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Publication Date

2023-10-01

DOI

10.1016/j.landurbplan.2023.104836

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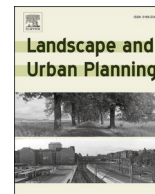
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Peer reviewed

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Seeking refuge? The potential of urban climate shelters to address intersecting vulnerabilities

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HIGHLIGHTS

- Climate refuges are public urban spaces that offer protection from extreme weather.
- We analyze Barcelona's Climate Shelter network using an intersectional perspective.
- Intersectional inequalities help explain unequal experiences of thermal discomfort.
- Critical urban infrastructures must address immediate risks and historic inequalities.
- Refuge spaces must be gender responsive, culturally inclusive, and easily accessible.

ARTICLE INFO

Keywords:

Climate shelters
Climate justice
Intersectionality
Intersecting vulnerabilities
Thermal comfort

ABSTRACT

Climate shelters are critical urban infrastructures to support adaptation to extreme weather. They offer spaces – e.g., parks, libraries, and civic centers – where residents can take refuge during episodes of extreme temperatures. With over 200 public spaces designated as “Climate Shelters”, Barcelona (Spain) serves as an emblematic example of whether these emerging spaces are meeting the needs, expectations, and everyday experiences of the most vulnerable residents. By applying an intersectional climate justice perspective and mixed-method approaches rooted in a survey of a particularly climate-exposed working-class neighborhood (La Prosperitat), we found that the intersecting vulnerabilities of marginalized populations remain poorly addressed, largely due to differences in access to coping mechanisms that overlap with intersecting social positions, exacerbating vulnerability to climate risks. We also found that housing inadequacy and energy poverty experienced by low-income residents and those originally from Global South countries made them the most affected and least able to cope with extreme temperatures. Women were also more affected by climate impacts and more concerned about current and future risks. We argue that unequal lived experiences of thermal (dis)comforts inform heat and cold inequalities, which, in turn, are attributed to intersecting social positions and structural vulnerabilities. These uneven lived experiences shape – and are reshaped by – limited adaptive capacity, culturally inappropriate approaches, and insufficiently inclusive public spaces, thus complicating an equity-driven provision of refuge infrastructures. Results call for developing refuge infrastructures that address the intersecting social and climate needs of residents who need them the most.

1. Introduction

With climate impacts intensifying on the ground, several cities

around the world are creating or reshaping public spaces as refuges for their most vulnerable residents to adapt to extreme risks. These refuges include greenspaces as well as air-conditioned indoor facilities, such as

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<https://doi.org/10.1016/j.landurbplan.2023.104836>

Received 3 January 2023; Received in revised form 12 June 2023; Accepted 25 June 2023

Available online 29 June 2023

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cooling centers (Berisha et al., 2017; Widerynski et al., 2017) and disaster relief sites that offer emergency shelter during episodes of storms, floods, and wildfires (Bashawri et al., 2014; Steer et al., 2017). Barcelona is one such example with its municipal network of “Climate Shelters”, which aim to provide thermal comfort to people who are especially vulnerable to extreme temperatures due to their socioeconomic situation, age, or health status (Barcelona, 2021c). The network encompasses open spaces of heat refuge, such as parks and gardens, as well as public indoor spaces like libraries, museums, and civic centers that provide protection from heat and cold extremes. Notably, Barcelona aims to ensure that all residents live within a 5-minute walk of a climate shelter by 2030 (ibid). Questions around how outdoor spaces can serve as effective climate shelters will likely have a large impact on urban greenspace planning, especially on how to adapt existing design practices and maximize diversity of uses as the need for such refuge increases.

The pilot nature of climate shelters in early-adopter cities like Barcelona poses lingering questions over whether and to what extent these spaces account for the differential and intersecting vulnerabilities of marginalized communities in relation to climate change impacts. Within the literature on equitable urban climate adaptation and design justice (Anguelovski et al., 2016; Goh, 2021; Piazzoni et al., 2022), the distribution, accessibility, and inclusivity of climate-adaptive interventions and infrastructures have been questioned. Studies indicate that low-income and non-white populations experience disproportionate heat exposure but limited access to refuge facilities (Fraser et al., 2017; Kim et al., 2021; Voelkel et al., 2018). These critiques might also be leveled at Barcelona since the climate shelters network could be interpreted as a simple repackaging of existing facilities without adequate consideration of the lived experiences and intersecting vulnerabilities of marginalized populations. However, if public refuge spaces are to be scaled up to protect the most vulnerable groups, there is a need to unpack the push towards somewhat rushed adaptation projects to respond to immediate climate impacts, while addressing intersecting inequalities that underlie drivers of climate injustice (Amorim-Maia et al., 2022; Chu & Cannon, 2021).

