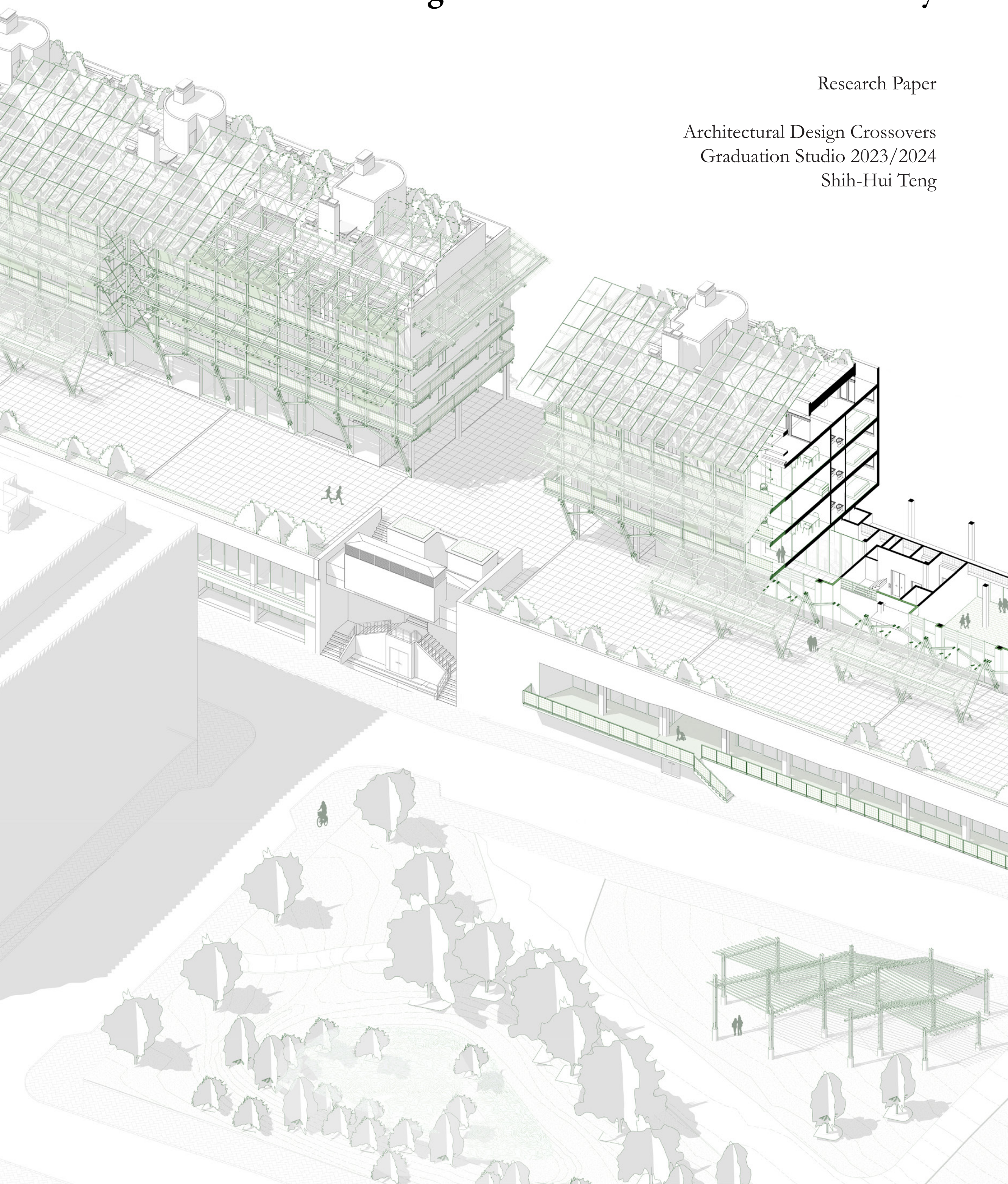
Heat, Inequality, and Microclimates: Rethinking Architecture for Thermal Security

Research Paper

Architectural Design Crossovers
Graduation Studio 2023/2024
Shih-Hui Teng



Expanded City – Madrid

Architectural Design Crossovers Graduation Studio 2023/2024

Research Paper + Reflection

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Content

Introduction

Heat inequality, which arises from the intersection of climate change and urbanisation, is an increasingly urgent issue in contemporary architecture and urban planning. As cities grow denser and global temperatures rise, the impact of extreme heat is felt most acutely in urban areas. Here, the urban heat island effect—where the built environment traps heat, exacerbated by high population density, building materials, and lack of green spaces—intensifies the already severe consequences of rising global temperatures. Ensuring thermal security has become critical, as heat is among the foremost health threats exacerbated by climate change; it can cause illness, worsen existing health conditions, and even lead to premature death[1]. The effects of extreme heat are disproportionately distributed, with some communities facing far greater risks than others, particularly those with limited access to resources for mitigating heat exposure.

In addressing heat inequality, it is essential to examine how we understand heat and inequality carefully. The first step is critically assessing the prevailing epistemological frameworks through which heat is understood. As explored in Chapter 2, the dominant methods of measuring heat focus primarily on scientific and quantifiable data such as temperature readings, heat indices, and climate models. While these metrics are essential, they often reduce heat to a depersonalised, objective phenomenon, overlooking individuals' embodied, lived experiences. By focusing exclusively on empirical data, these approaches risk overlooking the full complexity of heat as it impacts human lives. Therefore, understanding heat inequality requires moving beyond numbers to encompass the personal and social dimensions of heat experiences and their implications for thermal security.

Similarly, how inequality is understood must be reconsidered. In Chapter 3, the research examines the limitations of current methodologies used to define and assess vulnerability. Conventional approaches, often based on socio-economic indicators, tend to oversimplify complex realities by categorising people into broad groups according to census tracts or administrative districts. This generalisation risks overlooking the diverse, nuanced experiences of individuals. By re-examining these frameworks, it becomes clear that heat vulnerability extends beyond individual identities and is shaped by intersecting social, economic, and environmental factors. Addressing heat inequality, therefore, requires an intersectional approach that considers how different forms of inequality overlap and intensify vulnerability.

1. Mora, C., Dousset, B., Caldwell, I. R., et al. (2017). Global risk of deadly heat. Nature Climate Change, 7(7), 501–506. https://doi.org/10.1038/nclimate3322

To address these epistemological gaps, this research proposes a new approach that integrates both the physical and social dimensions of heat. Chapter 4 introduces alternative perspectives to bridge the divide between large-scale scientific approaches and individuals' localised, lived experiences. A key focus is the role of microclimates—localised atmospheric conditions within cities—which present tangible opportunities for architectural intervention. Architects can develop solutions that respond to specific local conditions and community needs by concentrating on microclimates, offering a more targeted approach to mitigating heat inequality and enhancing thermal security.

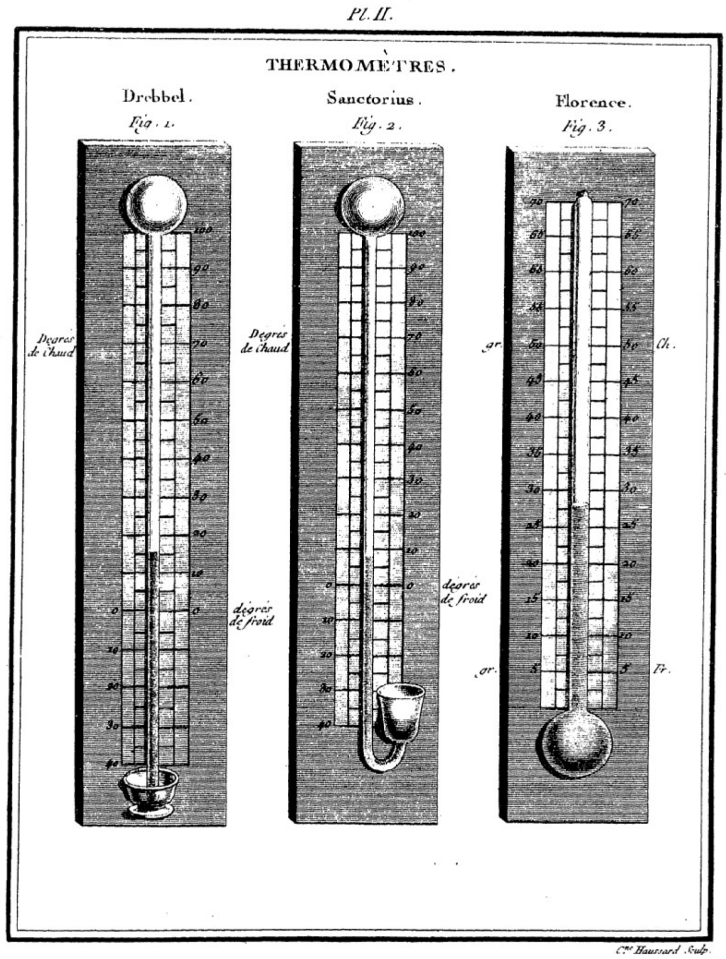
The research thus suggests that small-scale, incremental changes across various scales of microclimate offer significant potential in addressing heat inequality. Rather than relying solely on large-scale, top-down interventions, this study highlights the impact of localised, context-sensitive solutions. These smaller actions can collectively challenge the systemic inequalities deeply embedded within contemporary social and economic structures. This approach proposes that architects, alongside communities, can engage with their environments in adaptive, flexible ways, creating solutions tailored to specific contexts. These 'minor' efforts disrupt conventional architectural practices, opening new pathways for addressing entrenched inequalities across urban spaces while integrating thermal security as a core objective.

Rethinking Heat: The Epistemological Gaps in Understanding Heat Experience

To better understand heat inequality, it is essential first to examine the epistemological frameworks through which heat has been studied. Current literature indicates that scientific and quantifiable measures—such as temperature readings, heat indices, and climate models—dominate the discourse on heat. While these metrics are valuable for capturing its physical aspects, they often reduce heat to a disembodied, depoliticised entity[2], detached from the broader contexts that influence how heat is experienced and managed. By focusing primarily on empirical measures, conventional approaches may neglect key dimensions of heat that are not easily quantified. This chapter critically examines these dominant frameworks and their limitations, laying the foundation for a more nuanced exploration of heat as a multifaceted phenomenon.

2. Hamstead, Z. A. (2023). Thermal insecurity: violence of heat and cold in the urban climate refuge. Urban Studies, (20230713). https://doi.org / 10.1177 / 00420980231184466

2-1 Heat Measurement: The Meteorological Perspective



The thermometer, invented centuries ago, continues to shape how we understand heat today.

[Treatise on meteorology, Cotte, Louis (1740-1815). Bnf. https://gallica.bnf.fr/ark:/12148/bpt6k94863w/f675.item]

3. Schwartz, S. W. (2017). Temperature and Capital Measuring the Future with Quantified Heat. Environment and Society, 8, 180–197.

The epistemology of heat has long been shaped by a meteorological framework, which dates back centuries[3] and treats heat as a physical phenomenon measurable through objective data like temperature, humidity, and wind speed.

This approach allows heat to be analysed through statistical and geographical patterns, making it predictable and quantifiable. However, it has led to the misconception that "temperature is synonymous with heat," when in fact, it is only by considering human experience that we derive meaning about sensations like hotness or coldness[4].

In this framework, heat is predominantly understood through numerical and visual representations. Meteorological tools, such as weather maps, temperature scales, and heat indices, reinforce the view that heat can be captured through data points. The development of these tools has been vital for scientific advancement, yet they operate within an epistemology that prioritises measurable aspects of heat. Hamstead (2023)[5] critiques this reductionist view, stating, "Far from being an objective statistical fact, heat is deeply cultural, embodied, place-based, and political." This observation highlights the limits of conventional frameworks, which often overlook non-quantifiable aspects of heat.

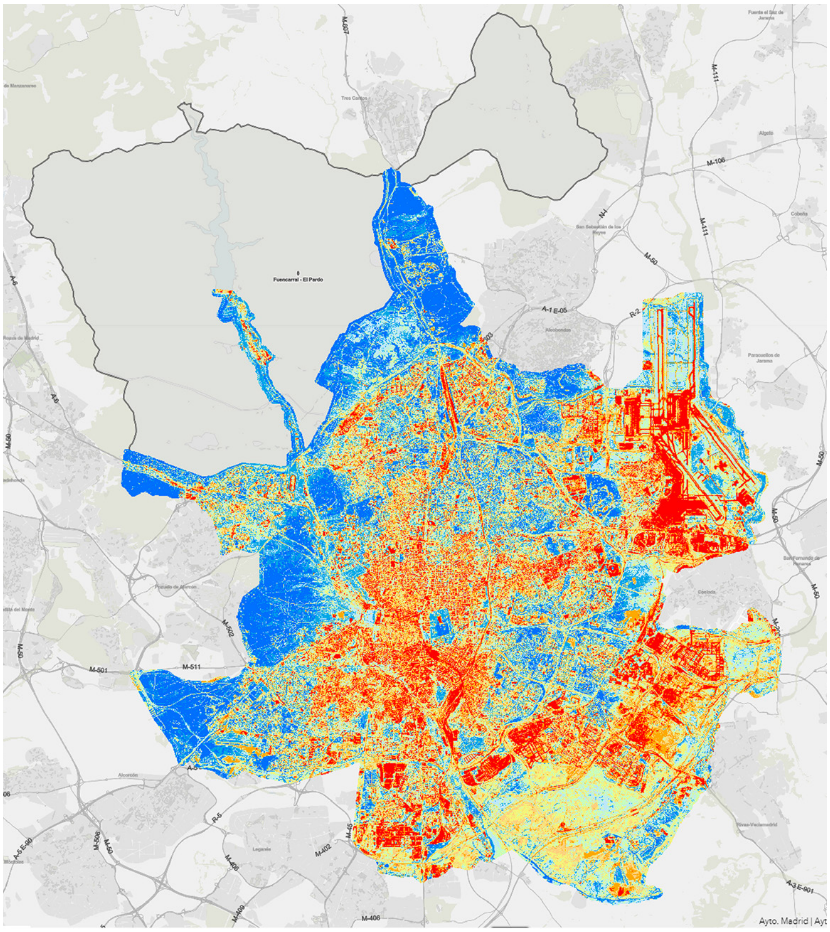
One significant example of the abstraction of heat is the invention of the thermometer, which transformed heat—once a non-visual, sensory experience—into a measurable and numerical value. By converting the sensation of heat into degrees, scientists could observe and quantify heat as a distant, objective entity detached from the immediate bodily experience of warmth or discomfort. Horkheimer (1989) [6]critiques this shift, noting that "we may privilege the visual or audial over the tactile; that we may privilege the 'objective' (e.g., meteorological measures) over the 'subjective' (e.g., sensory experience)." This reliance on numerical abstraction can obscure how heat is felt and experienced in daily life.

