat exposure across urban populations can inform efforts to make heat adaptation policies more effective and equitable[5]. Decision-making processes across government agencies and other organizations can influence not only the types of interventions prioritized but also which communities benefit most from available resources. To operationalize a more equitable decision-making framework, policy actors often employ participatory governance approaches, bringing together multiple stakeholders to collectively identify priorities and actions that address climate-mitigation issues in conjunction with other development challenges [6]. Governance approaches directly shape the recommendations, outreach, and channels of information shared with diverse communities. Effective, even-handed engagement with vulnerable communities regarding the heat-related issues they face, and options for mitigating their exposure, is thus a vital first step[7]. Legal and informal accountability norms, combined with broader regional networks for monitoring tracking actions taken within and across jurisdictions against stated climate-related commitments can help promote equity-related goals consistently [8].

Case Studies and Comparative Perspectives

Access to cooling in public spaces, air conditioning, and urban greenery are unevenly distributed, influencing the amount of heat people can escape. Conducted in Atlanta, Philadelphia, San Antonio, and Seattle, interventions examining the cooling effect of trees and green roofs can inform equity-based urban heat mitigation [1]. European cities often integrate health into urban planning policies, with public health agencies collaborating on heat land use and green infrastructure proposals to improve health outcomes [2]. Durban and Cape Town face extreme land and home-seeker pressures from informal settlements. They prioritize resilience in affordable housing, public transport, and sustainable energy. As migrants unimaginably occupy open land, the "othered" move without services to flood-prone terrain [3]. Each Southern city prioritizes investment and reform in citizen safety, disparate infrastructure, and equal participation for collective and contextual action [3]. Santiago's rapid 1960s residential transition and informal settlements within cities accelerated pollution, irregular supply, and critical central services loss. Shanty conditions dramatically increased during the 1973 socio-political crisis. Subsequent survival-led informal settlements adopted topography-adapted, "bio-climate" approaches to building form, structure, and materials; services focused on sanitation and hygiene; and low-tech solutions for ventilation, heat mitigation, energy savings, and waste treatment [1].

North American Cities

Urban heat exposure represents a critical public health concern, with higher temperatures linked to elevated morbidity and mortality rates. In the United States, urban populations experience average temperatures of 1-3 °C greater than surrounding rural areas [4]. Under a mid-century emissions scenario, metro areas across the country could see summer heat indexes climb 10-12 °C above pre-industrial values [5]. This situation threatens urban residents, including those who depend on outside jobs, physically vulnerable individuals, and those lacking access to heating/cooling systems. Yet public health responses to urban heat have often overlooked the inequitable distribution of exposure across demographic and economic lines [6]. While surface temperatures have increased considerably across cities nationwide, exposure rates have tended to decline overall. Previous studies revealed both elevated precipitation and increased/programmed vegetation cover from 1986 to 2016 in many North American cities, with precipitation and vegetation (due to tree cover, landscaping, and impervious/vegetated surfaces) enhancing cooling rates [1]. Such cooling effects appear particularly concentrated in the suburbs of large metropolitan areas during periods without widespread climate-driven modification, yet climate-related shifts (e.g., reduced rainfall, decreased vegetation) have raised exposure in other parts of cities [2].

European Cities

Cities across Europe face increasing exposure to extreme heat as a consequence of climate change. Those challenges constitute a growing public health threat and exaggerate socioeconomic inequalities, suggesting that heat exposure is a matter of environmental justice [7]. A recent study examined the connection between socioeconomics and exposure to extreme heat in Switzerland, France, and the Netherlands, estimating links between urban heat and the distribution of four socioeconomic factors (income, education, occupation, and age) and highlighting the role of "associational democratization" [1]. Results indicate that while a relationship between socioeconomic status and heat exposure exists, the connection has weakened in larger European cities over the past three decades.

Global South Contexts

Rapid urbanization, resource constraints, and climate vulnerabilities characterize Global South cities, limiting options for addressing urban heat and exacerbating inequality [8]. Most urban-heat studies focus on the Global North, a gap that impedes policy relevance. Nevertheless, some low- and middle-income countries and cities have emerged as policy and experimental leaders [1].