4. Hamstead, Z. A. (2023). Critical heat studies: deconstructing heat studies for climate justice. Planning Theory and Practice, 24(2), 153–172. https://doi.org/10.1080/14649357.2023.2201604

5. Hamstead, Z. A. (2023). Thermal insecurity: violence of heat and cold in the urban climate refuge. Urban Studies, (20230713). https://doi.org / 10.1177 / 00420980231184466

6. Horkheimer, M. (1989). Traditional and critical theory. In M. J. O'Connell (Ed.), Critical theory: Selected essays (pp. 188–243). Continuum.

2-2 Mapping Heat: Limits of UHI Analysis



[Government of Madrid. (2022). Mapa de Isla de Calor Urbano. Año 2022 [Map]. Geoportal del Ayuntamiento de Madrid. https://geoportal.madrid.es/IDEAM_WBGEOPORTAL/dataset.iam?id=3ffba0d0-5ba2-4051-8a52-954b8b540207]

Urban Heat Island Map of Madrid primarily utilises data from infrared satellites, further adjusted through the weighting of 7 additional factors:

- Estimation of the earth’s surface temperature
- Estimation of ambient temperature
- Proximity to rivers and bodies of water
- Urban Compactness
- Wind
- Shadows
- Greenness (greenness)

Satellite-based infrared imaging is a widely used method for studying the urban heat island (UHI) effect. It provides a broad overview of temperature distribution. To fully understand these maps, it's essential to recognise the processes behind their collection and analysis.

One limitation is that satellite imaging doesn't capture non-temperature factors such as humidity, wind speed, and radiation, which contribute to heat stress[7]. Additionally, the standard one-kilometre resolution is often too coarse to detect variations at the neighbourhood or building level. This generalisation can obscure local variations where heat exposure differs significantly due to factors like building material and vegetation.

Daytime satellite images may overestimate UHI intensity because they don't account for shading from trees or buildings, which lowers air temperature during the day[7]. Furthermore, daytime data doesn't capture the peak UHI effect, which typically occurs at night when urban areas release stored heat more slowly than rural regions[8].

To address these limitations, complementary data is often integrated to refine UHI estimates. For instance, to improve map accuracy, the 2022 Urban Heat Island map of Madrid[9] incorporates seven key variables—estimation of surface temperature, ambient temperature, proximity to water bodies, urban compactness, wind, shadows, and vegetation (greenness). While these variables provide a more detailed picture of heat distribution, the data used are still represented in gridded or point formats (e.g., remotely sensed images or station-based observations), adding an additional layer of abstraction that may not fully capture the human-scale experience of heat.

7. Oleson, K. W., Monaghan, A., Wilhelmi, O., Barlage, M., Brunsell, N., Feddema, J., Hu, L., & Steinhoff, D. F. (2015). Interactions between urbanization, heat stress, and climate change. Climatic Change : An Interdisciplinary, International Journal Devoted to the Description, Causes and Implications of Climatic Change, 129(3-4), 525–541. https://doi.org/10.1007/s10584-013-0936-8

8. Coral, D. S. (2013). [Methodology for evaluating the urban heat island and its use in identifying energy and urban planning problems]. Universidad de Zaragoza, Zaragoza.

9. Centro de Observación y Teledetección Espacial, S.A.U. (2022). [Urban Heat Island Map: Methodology for generating the urban climate analytical map]. Ayuntamiento de Madrid. https://geoportal.madrid.es/IDEAM_WBGEOPORTAL/dataset.iam?id=3ffba0d0-5ba2-4051-8a52-954b8b540207

Despite these refinements, satellite imaging's inherent limitations mean these maps provide a broad visual representation, not detailed, localised heat experiences. While useful for identifying broad trends, these estimations may not fully align with lived heat exposure in specific neighbourhoods or among different groups. Capturing a more accurate picture of UHI impacts at a micro level will require incorporating detailed, on-the-ground data that reflects the complex, varied realities of urban heat exposure.

2-3 Managing Heat: Government Responses

Classification of the risk	Definition	Intervention	Responsible institutions
Level: 0 Normal	Maximum temperature expected for the current day and the following four days not exceeding 36.5ºC.	• There is no Alert. • Normality Situation. • Population information general.	• DG Public Health.
Level 1 Caution	Maximum temperature expected for the current day or one of the following four days higher than 36.5ºC and not higher than 38.5ºC, with a maximum of three consecutive days.	• Alert Communication 1. • Information aimed at caregivers and groups specific risks.	• DG Public Health. • Institutions of Social services. • Assistance Network Sanitary.
Level 2 High risk	Maximum temperature expected for the current day or one of the following four days above 38.5ºC, or four consecutive days with a temperature above 36.5ºC.	• Alert Communication 2. • Information aimed at caregivers and groups specific risks. • Direct intervention on vulnerable population in the home environment, institutional, health or social.	• DG Public Health. • Institutions of Social services. • Assistance Network Sanitary.

Comunidad de Madrid. (2023). Plan de actuación ante episodios de altas temperaturas 2023 [Action plan for episodes of high temperatures 2023]. Comunidad de Madrid.

Madrid's municipality disaster prevention-focused heat risk plan categorises risk levels based on forecasted temperatures with specific interventions and responsible institutions outlined for each level.

Governmental heat management plans are heavily influenced by public health frameworks and disaster mitigation strategies commonly used for environmental hazards, like those for floods or storms[10]. This influence is evident in both the national and municipal guidelines in Spain in 2023[11]. These plans adopt a public health-driven approach, primarily focusing on reducing mortality and addressing the immediate health risks of heat exposure, particularly for vulnerable groups like the elderly, children, and those with pre-existing medical conditions.

The National Plan outlines critical strategies, including temperature prediction, risk communication, vulnerable group identification, and interdepartmental cooperation to coordinate heat management. These measures involve predicting heatwaves, informing the public about heat-related risks, and ensuring support for at-risk populations. However, as with disaster response plans, the framing treats heat as an episodic emergency, focusing on short-term individual actions rather than addressing heat as a persistent and structural challenge.

Madrid's Plan de Actuación ante Episodios de Altas Temperaturas similarly adopts a reactive approach. It includes measures such as monitoring temperatures in public transport, health centres, and hospitals and notifying vulnerable groups and healthcare facilities during heatwaves. While the plan does touch on infrastructural interventions—thermal insulation investments, school upgrades, subsidies for energy-efficient refrigeration, and extended swimming pool access—the emphasis remains on immediate responses, lacking detailed, long-term frameworks for addressing urban heat.

As extreme heat emerges as a more constant and chronic hazard, relying solely on disaster-style responses reveals

10. Hamstead, Z. A. (2023). Critical heat studies: deconstructing heat studies for climate justice. Planning Theory and Practice, 24(2), 153–172. https://doi.org/10.1080/14649357.2023.2201604

11. Ministerio de Sanidad. (2023). [National plan of preventive actions for the effects of excessive heat on health 2023]. Ministerio de Sanidad. Retrieved from https://www.sanidad.gob.es/ciudadanos/saludAmbLaboral/planAltasTemp/2023/docs/Plan_Excesos_Temperatura_2023.pdf

Comunidad de Madrid. (2023). [Action plan for episodes of high temperatures 2023]. Comunidad de Madrid. Retrieved from https://www.comunidad.madrid/sites/default/files/plan-contra-calor.pdf limitations. While such plans offer necessary interventions, they often frame heat as a personal health issue, emphasising individual actions over structural solutions. In cases where informational campaigns are the primary heat mitigation strategy, the message can imply that "if people are suffering from extreme heat, it is because they have not taken appropriate actions to protect themselves."[10] This framing risks overshadowing the broader systemic factors—such as infrastructure, urban design, social services, and public policy—that contribute to heat vulnerability and should be addressed through more comprehensive governance. By focusing mainly on individual actions, these plans may neglect the structural changes needed to build long-term resilience against rising temperatures.

2-4 The Indoor-Outdoor Thermal Divide

The concept of "thermal comfort" in architecture, which focuses on creating controlled indoor environments, has historically led to a division between indoor and outdoor climates. This framework promotes the idea that regulating factors like temperature, humidity, and air circulation within buildings create a self-contained environment independent of external conditions. However, this compartmentalisation overlooks the inherent interdependence between indoor and outdoor environments.

In the mid-20th century, when interior climate control became central to architectural design, outdoor climate was still viewed through outdated meteorological frameworks. Climate was understood as static and homogeneous, based on simplified metrics like maximum and minimum temperatures[12]. This perspective aligned with thermodynamic models of air conditioning, which sought complete control over indoor conditions. Buildings were thus designed to minimise interaction with external climate variability, isolating their interiors from local weather conditions.

12. Garcia-German, J. (2017). Thermodynamic Interactions: an Exploration into Material, Physiological and Territorial Atmospheres. Actar D. http://public.eblib.com/choice/PublicFullRecord.aspx?p=6526545

Moe critiques this mindset, arguing that insulation practices are not only over-reliant on isolation but also fundamentally misunderstand how energy dynamics should be approached in architecture. He explains that "if insulation initially aimed to resist heat transfer, historically its habits of mind have also resisted basic thermodynamic realities and possibilities"[13]. By conceptualising buildings as isolated systems, modern architectural practices often overlook critical opportunities to engage with the full spectrum of thermodynamic processes in architecture.

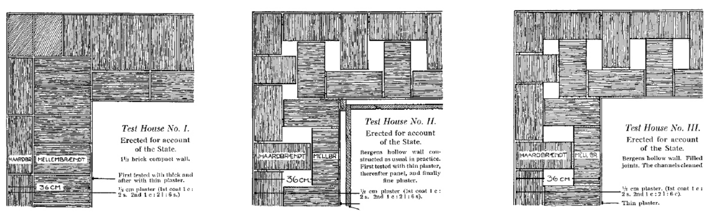
13. Moe, K. (2014). Insulating modernism. Birkhauser Verlag. https://doi.org/10.1515/9783038213215

Elisabeth Shove expands on the environmental implications of this separation, noting that the resources consumed to manage indoor environments significantly contribute to outdoor climate change[14]. In other words, creating comfortable indoor climates—through heating, cooling, and insulation—directly affects the urban environment, intensifying outdoor heat through increased energy consumption and emissions. This disconnect in thinking, where indoor and outdoor climates are treated as separate issues, prevents a holistic approach to thermal management.

14. Shove, E. (2009). Manufacturing weather: Climate change indoors and out. In V. Janković & C. H. Barboza (Eds.), Weather, local knowledge and everyday life: Issues in integrated climate studies. MAST.

Thinking of indoor and outdoor climates as completely separate has led to a problematic tendency in architectural design, where buildings are treated as isolated from their surroundings.

This approach, focused on maintaining consistent indoor conditions, has resulted in sealed, insulated structures that overlook the dynamic interactions with the external environment. As cities face growing environmental challenges, it is becoming clear that this disconnect is unsustainable. It is crucial to recognise the interdependence between indoor and outdoor climates to address the complex thermal dynamics in urban areas and create more resilient designs.



Moe, K. (2014). Insulating modernism: Isolated and non-isolated thermodynamics in architecture [Norway: 1920–1927 “Warm and Cheap” Wall Types Tested] (p. 81, 84). Birkhäuser.

Early insulation studies predominantly emerged from colder climates where heating demand shaped architectural practices. The 'Warm and Cheap' wall types tested in Norway illustrate how insulation was initially conceived as a means to resist heat loss.

Key Takeaway

This chapter provides a critical lens for understanding heat, encouraging us to look beyond its definition as a meteorological event or a mere numerical value. The dominant reliance on quantitative data creates an illusion of objectivity, suggesting that heat is a uniform, evenly distributed phenomenon. In reality, heat interacts with the built environment, infrastructure, and social systems in complex ways that cannot be fully captured by technology or numbers alone.

Recognising urban climates as cultural artefacts reframes heat as both a product of and an influence on human actions.[15] This perspective opens new possibilities for architectural and urban design responses that prioritise the social needs of city inhabitants, fostering more adaptive and equitable strategies for managing urban heat. By embracing this complexity, it becomes possible to address the root causes of heat inequality and create more resilient urban environments capable of withstanding rising temperatures.

15. Roesler, S., Kobi, M., & Stieger, L. (2022). Coping with urban climates : comparative perspectives on architecture and thermal governance. Birkhäuser.

Unequal Heat:
Social Dimensions of Heat Vulnerability

Heat inequality is not just a climatic issue; it is intertwined with deeper social, economic, and environmental disparities. From insufficient green spaces to outdated housing standards, vulnerable populations disproportionately bear the impacts of extreme heat. This chapter examines studies and frameworks that define heat vulnerability, exploring the diverse factors shaping heat experiences while questioning whether current methodologies adequately address these complexities or risk oversimplifying human realities. By critically analysing these approaches, the chapter advocates for a more socially aware and comprehensive understanding of heat inequality.

3-1 Where do we see heat inequality?

Heat inequality is a multifaceted problem that reflects the interaction of social, economic, and environmental injustices. It is not merely a geographic or climatic phenomenon but a product of more profound structural inequalities within society. As research demonstrates, different frameworks—including climate change and social inequality, energy poverty, and green gentrification—help illuminate the layers of heat inequality, each adding its own dimension to how vulnerable populations disproportionately bear the burnt of extreme heat events.

One significant aspect of heat inequality is its relationship with **climate change and social inequality**, as outlined by Islam and Winkel (2017).[16] The authors highlight a vicious cycle where disadvantaged groups are exposed to more significant risks from climate change, leading to further socio-economic marginalisation. The inequality-aggravating effects of climate change manifest through three main channels: "(a) increase in the exposure of the disadvantaged groups to the adverse effects of climate change; (b) increase in their susceptibility to damage caused by climate change; and (c) decrease in their ability to cope and recover from the damage suffered." This dynamic is particularly evident in urban areas, where low-income communities often reside in high-density neighbourhoods with insufficient green infrastructure, increasing their exposure to heat. Poor housing conditions further heighten their susceptibility to the urban heat island effect. The lack of green spaces and limited access to cooling resources exacerbate heat exposure for these populations, reinforcing existing social inequalities.

16. Islam, N., Winkel, J., & United Nations Department of Economic and Social Affairs. (2017). Climate change and social inequality. Department of Economic & Social Affairs. http://www.un.org/esa/desa/papers/2017/wp152_2017.pdf

The issue of **energy poverty** adds another layer to this complex problem. As outlined by Sanz-Fernández and colleagues (2016)[17], energy poverty arises from the interaction of three factors: high energy prices, low household income, and poor energy efficiency in homes. Certain groups, such as the elderly, pregnant women, dependent individuals, children, and people with neurodegenerative diseases, are more physically affected by extreme heat and are often regarded as socially vulnerable. Additionally, other groups like renters and immigrants are disproportionately affected by energy poverty. During heatwaves, low-income households that cannot afford air conditioning or proper insulation suffer the most, exacerbating their exposure to extreme temperatures.

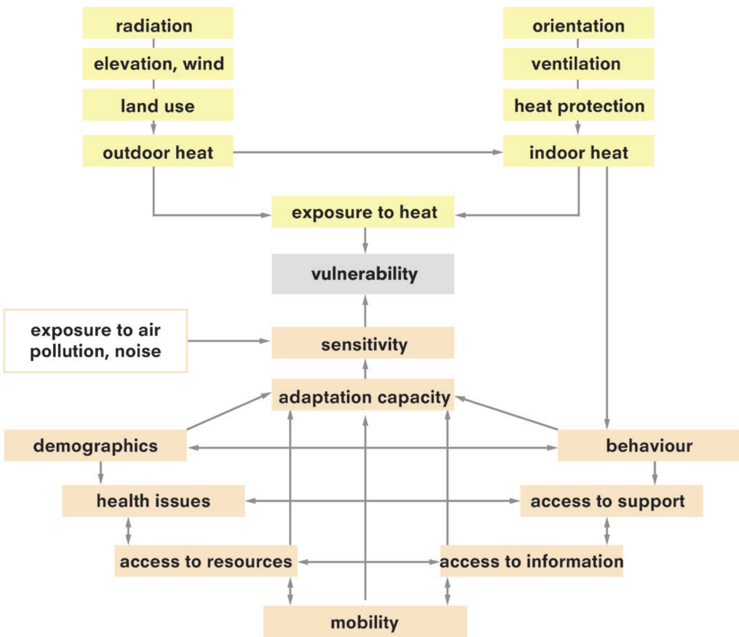
17. Sanz-Fernández, A., Gómez Muñoz, G., Sánchez-Guevara, C., & Núñez Peiró, M. (2016). Estudio técnico sobre pobreza energética en la ciudad de Madrid [Technical study on energy poverty in the city of Madrid]. Ayuntamiento de Madrid. Retrieved from https://www.researchgate.net/publication/ 321098706_Estudio_tecnico_sobre_pobreza_energetica_en_la_ciudad_de_Madrid

Adding complexity to the issue is the phenomenon of **green gentrification**. As Campbell, Eckerd, and Kim (2024)[18] explain, green gentrification occurs when environmental improvements—such as the creation of parks or sustainable housing—attract wealthier residents, pushing out low-income populations. Although these environmental interventions are intended to improve urban resilience to climate change, they often have the unintended consequence of displacing vulnerable communities to areas with fewer environmental protections, thereby increasing their exposure to climate impacts. This process highlights how well-meaning climate adaptation strategies can exacerbate social inequalities by concentrating environmental benefits while leaving the most disadvantaged even more vulnerable to climate impacts like extreme heat.

18. Campbell, H. E., Eckerd, A., & Kim, Y. (2024). Green gentrification and environmental injustice : a complexity approach to policy. Springer. https://doi.org/10.1007/978-3-031-65100-7

In each case, heat inequality emerges as a symptom of broader social, economic, and environmental disparities. Forces such as climate change, energy poverty, and urban development amplify these inequities, leaving marginalised communities disproportionately vulnerable to extreme heat. Understanding these dynamics provides a foundation for exploring the components of heat vulnerability—exposure, sensitivity, and adaptive capacity—and how they shape the risks faced by different populations.

3-2 Vulnerability=Exposure+Sensitivity



The concept of heat vulnerability naturally emerges from broader climate change research, as extreme heat is a direct consequence of anthropogenic warming and changing weather patterns. Brooks (2003) notes that the study of climate impacts, especially how societies and ecosystems adapt to climate hazards, is still relatively new. However, it is rapidly evolving into a multidisciplinary field, integrating climate science, disaster management, urban planning, social sciences, and economics to address the wide-ranging effects of climate change.[19]

19.Brooks, N. (2003). Vulnerability, risk and adaptation: A conceptual framework (Working Paper No. 38). Tyndall Centre for Climate Change Research.

A fundamental framework in this area is the Intergovernmental Panel on Climate Change[20], which defines vulnerability through three primary components: exposure, sensitivity, and adaptive capacity. Exposure refers to the "nature and degree to which a system is exposed to significant climatic variations (p.987)". At the same time, sensitivity describes how these systems are affected by climate stimuli, either adversely or beneficially (p.993). Adaptive capacity, meanwhile, is "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. (p.982)

20. Intergovernmental Panel on Climate Change (IPCC). (2001). Climate change 2001: Impacts, adaptation, and vulnerability: Summary for policymakers. World Meteorological Organization (WMO).

In the context of heat inequality within cities, social vulnerability, as described by Brooks[19], offers a more nuanced framework compared to biophysical vulnerability. While climate scientists focus on the likelihood and impacts of climate events[21], social scientists emphasise how socioeconomic factors—such as income, housing, and access to resources—determine people's ability to cope with stress or change[22]. This approach emphasises how pre-existing social disparities shape the varying impacts of heat on different groups of people.

21. Swain, D. L., Singh, D., Touma, D., & Diffenbaugh, N. S. (2020). Attributing Extreme Events to Climate Change: A New Frontier in a Warming World. 2(6), 522–527. https://doi.org/10.1016/j.oneear.2020.05.011

22. Allen, K. (2003). Vulnerability reduction and the community-based approach: A Philippines study. In M. Pelling (Ed.), Natural disasters and development in a globalizing world (pp. 170–184). Routledge.

Building on the IPCC’s definitions of exposure and sensitivity, many studies on heat vulnerability define these terms in ways that align with their application to urban heat risk. For example, in The Development of a Heat Wave Vulnerability Index for London, United Kingdom[23], **exposure** refers to the degree to which individuals are subjected to heat, influenced by factors like outdoor temperature (shaped by radiation, elevation, wind, and land use) and indoor conditions (affected by building orientation, ventilation, and heat protection measures). **Sensitivity**, on the other hand, is influenced by individual and social characteristics, including age, gender,

23. Wolf, T., & McGregor, G. (2013). The development of a heat wave vulnerability index for London, United Kingdom. Weather and Climate Extremes, 1, 59–68. https://doi.org/10.1016/j.wace.2013.07.004

health status, family structure, and access to resources such as information on heat protection or mobility. These characteristics directly impact **adaptive capacity**, shaping an individual's ability to cope with extreme temperatures and thus determining their vulnerability to heat.

In the study, Principal Components Analysis (PCA)[24] combines various datasets into a single vulnerability score by identifying key factors contributing to heat risk. The datasets for exposure include surface temperature data, urban density, and proximity to cooling infrastructure like green spaces or water bodies. For sensitivity, the study incorporates demographic data (e.g., age distribution with a focus on the elderly), health indicators (e.g., prevalence of chronic illness), and housing conditions (e.g., poor insulation or lack of air conditioning). These combined factors provide a detailed spatial map of heat vulnerability, allowing for targeted interventions in the most at-risk neighbourhoods.

The methodology provides a valuable tool for identifying heat vulnerability by presenting a spatial map that colour-codes areas in a city, representing varying degrees of vulnerability to extreme heat. This result helps policymakers identify the most affected areas, offering a clear starting point for interventions to reduce heat exposure. However, such approaches raise fundamental questions about the oversimplification of vulnerability. While categorising populations by exposure and sensitivity provides a practical framework, its inherent limitations make it challenging to capture the complexity of lived experiences. As is often the case, what is easy to measure and quantify is too often what gets quantified, leaving key socio-economic and structural dimensions unaddressed. Recognising these challenges is critical when interpreting the results of such studies.

24. Principal Components Analysis (PCA) is a statistical technique used to reduce the dimensionality of large datasets while preserving as much variance as possible. It does this by transforming the original variables into a smaller number of uncorrelated variables called principal components, which are linear combinations of the original variables. The first principal component captures the greatest variance in the data, and each subsequent component captures the remaining variance under the constraint of being orthogonal to the previous components. Jolliffe, I. T. (2002). Principal component analysis (Second edition). Springer. https://doi.org/10.1007/b98835.

3-3 Limitations in Assessing Vulnerability: A Closer Look at Methodology

Similar to the approach discussed in the previous section, many current methods for assessing vulnerability categorise populations based on measurable indicators. One such example is the APIRU[25], an assessment tool used in Madrid to identify vulnerable areas for urban regeneration. The primary goal of the APIRU map is to guide local authorities in targeting neighbourhoods for urban renewal, sustainable development, and climate adaptation efforts. The APIRU map categorises vulnerability into three main types: social, economic, and residential. Social vulnerability considers factors such as age, education, and family composition, while economic vulnerability focuses on indicators like household income and unemployment rates.

25. Mapa de Áreas Preferentes de Impulso a la Regeneración Urbana (APIRU): Ayuntamiento de Madrid. (2016). Map of Priority Areas for Promoting Urban Regeneration (APIRU). Dirección General de Estrategia de Regeneración Urbana. https://www.madrid.es/UnidadesDescentralizadas/UrbanismoyVivienda/Urbanismo/Destacamos/ficheros/MapaAreasPreferentes.pdf

A crucial aspect of residential vulnerability is the condition of housing stock, specifically focusing on the age of buildings. The year 1980 is used as a threshold in both the APIRU and the energy poverty study in Madrid[26]. Buildings constructed before 1980 are considered more vulnerable due to outdated construction standards that lack modern insulation, energy efficiency, and structural resilience. This threshold is significant because it marks the introduction of stricter building codes (NBE CT-79), making post-1980 buildings better equipped to handle extreme heat and more energy efficient. The studies highlight that older buildings often require significant rehabilitation to comply with modern safety and energy standards. While the pre-1980 threshold provides a useful guideline, it risks oversimplifying the complexities of building conditions.

26. Sanz-Fernández, A., Gómez Muñoz, G., Sánchez-Guevara, C., & Núñez Peiró, M. (2016). Estudio técnico sobre pobreza energética en la ciudad de Madrid [Technical study on energy poverty in the city of Madrid]. Ayuntamiento de Madrid.https://www.researchgate.net/publication/321098706_Estudio_tecnico_sobre_pobreza_energetica_en_la_ciudad_de_Madrid

As highlighted in the Estudio Técnico sobre Pobreza Energética en la Ciudad de Madrid[26], using building age as a proxy fails to account for the diversity in housing conditions. Many older buildings may have been renovated or retrofitted, bringing them up to modern energy efficiency standards, while some newer constructions may still suffer from poor design or low-quality materials. This creates an inaccurate reflection of vulnerability when building age alone is used as an indicator. The report also underscores that focusing too much on structural factors—like building age and insulation—overlooks critical social and behavioural elements, such as household energy practices or access to energy-saving resources, which significantly affect how individuals cope with energy poverty.

Another critical limitation can be seen in the Disproportionate Exposure to Urban Heat Island Intensity Across Major US Cities[27]. This research uses census tract-level data to analyse exposure to urban heat island effects. The choice of census tracts as the unit of analysis reflects a compromise between the precision of demographic and satellite data. While census block group-level demographic data are more detailed, aggregation to larger tracts reduces the potential for inaccuracies in satellite data, which have higher uncertainty at finer resolutions, especially in urban areas. However, this aggregation can result in a loss of information and may obscure important intra-neighbourhood variations, such as disparities in resource access or adaptive capacities, limiting the ability to capture the full complexity of heat exposure.

27. Hsu, A., Sheriff, G., Chakraborty, T., & Manya, D. (2021). Disproportionate exposure to urban heat island intensity across major US cities. Nature Communications, 12(1), 2721. https://doi.org/10.1038/s41467-021-22799-5

Despite the limitations mentioned, the methodologies employed in these and similar studies provide critical insights into the uneven impacts of heat across factors such as age, gender, ethnicity, and income[28]. By connecting

28. (Vaidyanathan et al., 2020; Gronlund et al., 2015; Harlan et al., 2013; Kuras et al., 2015; Hoffman et al., 2020; Wilson, 2020)

the built environment to socio-demographics and health outcomes, these studies illuminate important risk patterns. However, their reliance on demographic data and proxies, such as building age or aggregated census data, necessitates careful scrutiny to ensure they capture the complexities of heat vulnerability without oversimplifying the diverse and layered challenges faced by different populations.

Key Takeaway

Efforts to address inequality through vulnerability assessments provide critical tools for identifying at-risk populations and areas. These studies shown in Chapter 3 are invaluable in identifying patterns and guiding interventions, but it is crucial to understand what these analyses represent. Simplifying complex realities into measurable indicators makes it possible to analyse and act, but it also means some nuances may be lost. Raising awareness of these trade-offs helps ensure that the findings of such studies are interpreted thoughtfully, with an appreciation for the broader social and structural contexts they aim to address.

Towards Alternative Perspectives

The study of heat inequality has predominantly relied on quantitative measurements and demographic proxies, providing valuable but incomplete insights into the complexities of lived heat experiences. While these methods help identify patterns and vulnerabilities, they often fall short of addressing the deeper social and structural factors that influence heat inequality. This chapter introduces alternative perspectives — encouraging architects to look beyond conventional metrics and surface-level data. By considering a broader range of factors that influence heat experiences, architects can address the interconnected realities of heat and foster more equitable urban environments.

4-1 Layered Vulnerability Through the Lens of Intersectionality

Current studies, as discussed in previous chapters, often address heat and vulnerability through numerical and demographic data. This reliance on measurable indicators tends to result in quantitatively driven interventions, such as resource distribution—planting more trees in neighbourhoods with fewer green spaces. While such strategies provide tangible benefits, they often address symptoms rather than fully capture the complexity of heat vulnerability. Equity and equality are fundamentally different concepts: equality distributes resources uniformly, while equity tailors interventions to the unique needs and circumstances of different communities. Recognising this distinction is essential to creating more effective solutions.

Intersectionality, a concept introduced by Kimberlé Crenshaw in 1989[29], offers a deeper understanding of the interconnected factors that shape vulnerability. Originating from critical race theory, Crenshaw's work highlighted how traditional legal and social frameworks often fail to account for the experiences of individuals who belong to multiple marginalised groups. She initially used the term to examine how Black women's experiences were excluded from both feminist and anti-racist discourse, as these frameworks often addressed race and gender separately rather than considering how they intersect. Intersectionality thus examines how overlapping identities—such as race, gender, class, and age—interact within systems of power and oppression to create unique experiences of privilege or disadvantage.[30]

29. Kimberle Crenshaw. (n.d.). Demarginalizing the Intersection of Race and Sex: A Black Feminist Critique of Antidiscrimination Doctrine, Feminist Theory and Antiracist Politics. The University of Chicago Legal Forum, 1989(1).

30. Hankivsky, O., Grace, D., Hunting, G., Ferlatte, O., et al. 2012. Intersectionality-based policy analysis. Vancouver, BC: Institute for Intersectionality Research and Policy, Simon Fraser University, 33-45.

In the context of heat vulnerability, intersectionality allows us to understand how structural inequalities compound to shape distinct experiences. For instance, low-income immigrant communities may lack access to green spaces while also facing precarious housing conditions, economic instability, language barriers, and higher exposure to heat through outdoor labour. These intersecting factors shape vulnerabilities that extend beyond what quantitative data alone can reveal. By recognising the interplay between these identities, intersectionality highlights the broader systemic inequities that resource distribution alone cannot resolve.