Methodological Considerations for Research

Rising temperatures and climate change have increased the frequency and severity of heat waves, making extreme heat the deadliest weather-related hazard in the United States [5]. A growing body of research indicates that a substantial portion of the population has unequal access to resources that mitigate their exposure to increasing heat. These social inequalities exist across race, ethnicity, income, education, occupation, housing, and other dimensions of social stratification. Moreover, climate change and urbanization have combined to increase average temperature and extreme heat days throughout the country [6]. In response, local governments and public health authorities have begun to adopt heat action plans that address urban heat exposure and risk. However, existing policies, plans, and measures remain largely unintegrated, and the evidence underpinning heat policy responses is still developing. Research highlights the need to systematically study urban heat exposure and risk in the United States. Past research on urban heat islands has shed light on the generation, determinants, and mitigation of urban heat [7]. More recently, scholars have begun to examine the health impacts of extreme heat and the distribution of population vulnerability [8]. Research indicates that surface and land surface temperature (LST) remain the most common metrics in studies of urban heat island intensity in the USA and that air temperature is most typically used as an exposure metric in epidemiological studies of health consequences [1]. A range of social characteristics including income, race, education, and occupation, condition population exposure to urban climate stressors. At the same time, scholars remain divided on the extent to which different social characteristics condition relative exposure in urban contexts [2]. Existing studies map broad trends and develop indicators to operationalize exposure and vulnerability to urban climate change, but analyses remain unconsolidated, inconsistently defined, and characterized by significant measurement and reporting gaps [3].

Data Sources and Measurement Techniques

Scholarly investigations of urban thermal inequality require spatially and temporally explicit datasets capturing both heat and spatially differentiated exposure. A study by Dialesandro et al. illustrates how these data can be assembled for six southwestern U.S. cities from openly accessible sources [1]. The following discussion borrows their measurement approach and documentation while introducing additional datasets, covering epidemiological datasets that describe heat-related morbidity and mortality and remote-measurement, visit-based surveys, and modelled estimates of exposure duration [2].Urban heat is defined as higher summertime land surface temperature (LST) and nighttime air temperature in densely built regions relative to surrounding areas. The primary heat metrics in emerging research are daytime LST, nighttime LST, and nighttime air temperature, capturing both exposure risk and spatially differentiated exposure duration [3]. A variety of temperature datasets meet these requirements, with different spatial footprints ranging from one to several kilometers [4]. The data collection relies primarily on satellite-based observations and influence the choice of exposure and inequality indicators defined earlier, determining the locations and frequency of temperature observations. A proxy for exposure duration is available for multiple metropolitan areas as counts of temperatures exceeding recognized daytime and nighttime thresholds. The environmental justice literature recognizes multiple relevant inequity dimensions beyond social stratification, and therefore access to formal and informal resources is frequently included [5].

Causal Inference and Policy Evaluation

The causal inference literature has emphasized the difficulty of evaluating policies designed to reduce the health impact of climate variability. Studies spanning multiple national and international contexts reveal a canonical set of health effects to climate hazards, particularly temperature extremes [6]. At the same time, many countries, including the United States, exhibit significant degrees of segregation across racial, ethnic, and socioeconomic lines, and access to political and economic resources varies widely across these groups [7]. Analysis suggests that specific determinants of urban built environments, which are in turn shaped by historically situated patterns of segregation and resource access, continue to influence the average degree of heat exposure experienced by population subgroups [8]. Social stratification, therefore, offers an important framework for understanding urban heat inequality, while also helping to delineate the causal mechanisms that link urban heat exposure to social processes [4].

Equity-Focused Metrics

Inequitable urban heat exposure and its health effects are significant issues in cities worldwide. The heat-inequality literature is growing but remains underdeveloped, especially regarding the equity definitions and measures most useful for research and policy [6]. Current heat-inequality studies employ various definitions and measures, yielding inconsistent findings that hinder understanding of the relationship between social stratification and heat exposure and their associated health impacts. To support rigorous research and informed policymaking, equity-focused heat-exposure metrics grounded in social stratification theory and relevant to heat policy are urgently needed[7].