Rather than isolating single factors like income or housing, intersectionality encourages a holistic view of vulnerability. For example, planting trees in underserved neighborhoods may reduce outdoor temperatures but does little to address inadequate housing insulation, limited access to cooling centres, or economic barriers to using air conditioning. An equitable approach informed by intersectionality would consider these additional dimensions, tailoring interventions to meet the broader needs of affected communities.

The goal of intersectionality is not to rank which group suffers the most but to acknowledge how overlapping systems of inequality create unique vulnerabilities. By integrating this framework into studies of heat vulnerability, planners and policymakers can design responses that are more socially responsive, inclusive, and effective in addressing the full scope of human experiences.

4-2 Ethnographic and Qualitative Approaches to Heat

Heat is not just a measurable phenomenon but a profoundly personal and contextual experience shaped by social, cultural, and environmental dynamics. Ethnographic and qualitative research offers valuable insights by uncovering the nuanced ways individuals and communities adapt to and navigate heat in their daily lives. Unlike methods focusing on general patterns or abstract metrics, these approaches provide a detailed and grounded understanding of how heat is lived and managed in specific urban contexts. For example, Madlen Kobi's study of Chongqing[31] and Dalila Ghodbane's research in Cairo[32] demonstrate how qualitative methodologies can uncover human stories and localised strategies that conventional frameworks often overlook.

In the study on Chongqing, Kobi conducted four months of ethnographic fieldwork between 2017 and 2020. The methodology included semi-structured interviews, participant observation, photography, mapping, and oral histories. By combining these qualitative tools, Kobi gained insights into how residents and experts manage the electrification of the urban fabric, especially in the context of transitioning from fossil fuels to electricity.

This multi-faceted approach reveals how both active (mechanical) and passive (design-based) strategies are used to manage heat in Chongqing. The study highlights that thermal experiences are shaped not just by individual actions but also by broader governance structures and energy transitions. Kobi's work interweaves ethnographic, historical, and policy-related

31. Kobi, M. (2022). The electrification of the urban fabric: On governing the built environment's seasonality. In S. Roesler, M. Kobi, & L. Stieger (Eds.), Coping with Urban Climates: Comparative Perspectives on Architecture and Thermal Governance (pp. 97-118). Birkhäuser.

32. Ghodbane, D. (2022). The domestication of urban heat: On the everyday production of microclimates. In S. Roesler, M. Kobi, & L. Stieger (Eds.), Coping with Urban Climates: Comparative Perspectives on Architecture and Thermal Governance (pp. 119-146). Birkhäuser.

data to show how the boundaries between indoors and outdoors, as well as city and nature, are deeply interconnected. This interconnectedness challenges architects and urban planners to consider how their design decisions influence broader urban and environmental systems.

Dalila Ghodbane’s study in Cairo adopts a similar ethnographic approach but focuses on how residents of lower-income neighbourhoods create microclimates within their homes and public spaces. The 16 months of architectural ethnography involved participant observation and detailed surveys of four case-study dwellings across different neighbourhoods. Ghodbane's work reveals that heat adaptation in Cairo is shaped not only by architectural factors like building height, materials, and ventilation but also by cultural norms, kin relations, and socio-economic conditions.

The ‘microclimate’ approach Ghodbane describes underscores the importance of everyday practices in shaping thermal comfort. Residents use readily available materials such as curtains, plants, and makeshift shades to blur the lines between indoor and outdoor spaces, creating hybrid thermal zones. These practices demonstrate that heat management is not solely reliant on technological interventions or formal architectural solutions but is embedded within the daily lives of individuals. The study highlights how microclimates are both socially and materially constructed, offering a nuanced understanding of how people adapt to heat through spatial and social means.

The value of these qualitative approaches lies in their ability to capture the personal and cultural dimensions of heat experiences, which quantitative metrics often overlook. Ethnography, focusing on people’s daily lives and interactions with the built environment, offers insights into the psychological and behavioural aspects of heat management. It also emphasises the importance of agency—how people can modify their surroundings to improve thermal comfort, even when faced with unfavourable conditions.

4-3 Localized Perspectives: Living with Heat in Madrid

Understanding how individuals and communities experience and adapt to heat requires exploring their lived experiences in greater depth. To supplement the broader perspectives discussed in earlier sections, I conducted a questionnaire in Madrid, the full summary of which is included in the appendix, to capture how residents cope with extreme heat. The survey focused on personal strategies, daily routines, and attitudes toward governmental interventions, offering a snapshot of adaptation practices within the city.

Most of the questions were simple and multiple-choice to encourage participation. Despite this simplicity, the responses revealed a rich tapestry of coping strategies. For instance, when asked about government measures to manage heat, respondents were divided: roughly equal proportions viewed these interventions positively, negatively, or expressed uncertainty. This range of opinions underscores the varied expectations and levels of satisfaction with public efforts to mitigate heat stress.

The questionnaire further explored personal coping strategies, with 85% of respondents opting to stay indoors on hot days and 60% travelling to cooler locations (for example, suburban areas) over the summer to escape the city's extreme temperatures. Within their homes, most respondents used strategies such as closing windows and shutters to block out the heat, indicating a cultural or habitual preference for isolating themselves from the outdoor environment during extreme heat.

When asked if heat impacted their daily routines, many respondents reported adjustments such as changing when they go out, modifying work hours, or altering sleep schedules. This reliance on behavioural adaptations rather than modifications to the built environment suggests a generally passive approach to managing heat. This contrasts with cultural practices like seasonal dietary changes, which, while not fully explored in the questionnaire, illustrate a more dynamic and integrated response to climate variability.

The questionnaire responses highlight the significant gap between personal behaviours and broader solutions for the built environment. While residents may have developed individual strategies to navigate heat, these approaches often need more integration with architectural or urban planning efforts. This disconnect presents a compelling challenge for architects and planners: to reassess the current built environment and enhance it by addressing the needs of individuals, creating spaces where residents can manage heat with greater resilience and security.

4-4 Visualising Thermodynamics in Micro-Climates

As explored in the previous chapters, heat is an exceptionally complex subject that cannot be fully captured through a single perspective. This complexity underscores the value of examining heat at varying scales of microclimates to understand the factors that influence thermal dynamics, layer by layer.

Urban microclimates function as open systems, interconnected with their surrounding areas and forming a dynamic thermal mosaic across the city. Rather than existing in isolation, each microclimate is influenced by neighbouring zones, creating diverse and fluctuating heat patterns. These localised thermal environments provide a compelling framework for reframing the study of urban heat.

By focusing on specific scales—from individual physiology and building interiors to streets, neighbourhoods, and broader urban zones—architects and planners can uncover the nuanced processes driving thermodynamics. This granular approach illuminates how heat interacts with its surroundings and supports the development of interventions that align more closely with residents' lived experiences and needs.

Unravelling Heatscape: The Case of Madrid

To explore these dynamics, this section presents a series of annotated photographs taken during several field trips to Madrid, aiming to uncover often-overlooked elements that shape urban heat. The images and accompanying notes delve into the fundamentals of thermodynamics while also capturing the unique cultural and contextual characteristics of Madrid and its inhabitants. They highlight how factors such as urban morphology, building materials, vegetation, and infrastructure interact to create microclimates across the city.

These microclimates are inherently relational, with their scope and scale influencing how heat dynamics are understood in urban spaces. By examining heat at multiple levels—from the city-wide scale to neighbourhoods, buildings, and even individual bodies—the photographs illustrate how heat is experienced differently across various urban contexts. Viewing heat through the lens of microclimates provides a more nuanced understanding of its specific drivers, challenging the notion of heat as a uniform phenomenon. This iterative, scale-sensitive approach lays the groundwork for designing environments that respond more thoughtfully to the complex, layered realities of urban heat.

Thermal Regulation in Human Physiology

To maintain a core temperature of 37°C, the human body relies initially on natural thermal regulation processes like thermogenesis and thermolysis. When these mechanisms are insufficient in extreme temperatures, additional methods become necessary to offset external climatic conditions. For instance, in the metro, passengers employ personal fans to generate a localised airflow, boosting evaporative cooling from sweat. Wearing lightweight, breathable clothing enhances air circulation around the skin, supporting the body's thermoregulatory efforts.


spanish hand fan
portable fan
Thermolysis:
-sweating
-vasolidation
(increasing blood flow to skin surfaces to maximize heat transfer to the air
Thermogeneic:
-shivering
-muscle contraction
-vasoconstriction
(decreasing blood flow to skin surfaces to minimize heat loss to the air)

Thermal Regulation in Human Physiology

The human body constantly exchanges heat with its surroundings through radiation, convection, evaporation, and conduction, creating a microclimate around itself. In an outdoor market, a woman shields herself with an umbrella-shaped hat, blocking direct sunlight and reducing heat absorption. Others around her wear lightweight clothing suited to the season, enhancing air circulation. The shaded areas provide additional relief. This scene illustrates adaptations such as clothing choices and shade-seeking to help individuals manage the heat.


radiation
seaking shade
UV-blocking wearable
evaporation
convection
clothing
conduction

Building Envelope: Insulation = Isolation?

Despite being a community centre, the dark façade feels unwelcoming, its low albedo material absorbing significant solar radiation and radiating heat back into the surrounding environment. The minimal openings reduce indoor heat gain but intensify the oppressive heat outdoors, making the space less inviting. The solid, windowless ground floor—likely shaped by Madrid's uneven terrain—adds to this sense of separation, creating both a thermal and psychological barrier for those it aims to serve.


low albedo
openings
natural ventilation

Building Envelope: Insulation = Isolation?

This patchwork façade showcases the individual strategies residents employ to contend with the sun's relentless heat. Designed initially with open balconies to provide horizontal shading, many have enclosed these spaces, unintentionally trapping heat. Now, a layering of apparatus—curtains, windows, shutters, awnings, and louvres—allows residents to adjust height and angle, ensuring just the right amount of sunlight enters without overheating their homes. Each adaptation reflects a family's ongoing negotiation with the heat, one window at a time.


awning
shutters
balcony enclosure
external louvre
air-conditioner
horizontal shading

Thermal Impacts of Urban Streetscapes

Under the protective canopy of trees, the street feels like a sanctuary. Beyond offering shade, the trees release moisture through transpiration, further cooling the air and enhancing comfort. This tranquil oasis highlights the profound role greenery plays in mitigating heat, a privilege often more evident in some neighbourhoods than others. The shade not only reduces thermal gain to surrounding buildings but also cools the streetscape, inviting moments of pause, connection, and relief from the urban heat.


transpiration
provide shade
trees
width of sidewalk

Thermal Impacts of Urban Streetscapes

The narrow street lacks space for trees, depriving pedestrians of cooling greenery. While the low sky view factor allows buildings to provide shade, it also traps heat, with surfaces reflecting warmth between them, making midday walks an ordeal. At her doorway, an old woman sits on a stool, escaping the stifling heat of her home—a building older than the rest, likely constructed before modern regulations for thermal efficiency. With limited ventilation and thermal insulation, the building struggles to shield its occupants from the unrelenting heat.


building age
Sky View Factor
building height
width of street
width of sidewalk

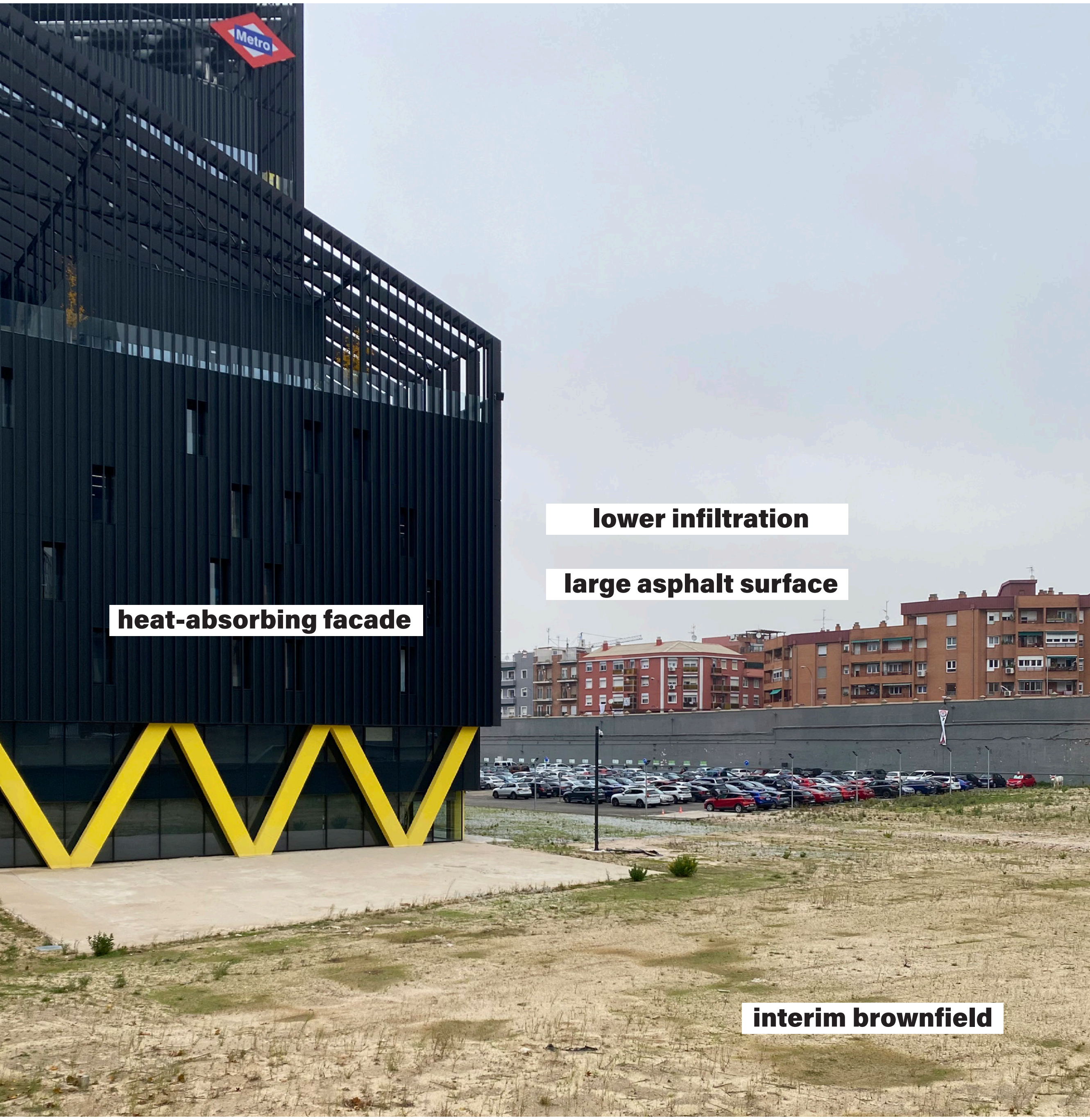
Scaling Up Heat: Development and Environmental Costs

The mirrored glass façade reflects distorted images of the four towers in the CBD onto the opposite side of the boulevard, creating a surreal and almost confrontational experience. While the low emissivity system reduces heat entering the offices, its high reflectivity intensifies glare and radiates heat back into the surrounding streetscape. Pedestrians squint and adjust their paths to escape the searing reflections, while office workers behind the glass retreat into air-conditioned bubbles, further disconnected from the baking street below.


(newer)building standards
low emissivity
visible light
UV
infarred
shortwave radiation
(older)building standards
161 COCHERAS
STOP
CALLE CONDE DE TORRALBA

Scaling Up Heat: Development and Environmental Costs

This barren expanse, an interim brownfield, lies idle as part of a planned development that has yet to materialise. Without vegetation, the dry, exposed soil and sprawling asphalt parking lots absorb and radiate heat, amplifying the urban heat island effect and adding to air pollution in the area. While the proposed design envisions this site as a green, welcoming public area that could enhance the neighbourhood, its current state serves as an environmental burden, intensifying thermal stress and reducing the overall comfort for nearby residents.


Metro
lower infiltration
large asphalt surface
heat-absorbing facade
interim brownfield

Accessibility to Adaptive Cooling Resources

This loggia, originally designed as a shaded, semi-open space to respond to the local climate, reflects architectural efforts to provide cooling and comfort. However, its potential as a communal space has been compromised by the addition of gates, likely installed to deter use by the homeless. The uneven terrain and height difference in this area further limit accessibility, making what was intended as a cooling, inviting space inaccessible and leaving its original purpose unfulfilled.


awning
shutters
air-conditioner
privatised loggia

Accessibility to Adaptive Cooling Resources

The sloping terrain of Madrid presents a challenge for those navigating the city. The incline demands physical effort, turning what might be a simple walk into an exhausting ordeal under the relentless sun. The lack of shaded pathways or cooling resources along these streets compounds the struggle, leaving pedestrians exposed to both the heat and the effort of climbing. For many, the combination of uneven topography and high temperatures transforms everyday mobility into an uncomfortable and draining experience.


street height barriers
narrow walkway

Formal vs. Informal Cooling Strategies

The community garden offers a refuge from the heat and a space for connection. In summer, as the sun lingers into the evening and houses radiate the heat absorbed during the day, residents gather here to cool off. A handmade shade canopy softens the harsh sunlight, while a hose sprays water onto the ground, cooling the surface and creating an evaporative cooling effect. Potted plants and small trees further enhance the microclimate, providing a welcoming space to escape the heat and spend time together.


self-made canvas shelter
spraying water

Formal vs. Informal Cooling Strategies

Madrid Río provides a thoughtfully designed, government-supported cooling infrastructure with its water play area, where mist and spray offer much-needed relief from the oppressive heat. Families gather under the shade of trees or stretch out on the grass, drinking cool beverages and enjoying a microclimate several degrees cooler than the surrounding streets. The water feature's evaporative cooling effect is both refreshing and socially engaging, inviting playful interactions that bring the community together.


splash pad
seeking cooling infrastructure

Conclusion

This thesis has explored the multi-faceted nature of heat inequality, emphasising the need for architects and urban planners to adopt more nuanced and equitable approaches to addressing the challenges posed by urban heat. It has proposed a shift from conventional quantitative frameworks to alternative perspectives that incorporate intersectionality, ethnographic methods, and an observation on microclimates. These perspectives reveal the layered nature of vulnerability, challenging architects and planners to adopt more inclusive approaches to addressing heat inequality.

5-1 Empowering in Heat Adaptation

The ethnographic studies of Chongqing[31] and Cairo[32] highlight the critical role that individual agencies can play in adapting to heat. These examples demonstrate how personal and collective actions significantly shape thermal environments. Research shows that the psychological ability to modify one's thermal environment significantly enhances overall comfort. Even when the quantifiable characteristics of a microclimate are less than ideal, having control over one's surroundings can greatly improve satisfaction.[33]

This insight underscores the importance of moving beyond purely technical solutions to consider how people interact with and adapt to their surroundings. Marginalised communities, in particular, can benefit from being empowered to reshape their environments through collective actions and everyday practices. By challenging existing policies and dominant ideologies that frame them as inherently vulnerable, these communities can reframe their role in heat adaptation from passive recipients to active agents of change.

Empowering individuals and communities is a matter of improving thermal comfort and a pathway to social equity. Bottom-up approaches that centre on the lived experiences of affected populations offer more inclusive and sustainable solutions to heat inequality. These approaches can bridge the gap between top-down policies and the nuanced realities of daily life, fostering resilience and agency in the face of rising temperatures.

31. Kobi, M. (2022). The electrification of the urban fabric: On governing the built environment's seasonality. In S. Roesler, M. Kobi, & L. Stieger (Eds.), Coping with Urban Climates: Comparative Perspectives on Architecture and Thermal Governance (pp. 97-118). Birkhäuser.

32. Ghodbane, D. (2022). The domestication of urban heat: On the everyday production of microclimates. In S. Roesler, M. Kobi, & L. Stieger (Eds.), Coping with Urban Climates: Comparative Perspectives on Architecture and Thermal Governance (pp. 119-146). Birkhäuser.

33. Steane, M. A., & Steemers, K. (Eds.). (2004). Environmental diversity in architecture. Taylor & Francis. https://doi.org/10.4324/9780203561270

5-2 Architectural Expertise: Bridging Knowledge and Practice

Architectural agency is pivotal in tackling heat inequality by shaping the built environment to improve thermal comfort and resilience. Architects and urban planners possess the expertise to influence urban spaces in ways that address both immediate thermal challenges and broader systemic inequities. Their professional responsibility extends beyond designing structures; it includes identifying and mitigating the elements of the built environment that exacerbate urban heat while clearly articulating the long-term implications of their designs.

A deeper understanding of the interconnected relationships between architecture, climate, and urban infrastructure allows architects to propose solutions that leverage natural climate conditions and enhance the potential of existing structures. Design strategies prioritising passive cooling—such as optimal building orientation, shading, natural ventilation, and the use of thermally adaptive materials—can reduce reliance on energy-intensive mechanical cooling systems. This creates more sustainable urban environments and aligns with the socio-economic realities of vulnerable populations, offering low-cost, context-sensitive solutions.

Beyond technical solutions, architecture can serve as a catalyst for social empowerment by challenging entrenched power dynamics within the built environment. For instance, designs that promote energy independence and adaptive thermal comfort reduce reliance on hierarchical systems like landlord-tenant relationships or corporate energy providers. Such approaches position architecture as a tool for fostering equity, enabling individuals and communities to take greater control over their thermal environments.

To achieve heat equity, architects must harmonise technical expertise with an understanding of human needs. Urban spaces should be designed to provide sustainable thermal comfort while allowing individuals the agency to adapt and personalise their environments. This integration ensures that urban spaces are both inclusive and responsive to the diverse challenges posed by rising temperatures and climate inequality.

5-3 Microclimates: Localized Opportunities for Change

The concept of microclimates provides a pragmatic way to address heat inequality. The term "micro" refers to spatial reduction, as well as the relational and intricate boundaries that shape smaller thermal environments. While the larger problem of urban heat and climate change can seem overwhelming, microclimates offer more graspable, manageable opportunities for intervention[34]. These microclimates—localised spaces where temperature, humidity, and airflow can be altered through design—are shaped by the interplay of natural elements and the built environment, offering tangible opportunities for architectural and urban solutions to heat inequality.

In addressing heat inequality, it becomes clear that conventional, data-driven studies and top-down solutions often overlook the nuanced, localised heat experiences of individuals and communities. Subtle but meaningful changes within existing urban structures—what can be thought

34. Ghodbane, D. (2022). The domestication of urban heat: On the everyday production of microclimates. In S. Roesler, M. Kobi, & L. Stieger (Eds.), Coping with Urban Climates: Comparative Perspectives on Architecture and Thermal Governance (pp. 119-146). Birkhäuser.

of as minor architectural practices—hold the potential to challenge entrenched inequalities in the built environment. Though modest in scale, these interventions, when implemented collectively, can disrupt urban systems that perpetuate climate injustice. Furthermore, such smaller-scale adjustments tend to offer more immediate relief compared to larger city-wide planning efforts, making them especially valuable in addressing pressing issues like extreme heat.

35. Stoner, Jill. (2012), Toward a Minor Architecture. Cambridge, MA etc.: MIT Press.

This "minor" approach underscores the transformative potential of small-scale, often overlooked architectural interventions in shaping urban life. As Jill Stoner explains in Toward a Minor Architecture[35], minor practices reject grand, authoritative designs in favour of fluid, adaptive, and ephemeral solutions that better align with the realities of urban living.

Large-scale interventions are essential but must be complemented by smaller, community-based efforts that address localised realities. By focusing on microclimates and the incremental adjustments that influence them, these localised strategies bridge the gap between broad planning initiatives and the lived experiences of communities. Grounded in microclimatic understanding, such context-specific approaches improve thermal comfort and promote equity and resilience, paving the way for more inclusive and sustainable urban environments.

5-4 Shaping Resilient Futures

Addressing heat inequality requires a balanced approach that integrates city-wide strategies with localised, adaptive interventions. While broad initiatives play an essential role in mitigating urban heat, they often rely on generalisations that may overlook the nuanced and complex ways people experience heat in specific contexts. Localised interventions, informed by the study of microclimates, highlight the importance of designing sensitively to the diverse scales and layers of urban life.

This thesis has emphasised the need to critically reassess current methodologies for studying and addressing heat. By introducing alternative perspectives—such as intersectionality, ethnographic research, and microclimate analysis—it encourages architects and planners to look beyond surface-level data and standard approaches. Rather than uncovering previously unseen issues, these frameworks offer a lens for questioning the assumptions behind existing studies, ensuring that interventions align more closely with lived realities and social equity.

Architects have a unique responsibility to bridge this gap between research and practice. Their ability to translate critical insights into thoughtful design solutions—whether through minor adjustments to existing structures or innovative strategies for future developments—positions them as key agents in shaping urban environments that are both equitable and thermally resilient.

Ultimately, the path forward lies in fostering urban environments that are not only adaptive to rising temperatures but also responsive to the social and cultural complexities of those who inhabit them. By integrating critical perspectives with actionable design practices, architects and planners can contribute to cities that are resilient, inclusive, and better equipped to navigate the challenges of a warming world.

Adapting Social Housing for Thermal Equity

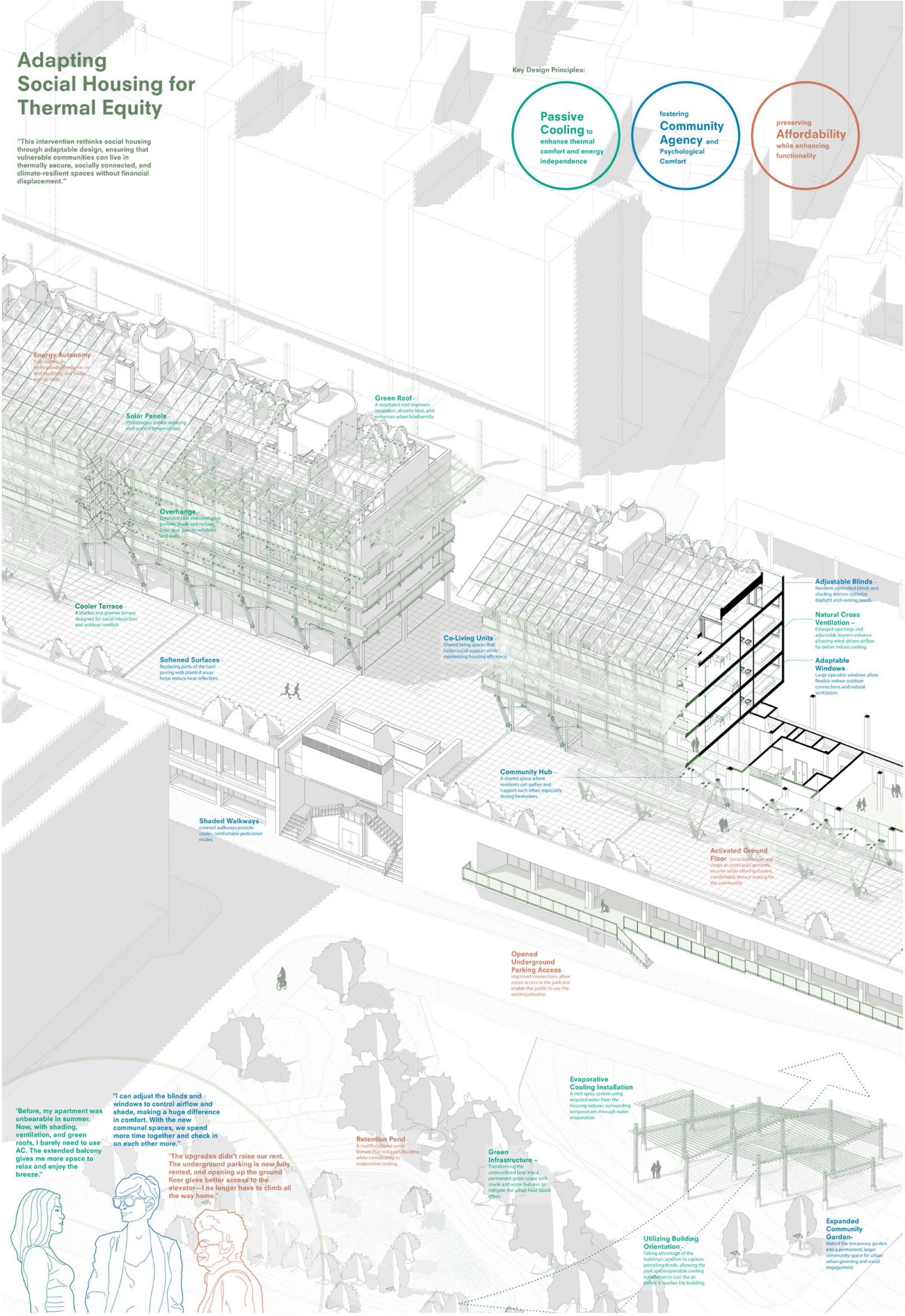
"This intervention rethinks social housing through adaptable design, ensuring that vulnerable communities can live in thermally secure, socially connected, and climate-resilient spaces without financial displacement."

Key Design Principles:

Passive Cooling to enhance thermal comfort and energy independence

fostering **Community Agency** and Psychological Comfort

preserving **Affordability** while enhancing functionality



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Appendix Questionnaire

This questionnaire was conducted from July to September 2024

Original Questionnaire

Calor extremo en Madrid

Extreme Heat in Madrid

Dear Participant,

I am Shih-Hui Teng from Taiwan, currently an architectural master's student at TU Delft in the Netherlands. I am conducting a research project focused on the impact of extreme heat in urban environments, specifically choosing Madrid as the place for study. As part of this study, I am gathering insights on how residents experience heat both indoors and outdoors, and their perceptions of heat management strategies in their community.