Synthesis, Gaps, and Directions for Future Research

Gaps in the literature on urban heat inequality reside in measurement validity, causal mechanisms, health impacts, policy responses, and decision-making processes [8]. Though accumulated evidence supports the existence of urban heat inequality, questions remain concerning its precise characteristics. Research explicitly linking social stratification and urban heat to elucidate underlying processes is scarce. Investigating the health risks tied to urban heat inequality and assessing the efficacy of potential redistributive interventions remain invaluable contributions. analysis of urban heat inequality has usually centered on social stratification, yet the explanatory role of social dynamics has frequently been overlooked[1]. A more nuanced examination of the diverse mechanisms by which urban heat inequality is produced and reproduced represents a promising avenue for exploration. Analysis of urban heat inequality in relation to health constitutes an underresearched area of inquiry. Investigating the differential health effects arising from varying exposure levels and the extent to which these ties are mediated by chronic illness, health care access, and other relevant considerations would enrich the knowledge base [7]. The policy landscape surrounding urban heat inequality also offers abundant opportunities for further study. Although the topic has garnered attention, systematic evaluations of intervention effectiveness, equity implications, and obstacles to equitable implementation are lacking [8]. Linking policy attention to certain stratification axes while neglecting others presents an additional gap ripe for investigation. Finally, the governance structures informing policy priorities and mechanisms merit closer scrutiny. Integrating analyses of urban heat, stratification, and health into broader political and institutional perspectives would sharpen the inquiry. Addressing these pressing questions would significantly advance the state of knowledge and enhance the quality of life for at-risk populations in urban contexts [2]. A considerable body of work examines urban heat mitigation measures such as green spaces, tree cover, and cool roofs. However, a more limited subset of research zeroes in on heat exposure and the additional question of inequality. Furthermore, the prevailing focus on environmental factors has allowed scholars to overlook other key mediating mechanisms. hese dimensions of social stratification, such as occupation, working conditions, and mobility practices, also exert influential effects on exposure that remain insufficiently theorized[2]. Many scientific fields have grappled with the implications of both diagrammatic representation and public engagement for their work, underscoring the need for complementary, closely interfaced strategies. Beyond direct environmental redistribution, health considerations both acute and chronic represent another essential factor in urban heat inequality and often shape population perspectives on the phenomenon under study. Different indicators and standards characterize the urban heat distribution; its inequitable urban distribution reflecting disparities in social stratification [5].

CONCLUSION

Urban heat inequality represents one of the most pressing environmental justice challenges confronting contemporary cities as climate change accelerates the frequency and intensity of extreme heat events. The evidence reviewed demonstrates that heat exposure is neither randomly distributed nor solely determined by climatic conditions; rather, it is strongly shaped by social stratification, urban development patterns, housing quality, access to green infrastructure, occupational conditions, and governance decisions. Consequently, disadvantaged populations including low-income households, racial and ethnic minorities, older adults, children, individuals with chronic illnesses, and residents of underserved neighborhoods experience disproportionately higher heat exposure and greater risks of heat-related illness and mortality. The review further highlights that urban heat inequality results from the interaction between environmental processes and long-standing socioeconomic inequalities. Unequal access to cooling infrastructure, quality housing, healthcare services, urban vegetation, and adaptive resources significantly amplifies vulnerability among already marginalized populations. These disparities are reinforced by historical patterns of segregation, unequal investment in neighborhood infrastructure, and inconsistent implementation of climate adaptation policies. Addressing urban heat therefore requires recognizing that climate adaptation is fundamentally a matter of social equity as well as environmental management. Policy evidence indicates that effective mitigation requires integrated, multisectoral approaches. Urban greening, expansion of tree canopies, cool roofs and pavements, climate-sensitive urban planning, improved housing quality, equitable land-use policies, and targeted public health interventions all contribute to reducing heat exposure when implemented alongside inclusive governance and meaningful community participation. Heat early-warning systems, community outreach programs, affordable housing improvements, and investments in resilient infrastructure can substantially reduce heat-related health risks while strengthening adaptive capacity among vulnerable populations. Despite considerable advances, important knowledge gaps remain regarding the causal mechanisms linking social stratification and urban heat, the long-term effectiveness of adaptation policies, standardized equity-focused indicators and the differential impacts of interventions across diverse urban contexts, particularly in rapidly urbanizing cities of the Global South. Future research should prioritize longitudinal and interdisciplinary studies that integrate environmental science, public health, urban planning, and social policy to generate stronger evidence for equitable climate adaptation. Ultimately, reducing urban heat inequality requires moving beyond purely technical approaches toward governance frameworks grounded in environmental justice, accountability, and inclusive decision-making. By integrating climate resilience with social equity, cities can

develop adaptation strategies that protect vulnerable populations, improve public health, reduce climate-related disparities, and foster more sustainable, resilient, and inclusive urban environments.

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