This questionnaire is designed in English and has been translated into Spanish using online tools. Please feel free to respond in whatever language you are most comfortable with.

Your responses will play a crucial role in understanding the challenges and effective strategies for mitigating heat in urban settings like Madrid. I am deeply grateful for your participation and would be more than happy to discuss this topic further or address any questions you may have. (This survey will not collect your email unless you voluntarily provide it at the end of the survey.)

Thank you for your valuable time and insights.

section 1

Demographic Information

1. Age

□ under 20	□ 21-30
□ 31-40	□ 41-50
□ 51-60	□ 61-70
□ 71-80	□ over 80

2. Gender
   - □ Male
   - □ Female
   - □ Other
   - □ Prefer not to say

3. Occupation _____________

4. City _____________

5. Postcode _____________

6. Neighbourhood Name _____________

section 2

Personal Experiences with Heat

1. In the past year, how many days did you experience temperatures that felt uncomfortably hot?

   □ less than 10 days

   □ 10 to 30 days

   □ 31 to 60 days

   □ More than 60 days

2. Considering the hottest days **last summer,** how would you rate the severity of the heat?

	1	2	3	4	5	6	7	8	9	10	
mild	○	○	○	○	○	○	○	○	○	○	extremely severe

3. Considering the hottest days **this summer,** how would you rate the severity of the heat?

	1	2	3	4	5	6	7	8	9	10	
mild	○	○	○	○	○	○	○	○	○	○	extremely severe

4. Have you ever suffered any health issues due to extreme heat?

   □ Yes [If yes, please specify] ____

   □ No

section 3

Coping strategies

1. With ambient (outdoor) temperature higher than which degree do you usually start feeling uncomfortable?

☐ 24°C	☐ 26°C	☐ 28°C
☐ 30°C	☐ 32°C	☐ 34°C
☐ 36°C	☐ 38°C	☐ 40°C

2. On hot days, what are your main strategies to stay cool outdoors? Select all that apply.

   - ☐ Traveling to cooler places during summer
   - ☐ Seeking shade
   - ☐ Seeking water infrastructure
   - ☐ Using open cooling spaces (parks with shade, underground spaces, or naturally ventilated areas)
   - ☐ Go to air-conditioned public spaces (shopping malls, libraries, or municipal buildings)
   - ☐ Stay indoors
   - ☐ Drink cold beverages
   - ☐ Other: ____

3. Are there adequate public facilities available to help you cool down during extreme heat? (e.g., shaded areas, public pools, air-conditioned public spaces)

   □ Yes [please specify where you go] ________________________________

   □ No

   □ Not sure

4. With ambient (indoor) temperature higher than which degree do you usually start feeling uncomfortable?

□ 24°C	□ 26°C	□ 28°C
□ 30°C	□ 32°C	□ 34°C
□ 36°C	□ 38°C	□ 40°C

5. What are your main methods to cool down indoors during hot days? Select all that apply.

   □ Use interior blinds or curtains

   □ Use awning

   □ Close exterior shutters

   □ Open windows

☐ Close the windows

☐ Install air-conditioners

☐ Install fans or other machined ventilation

☐ Enhance the insulation of exterior walls

☐ Enhance the insulation of roofs

☐ White roofing

☐ Plant greenery in front of windows

☐ Other: ____________________________

6. Can you recall a recent day when you felt uncomfortably hot? Please describe where you were and what you were doing.

____

____

7. How often do you find yourself changing your daily routine due to heat? Could you please describe them in detail? (examples might include altering your sleeping schedule, adjusting your diet, or modifying your route to work or school to cope with the heat. Please share any other changes you make related to how you manage your day.)

____

____

8. Do you know of any specific methods or practices unique to Spain or Madrid for coping with extreme heat? Please describe any traditional or culturally specific strategies that are used.

____

____

section 4

Observations and Perceptions of Heat Inequality

1. Are you aware of any areas within your city that suffer more from heat effects than others?

    □ Yes

    □ No

    □ Not sure

2. If yes, why do you think some areas are more affected than others? (Check all that apply)

 - ☐ Lack of tree cover
 - ☐ Density of buildings
 - ☐ Lack of public facilities
 - ☐ Difficulties with accessing public facilities
 - ☐ Socioeconomic factors
 - ☐ Poor air flow
 - ☐ Asphalt and concrete surfaces
 - ☐ Industrial heat output
 - ☐ Traffic heat output
 - ☐ Other ________________________________

3. Have you observed any differences in how heat affects you versus other people in different neighbourhoods or social situations?

____

____

____

____

4. In your opinion, what groups of people are most affected by heat? Why?

____
____

5. What do you think can be done to reduce the impact of heat on these vulnerable groups?

____
____
____

section 5

Attitudes Towards Urban Planning & Architectural Solutions

1. Are you aware of any local government or community initiatives to address heat-related issues?

    □ Yes

    □ No

    □ Not sure

2. If yes, what initiatives? Do you think they are effective?

    □ Very effective

    □ Somewhat effective

    □ Not effective

    □ Not sure

3. What kind of changes would you like to see in your local area to improve thermal comfort during hot weather? Please select all that apply and feel free to add any other suggestions.

   - ☐ Reduce street parking to decrease heat absorption
   - ☐ Replace asphalt with cooling pavements
   - ☐ Plant more trees along streets
   - ☐ Develop more community parks
   - ☐ Install more water infrastructure (e.g., fountains)
   - ☐ Increase the number of air-conditioned public spaces
   - ☐ Other ____

section 6

Nuevo Norte

1. Are you aware of the Nuevo Norte project before? (please check out the website of this project: https://creamadridnuevonorte.com/en/)

   - ☐ Yes
   - ☐ No
   - ☐ I’ve heard of it but don’t know the details

2. What is your overall opinion of the Nuevo Norte project?

   - ☐ Very positive
   - ☐ Somewhat positive
   - ☐ Neutral
   - ☐ Somewhat negative
   - ☐ Very negative

3. How do you think the Nuevo Norte project will impact **your community**? (Check all that apply)

   - ☐ Improve environmental sustainability
   - ☐ Enhance economic development
   - ☐ Improve urban infrastructure
   - ☐ Increase community engagement
   - ☐ Other ___________________________

4. How do you think the Nuevo Norte project will impact **the city of Madrid**? (Check all that apply)

   - ☐ Improve environmental sustainability
   - ☐ Enhance economic development
   - ☐ Improve urban infrastructure
   - ☐ Increase community engagement
   - ☐ Other ___________________________

5. Do you think the Nuevo Norte project will help reduce heat during extreme temperature events in your area?

    - ☐ Yes, significantly in the short term
    - ☐ Yes, significantly in the long term
    - ☐ Yes, but only slightly in the short term
    - ☐ Yes, but only slightly in the long term
    - ☐ No, it will have no impact
    - ☐ No, it might make it worse
    - ☐ Not sure

6. Which aspect of the Nuevo Norte project do you find most beneficial?

    - ☐ Setting examples for future sustainable urban design development
    - ☐ Creation of green spaces
    - ☐ Transportation improvements
    - ☐ Attracting more business
    - ☐ Providing more housing
    - ☐ Enhancing local infrastructure
    - ☐ Increasing pedestrian-friendly areas
    - ☐ Promoting environmental sustainability (carbon offsetting)
    - ☐ City marketing
    - ☐ Other ____

section 7

Suggestions and Feedback

1. Do you have any other comments or suggestions on how to improve living conditions related to extreme heat?

   ____

   ____

2. If you would like, please upload an image of your most memorable experience with extreme heat.
   Please provide a short description of the above image.

   ____

   ____

- If you are interested in receiving more information about the results of this questionnaire or the final design of my graduation project, please kindly leave your email address below. We assure you that your information will be used solely for sharing relevant updates related to this research.

  ____

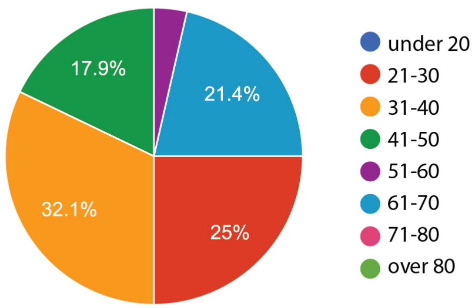
  ____

Thank you for your valuable time and insights. Your participation is greatly appreciated and will contribute significantly to understanding and addressing the challenges of extreme heat in urban environments.

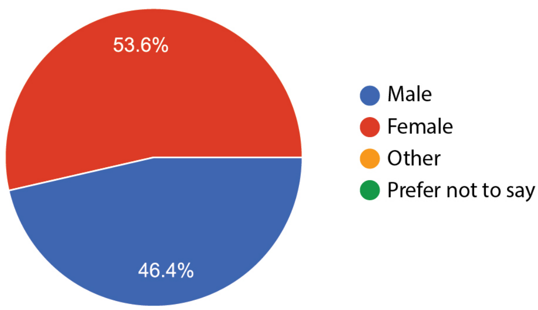
Participant Responses

section 1 Demographic Information

A total of 34 individuals responded to the survey, after excluding a few incomplete entries and those who did not reside in Madrid. The sample covered a broad age range but skewed toward young and middle adulthood. The largest age group was 31–40 years, followed by 21–30. Only one respondent was under 20, while eight were over 60.



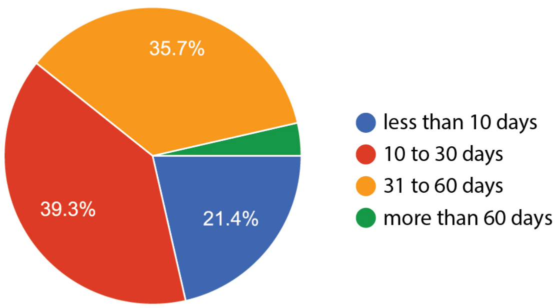
In terms of gender, the distribution was relatively balanced: 18 respondents identified as female, 17 as male, and 2 as other. No one selected "prefer not to say."



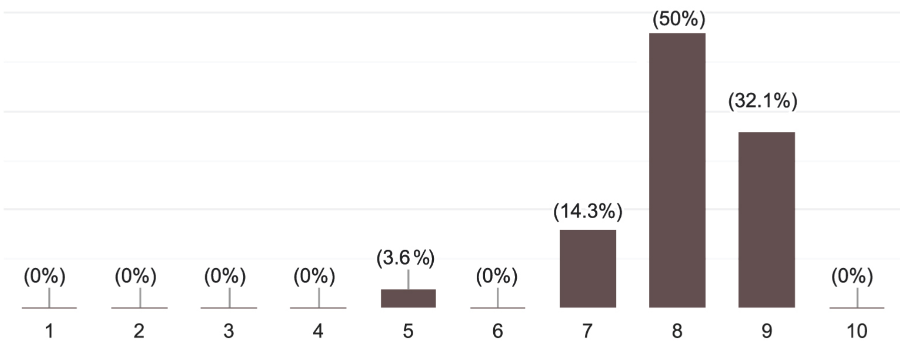
Participants represented diverse occupational backgrounds, including administrative workers, self-employed professionals, a pharmacist, a PhD student, and retired individuals. Geographically, respondents were spread across various neighborhoods in Madrid, with a significant number residing in Tetuán, the site of the design intervention.

section 2 Personal Experiences with Heat

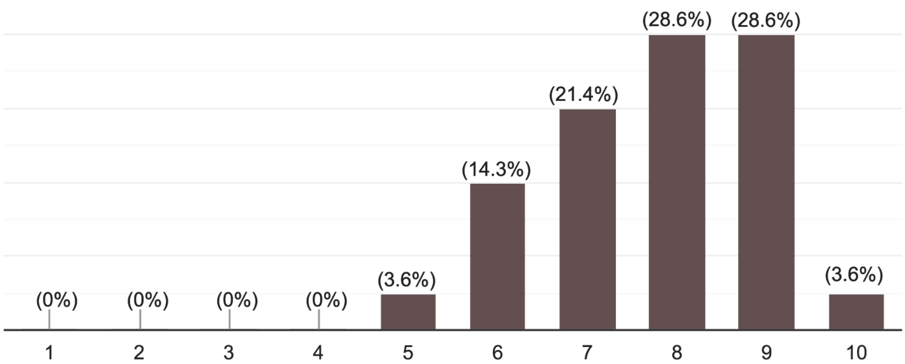
- In the past year, how many days did you experience temperatures that felt uncomfortably hot?



- Considering the hottest days **last summer,** how would you rate the severity of the heat?



- Considering the hottest days **this summer,** how would you rate the severity of the heat?

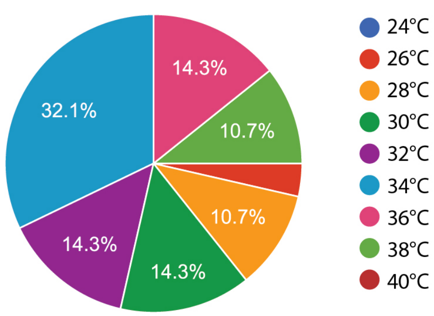


- Have you ever suffered any health issues due to extreme heat?

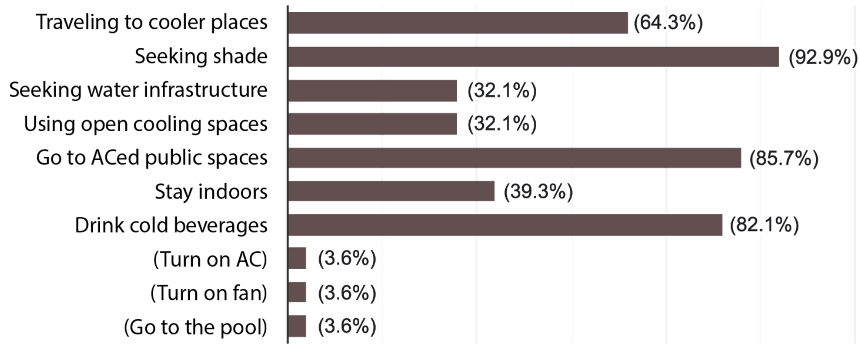
The most commonly mentioned heat-related health problems included dizziness and light-headedness (mareos), low blood pressure episodes, swelling in extremities (e.g. ankle edema), headaches, fatigue/weakness, and trouble sleeping (insomnia). A few respondents noted serious discomfort such as fainting or vomiting during heatwaves. One individual mentioned needing medication to manage a blood clot that was exacerbated by heat, and another pointed out increased irritability ("molestia hacia las personas") when overheated. These responses highlight that a significant subset of residents experience tangible health symptoms during extreme heat, predominantly circulatory or dehydration-related issues.

section 3 Coping strategies

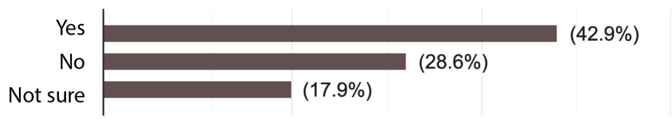
- With ambient (outdoor) temperature higher than which degree do you usually start feeling uncomfortable?



- On hot days, what are your main strategies to stay cool outdoors? Select all that apply.

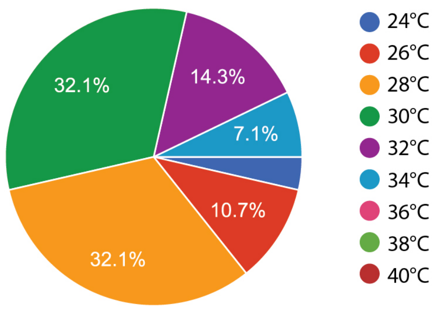


- Are there adequate public facilities available to help you cool down during extreme heat? (e.g., shaded areas, public pools, air-conditioned public spaces)

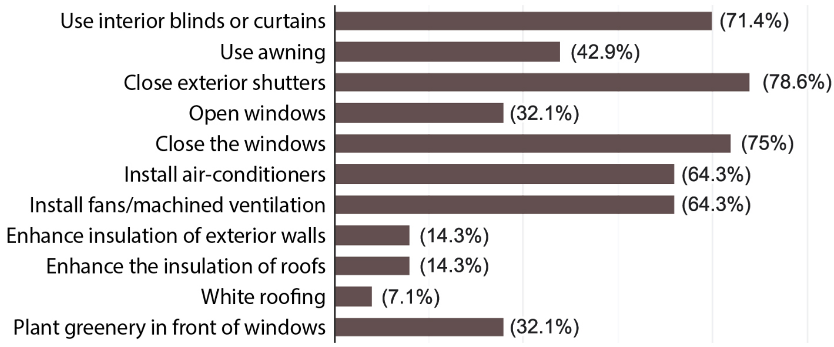


Those who answered “Yes” often pointed to specific facilities – for example, some mentioned the presence of public pools, large parks like Retiro with shade, or shopping centers with AC – but a number of them noted these could be improved (e.g. pools exist but get crowded, not enough shade in many neighborhoods, etc.). One respondent explicitly wrote “Yes, but mostly in the city center,” suggesting outer districts have fewer resources. Meanwhile, among those who felt facilities were lacking or were uncertain, common remarks were that more shaded areas and accessible cooling centers are needed, and that existing amenities (like public pools or fountains) are insufficient or not consistently available. In summary, only about 4 in 10 residents are confident about local public heat-mitigation infrastructure, while the rest see gaps or are unaware of what’s available.

- With ambient (indoor) temperature higher than which degree do you usually start feeling uncomfortable?



- What are your main methods to cool down indoors during hot days? Select all that apply.



Most Madrid residents in the survey cool their interiors by using shades/shutters and AC or fans, with some using natural ventilation at cooler hours. Structural solutions like insulation or reflective roofing are relatively rare, mentioned by only a small minority.

- Can you recall a recent day when you felt uncomfortably hot? Please describe where you were and what you were doing.

Their experiences included:

» Working from home at night, avoiding air conditioning but struggling to sleep with open windows due to high temperatures and street noise.

» A train commute (Cercanías) where the air conditioning failed, making the journey unbearably hot.

- Walking home from work in Madrid at 6:30 PM, when the heat was still intense.
- Vacationing in the mountains where temperatures reached 40°C, but the house had no air conditioning.
- Being outside in the late afternoon (around 6:30 PM on July 24, 2024) and finding it uncomfortably hot.
- Walking outside on July 22, 2024 and feeling extreme discomfort due to the heat.
- Working indoors at someone else's house and feeling that the heat was oppressive and even made them feel sick.
- Being forced to go outside after 11 AM until 7 PM, finding those hours unbearable.

- How often do you find yourself changing your daily routine due to heat? Could you please describe them in detail? (examples might include altering your sleeping schedule, adjusting your diet, or modifying your route to work or school to cope with the heat. Please share any other changes you make related to how you manage your day.)

  Participants described how heat forces them to change their daily habits:

  - Altering work hours or taking breaks due to heat exhaustion.
  - Adjusting outdoor activities to avoid peak heat hours (midday to early evening).
  - Choosing different transportation methods or avoiding public transport without air conditioning.
  - Modifying sleep schedules, often struggling to sleep due to nighttime heat.
  - Reducing time spent outside, especially for those who do not have access to cooling spaces.

- Do you know of any specific methods or practices unique to Spain or Madrid for coping with extreme heat? Please describe any traditional or culturally specific strategies that are used.

  Historical and Traditional Cooling Practices

  - Botijos (Clay Water Jugs): Historically used to keep drinking water cool due to their evaporative cooling properties.
  - Abanicos (Hand Fans): Still widely used, especially by older generations, to provide personal cooling.

- Sleeping with Damp Towels: A traditional technique to help lower body temperature at night
- Sangría: A cold, fruit-based drink often consumed in summer to help cool down.
- Siesta (Afternoon Nap): A common Spanish tradition of taking a short nap after lunch, helping people avoid outdoor activity during the hottest hours of the day.

<u>Architectural Adaptations</u>

- White Houses: Common in Andalucía and Castilla-La Mancha, white-painted buildings reflect heat and keep interiors cooler.
- Toldos (Awnings) and Persianas (Shutters/Blinds): Used extensively in Madrid and Andalucía, retractable awnings and window shutters provide shade and block heat from entering homes.
- Vegetation on Facades and Rooftops: Planting greenery on buildings and roofs helps reduce urban heat retention.

<u>Public cooling resources:</u>

- Public Shade and Water Features: Some respondents mentioned the importance of mist sprinklers, fountains, and shaded plazas to cool public spaces.
- Bathing in the Manzanares River: Families would visit the river to cool down, bringing food and spending time outdoors.
- Evening Social Gatherings in Parks: Families used to gather for dinner in public parks like La Dehesa de la Villa in Tetuán, taking advantage of cooler nighttime temperatures.
- Using Public Pools and Beaches: Those living near the coast go to the beach, while others use public swimming pools.

<u>Behavioral Adjustments</u>

Avoiding the Outdoors in Peak Heat: Many people try not to go outside between 1 PM and 8 PM, when temperatures are at their highest.

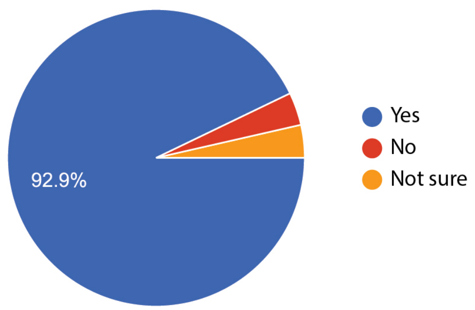
- Going to Air-Conditioned Public Spaces: Activities like going to the cinema during the hottest hours are common.
- Nighttime Social Life: Many people shift outdoor activities to late evening or night, once the sun has set.
- Nighttime Cooling: Opening windows only at night to allow cool air in while keeping them closed during the day to block heat.

Governmental and Workplace Measures

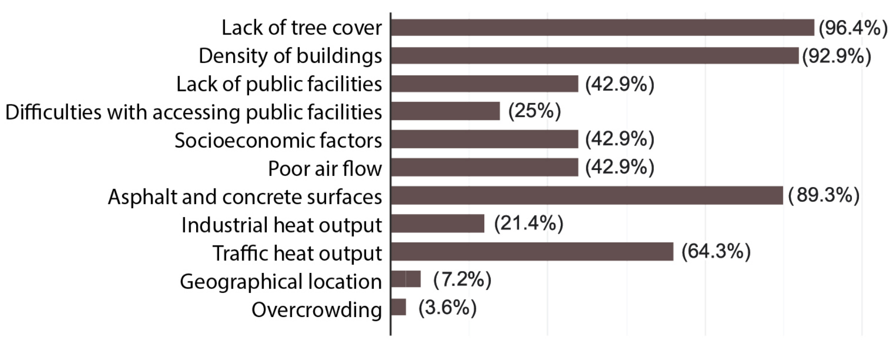
- » Work Restrictions for Outdoor Laborers: Some participants mentioned that jobs like trash collection and gardening prohibit work during peak sun hours to prevent heat strokes.
- » Heatwave Awareness Campaigns: Some government-led campaigns focus on raising awareness about heat-related risks and advising the public on protective measures.

section 4 Observations and Perceptions of Heat Inequality

- Are you aware of any areas within your city that suffer more from heat effects than others?



- If yes, why do you think some areas are more affected than others? (Check all that apply)



- Have you observed any differences in how heat affects you versus other people in different neighbourhoods or social situations?
- In your opinion, what groups of people are most affected by heat? Why?

About two-thirds of respondents provided additional commentary on how heat affects them or others differently. Many reiterated the neighborhood differences – for example, “It’s very clear the difference between neighborhoods according to economic level” was a sentiment expressed in a few responses. Some noted that people living in better-insulated buildings or with air conditioning (often in more affluent areas) handle heat more easily than those in old buildings with poor insulation. A couple of participants mentioned seeing outdoor workers (street vendors, construction workers) suffering more, or that homeless individuals are especially vulnerable. On a personal level, a few remarked on individual differences in heat tolerance (one humorously observed that their spouse could sleep fine in the heat while they themselves could not). Overall, the prevailing view was that heat exposure and its effects are not uniform – they are worse in certain hot districts and for certain vulnerable groups.

Respondents identified elderly people, children, low-income groups, pregnant women, the sick, and the homeless as the most affected by extreme heat. Some noted weight loss due to dehydration, while others observed workers struggling under high temperatures. Several mentioned that poorer neighborhoods suffer more, while wealthier areas have more shade and air conditioning. A few pointed out behavioral changes such as irritability and slower activity in the heat. Some mentioned that homeless individuals and outdoor workers face the worst conditions, with certain jobs restricting work hours to prevent heat-related illnesses.

- What do you think can be done to reduce the impact of heat on these vulnerable groups?

  » Cooling access: Guarantee air conditioning in at least one room, provide fans and cold water, and reduce electricity rates.
  » Public infrastructure: Increase public areas with fountains, trees, and large shaded spaces to allow social interactions. Expand public shelters with

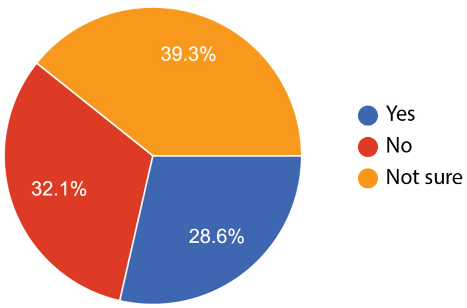
ventilation, cooling facilities, mist fountains, and watering playgrounds.

» Green solutions: Plant more trees throughout the city, create more parks, and expand wooded areas to provide natural cooling.
» Policy changes: Change work schedules for outdoor laborers and offer shelters for homeless individuals.
» Social and financial support: Provide public aid, greater social resources, and financing to insulate buildings and improve public spaces with more greenery and water infrastructure.
» Awareness and prevention: Create public awareness campaigns, implement heatwave prevention strategies before summer, and encourage recycling and irrigation.
» Daily routines and care: Vulnerable individuals need someone to remind them to drink water and help them avoid hot hours.

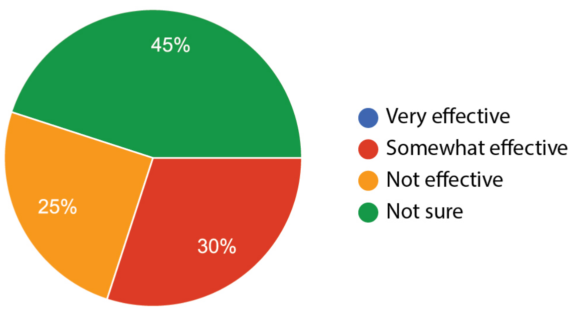
section 5

Attitudes Towards Urban Planning & Architectural Solutions

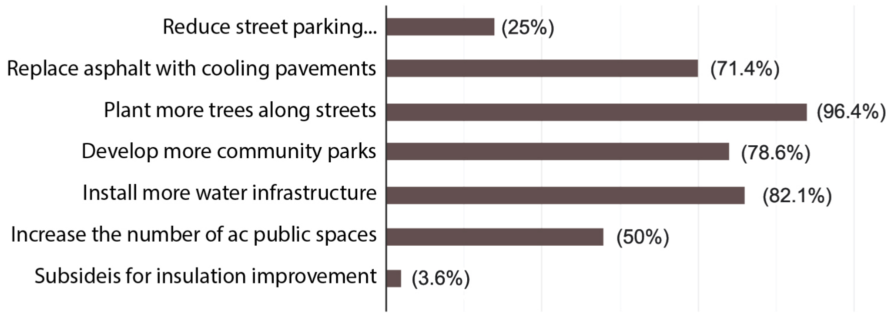
- Are you aware of any local government or community initiatives to address heat-related issues?



- If yes, what initiatives? Do you think they are effective?

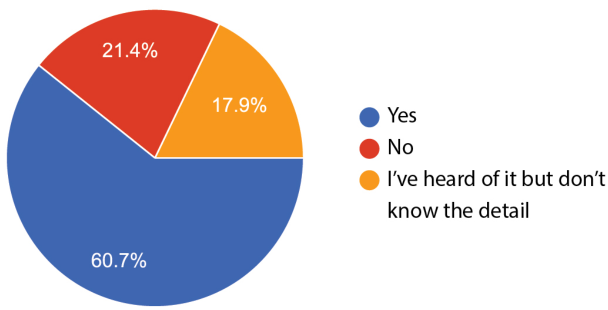


- What kind of changes would you like to see in your local area to improve thermal comfort during hot weather? Please select all that apply and feel free to add any other suggestions.

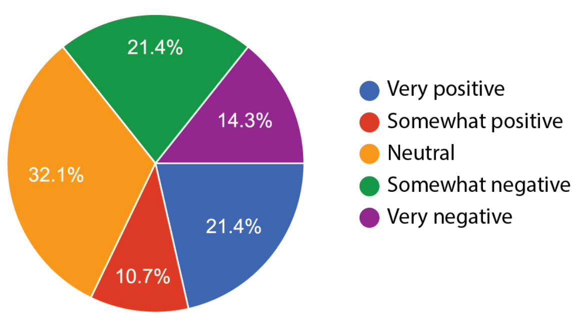


section 6 **Nuevo Norte**

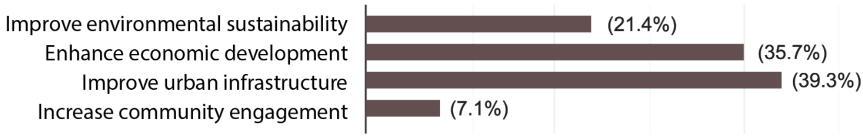
- Are you aware of the Nuevo Norte project before? (please check out the website of this project: https://creamadridnuevonorte.com/en/)



- What is your overall opinion of the Nuevo Norte project?



- How do you think the Nuevo Norte project will impact **your community**? (Check all that apply)



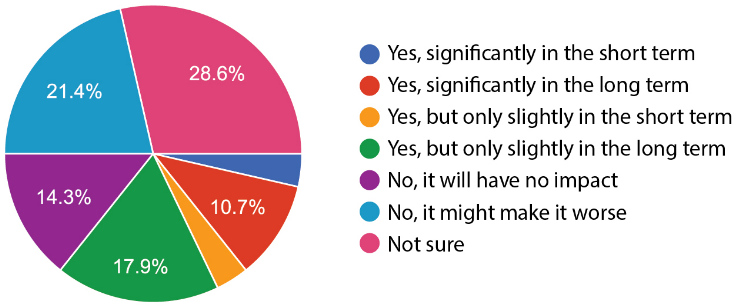
- How do you think the Nuevo Norte project will impact **the city of Madrid**? (Check all that apply)

Several respondents expressed skepticism and concern about the Nuevo Norte project, particularly regarding its social and economic impact on both their community and Madrid as a whole.

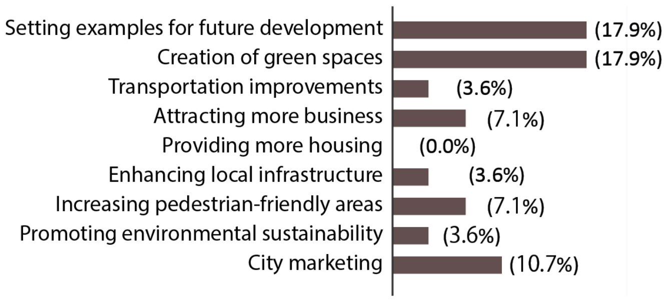
For local communities, many feared the project would widen inequality, increase housing costs, and create a divide between existing neighborhoods and the new development. Some noted that the area is already overcrowded, and adding more residents could further strain infrastructure and public services. Others believed it would lead to gentrification and isolation, negatively affecting social cohesion.

At the citywide level, respondents similarly viewed the project as a symbol of inequality, reinforcing the gap between wealthier and lower-income districts. Some criticized it as unnecessary and unsustainable, arguing that Madrid needs social housing, not luxury developments. Others warned that it would boost real estate speculation, increase tourism, and worsen traffic congestion due to greater reliance on private vehicles. A few dismissed the project entirely, stating that it would have no real benefits.

- Do you think the Nuevo Norte project will help reduce heat during extreme temperature events in your area?



- Which aspect of the Nuevo Norte project do you find most beneficial?



Conclusion:
Understanding the Lived Experience of Heat in Madrid

This questionnaire provides valuable insights into how residents of Madrid experience, perceive, and respond to extreme heat, revealing that the impacts of heat are far from uniform. While statistical climate data and urban heat models can outline broad trends, this survey highlights the human dimension of extreme heat—how it affects daily life, health, and social behavior in complex and often unequal ways.

A key takeaway is the diversity of personal experiences with heat. Some respondents manage through air conditioning and adapted homes, while others suffer from discomfort, dehydration, or even health complications. Behavioral adaptations, such as modifying schedules, using public spaces, or avoiding the outdoors, also vary greatly depending on socioeconomic status, work obligations, and access to cooling infrastructure. The responses emphasize how urban form, economic resources, and individual resilience shape the way people experience heat, underscoring disparities in vulnerability.

Another important finding is the strong awareness of heat inequality. Many participants noted that poorer neighborhoods suffer more, with fewer trees, less shade, and limited access to cooling facilities. Outdoor workers, the elderly, children, and the homeless were widely recognized as the most affected groups. This confirms that extreme heat is not just an environmental issue but also a social and urban justice issue.

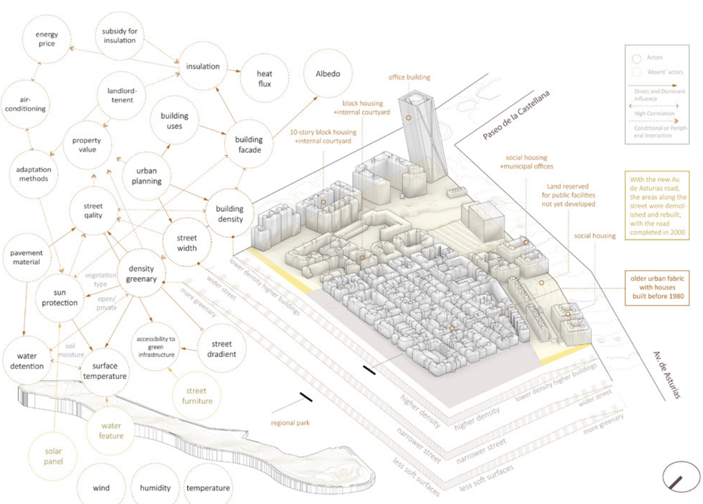
This survey also reflects public perceptions of government action—many feel that current efforts are insufficient, and there is a clear demand for more green spaces, public cooling areas, and housing improvements to address urban heat stress. Additionally, responses to the Nuevo Norte project suggest skepticism about large-scale developments addressing real climate needs, as many fear they may worsen inequality rather than provide solutions.

Ultimately, this questionnaire demonstrates the importance of understanding heat through lived experience. Capturing these diverse perspectives helps policymakers, architects, and urban planners develop solutions that are not just technically effective but also socially equitable, ensuring that all residents can adapt to rising temperatures with dignity and security.

Reflection

At the outset of my thesis, I aimed to explore the hidden and interconnected factors contributing to heat inequality. **Actor-network theory** and **urban political ecology** seemed like promising frameworks to uncover these dynamics, and I eagerly dove into their complex concepts. Initially, I believed these approaches would help clarify my research direction, but as I delved deeper, I found myself increasingly entangled in their complexity. While these frameworks provide valuable insights into how systems of power, human agency, and materiality interact, their intricate nature often felt more like a barrier than a bridge. Instead of sharpening my research focus, they expanded it into overly theoretical and abstract territory during the early stages of my work. This, in turn, prolonged my efforts to finalise my research paper, which ultimately evolved into a critical reflection on existing studies and methodologies, with an emphasis on trying not to oversimplify the multifaceted realities of heat inequality.

Although I did not achieve the groundbreaking discoveries I initially envisioned, engaging with these theories was far from futile. They encouraged me to examine the systems and tools used to study heat inequality critically. Importantly, they also pushed me to self-examine my own biases as a designer, asking whether my perspective might inadvertently overlook certain dynamics of power or lived experience. I came to realise that consistently challenging oneself to remain attentive to aspects of inequality—especially those we do not experience firsthand—is an essential yet ongoing effort. This reflective process enriched my understanding and reaffirmed my goal of humanising the study of heat inequality.



[some drawings and site analyses in the previous phase do not directly contribute to the final research paper or design]

Challenges in Engaging Local Perspectives

At the beginning of my research, I recognised that addressing the topic of inequality would require direct engagement with local people and their lived experiences. This realisation urged me to employ a more ethnographic method. However, time constraints, budget limitations, and language barriers made it difficult to fully implement approaches such as interviews, participant observation, and community engagement. Despite these challenges, I made an effort to bridge the gap by designing questionnaires, reaching out to numerous local organisations (though, unfortunately, none replied), and attending community events, such as one held at the community garden located within my design site. During my three visits to Madrid, I managed to connect with the community centre in La Ventilla, where I had meaningful conversations with its members. A kind neighbour invited me into his home and shared insights about their renovation efforts. I also visited a local food bank, where I had a conversation with the director.

While these methods offered some insights, they fell short of the depth and personal connection that immersive ethnographic approaches typically provide. At times, I felt uncertain whether my efforts truly captured the nuanced perspectives I hoped to uncover. These limitations often left me questioning the effectiveness of my approach. However, navigating these challenges highlighted the importance of flexibility and adaptation in research. Despite the compromises, the small interactions I managed to have with residents provided glimpses into their thoughts and shared strategies for coping with the heat. This experience made me reflect on the need to temper ambitious research goals with the practical constraints of fieldwork, especially in unfamiliar contexts. It reminded me that even modest connections can add meaningful layers to the research process.

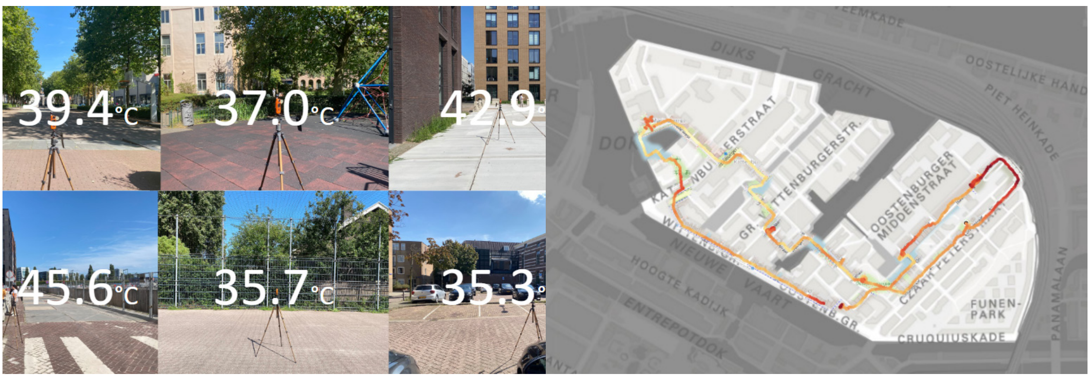


(Left) Visit to the real estate company Madrid Nuevo Norte
(Middle) A resident explains personal efforts to improve the thermal environment of their home
(Right) Community event held in the local community garden

Cultural Context and the Case for Site-Specific Observation

Reflecting on my research, I see that my background has significantly shaped my understanding of climate and architecture. Growing up in Taiwan, where architecture often prioritises shading and ventilation to address humid and subtropical conditions, I became keenly aware of how architecture responds to climate. Since moving to the Netherlands, I've observed a contrasting approach, where insulation and energy efficiency dominate the architectural discourse due to colder winters and milder summers. These distinct experiences highlight how deeply cultural and climatic contexts shape urban and architectural design, and they reinforced my conviction that studying heat inequality requires site-specific ethnographic observations.

Without immersing oneself in the local context, it is easy to miss the nuances of how people interact with their environments and adapt to challenges like heat. This awareness motivated my effort to focus on the lived experiences of Madrid residents, even though practical limitations meant my approach could only scratch the surface. My perspective allowed me to reflect on how diverse heat experiences can be and consider architecture's role in addressing these differences.



[Three different devices—two portable sensors and one stationary sensor—were used to identify hotspots in Amsterdam. During a summer school hosted by MIT Senseable Lab, I explored a more technology-driven and data-analytical approach to studying heat.]

Minor Architecture as a Guiding Principle

At the beginning of my thesis, the concept of minor architecture was an abstract inspiration—something I felt drawn to but couldn't yet articulate or fully understand. Jill Stoner's idea of small-scale, context-sensitive interventions resonated with me, but I struggled to grasp what it might mean in practice or how it would shape my work. As I progressed through my research and design process, my understanding of minor architecture began to crystallise.

What stood out to me was how minor architecture does not reject the existence of major systems or frameworks but instead finds ways to adapt, respond, and thrive within them. This mindset subtly mirrored my approach to critiquing existing methodologies for studying heat inequality. While I questioned the abstraction and limitations of large-scale studies, my goal was never to dismiss them but to complement their insights with alternative, human-centred perspectives. This parallel between my research and minor architecture helped me think more critically about the spaces in which smaller, adaptive approaches can make an impact.

More importantly, I'm pleased that this vision found its way into my final design proposal. I now see my project as embodying the principles of minor architecture—or at least coming closer to what it means to me. My proposal prioritises adaptability, inclusivity, and sensitivity to context, focusing on the human scale and the lived realities of the people it seeks to serve. It may not be grand or authoritative in its scope, but it is deeply rooted in the specific needs of the site and its community.

Looking back, I'm glad that the concept of minor architecture has remained a guiding thread throughout my journey. Although I didn't fully understand it at the outset, it has become a lens through which I view my work and, perhaps, my role as an architect. To me, minor architecture now represents a commitment to designing with humility, embracing the complexities of local contexts, and creating interventions that quietly but meaningfully improve people's lives. My final proposal may not fully realise all the aspirations of minor architecture, but it has brought me closer to understanding what it means and how I can strive toward it.

Reflection on the Design Proposal

How can the design reduce the use of new/carbon-intensive materials and construction processes to minimise carbon emissions while improving thermal comfort and social equity?

My design proposal aims to address heat inequality by reimagining and adapting existing social housing in Madrid. While the interventions focus on enhancing thermal comfort and resilience, they also prompt significant questions about resource use and sustainability. Given that inequality is the central focus of my project, I constantly ask whether the changes I propose are truly necessary or if there are alternative solutions that might achieve similar outcomes with fewer resources. For example, could smaller-scale, low-cost adaptations provide the same level of impact without requiring extensive materials or construction processes that contribute to carbon emissions? This tension aligns with the concept of exergy in mentioned in Kiel Moe's publication, which critiques the excessive use of materials in modern architectural solutions.

How can adaptive reuse strategies in the design proposal better align with the concept of minor architecture, maximising the potential of existing structures without imposing unnecessary changes?

Another critical consideration is how to maximise the potential of the existing built environment. Instead of focusing on large-scale transformations, I concentrated on making thoughtful, context-sensitive modifications to enhance the building's performance and responsiveness to its environment. This approach draws on the architect's expertise to identify and activate latent opportunities within the existing framework—making subtle adjustments that generate meaningful change while preserving and building upon the existing structure.

For instance, by improving shading, enhancing natural ventilation, and introducing greenery, I sought to integrate sustainable, efficient solutions that work with the existing structure, complementing its inherent qualities while addressing the community's and environmental needs.

Looking Ahead

Reflecting on my thesis, I see a journey marked by challenges, adaptations, and discoveries. My initial ambitions to uncover hidden dynamics and engage deeply with local communities were tempered by practical limitations, but navigating these obstacles taught me valuable lessons about research and design. My work has been as much about questioning existing methods as it has been about proposing alternatives, striving to make the study of heat inequality more human-centred and inclusive.

While my final design proposal may not be a grand solution, it represents a meaningful step toward addressing the complexities of urban heat. By emphasising the lived realities of the vulnerable, my work aims to bridge the gap between research and practice, contributing to a more equitable and responsive approach to climate adaptation. As I move forward, I plan to build on these lessons, continuing to explore how architecture can serve as a tool for resilience, equity, and attentiveness in addressing the challenges of a changing climate.