Drawing on Barcelona’s experience and data collected through a neighborhood-based survey, interviews, a focus group, and archival analysis, we ask: To what extent are adaptive urban infrastructures responding to the intersecting vulnerabilities and lived experiences of climate change of marginalized populations? To answer that question, we focus on a neighborhood deemed vulnerable to climate change and apply a feminist intersectional lens (Cho et al., 2013; Collins, 2015; Crenshaw, 1989), embracing the complexities of compounded experiences of discrimination and oppression (i.e., on the basis of gender, class, migrant status) and placing those who are marginalized at the center. This lens allows us to relate residents’ lived experiences of heat and cold with their (in)ability to cope with temperature extremes and (in)accessibility to spaces of refuge, drawing a parallel between embodied feelings of thermal comfort/discomfort and intersecting structural inequalities.

Based on our findings, we identify principles for a more transformative operationalization of refuge spaces, pointing to the need for investments beyond process and towards more (re)distributive critical urban infrastructures that protect people from extreme events while recognizing local needs and addressing intersecting vulnerabilities. Our results also highlight the role that climate shelters can play in building adaptive capacity across the built landscape of Barcelona, where there are clear variations in heat and cold impacts. Before turning to the methods and results of our analysis, in the following section, we situate our study within broader debates on intersectionality and climate justice.

2. An intersectional lens to assess the justice outcomes of adaptive urban infrastructures

In this study, we apply the conceptual framework of intersectional climate justice to understand the extent to which climate shelters are addressing the intersecting vulnerabilities of Barcelona’s marginalized groups. Intersectional climate justice proposes an analysis of the interconnected forms of socioenvironmental injustices that drive vulnerabilities in cities, paving the way for more concrete and integrated strategies of just urban adaptation and transformation (Amorim-Maia et al., 2022). We apply this lens to explore how spatial variations in heat/cold risks intersect with the accessibility of coping mechanisms and distribution of refuge spaces, highlighting implications for climate justice. Hence, this study addresses a deficit in theoretical and empirical connections between intersectionality and climate justice (Mikulewicz et al., 2023), and between climate justice and adaptive interventions that affect the urban landscape (Mohtat & Khirfan, 2021), with significant implications for distributive and recognitional justice.

First introduced in 1989 and rooted in Black Feminism and Critical Race Theory, the term intersectionality offered a critique of the marginalization of Black women within antidiscrimination law, feminist theory, and antiracist politics (Crenshaw, 1989). Over time, the term has involved into a method, analytic tool, and lens to theorize the dynamics of overlapping axes of identity and power relations, such as gender, race, and class, and the ways in which they intersect creating different experiences of oppression and exclusion (Carbado et al., 2013; Lutz et al., 2016). Recent theoretical developments have advanced the intersectional approach within environmental and climate studies, notably using the intersectional lens to examine the oppressive systems and structures that reinforce social, environmental, and climate injustices (Ducre, 2018; Kaijser & Kronsell, 2014; Tuana, 2023).

An intersectional lens exposes how single-axis thinking undermines struggles for social justice and thus offers a broader understanding of vulnerability to climate change beyond essentialist analyses focused on single social categories (Arora-Jonsson, 2011; Djoudi et al., 2016). In this sense, intersectionality helps theorize climate vulnerability as multidimensional and dependent on historical, socioeconomic, and material conditions that affect the exposure, sensitivity and adaptive capacity of those deemed at risk to climate change (Adger, 2006; Ranganathan & Bratman, 2021; Vickery, 2018). Moreover, a feminist intersectional perspective on vulnerability recognizes that prioritizing the needs of the most vulnerable ultimately benefits society as a whole (Crenshaw, 1989). Recent studies attribute climate vulnerability to the intersection of axes of inequality – such as race, age, disability, and neighborhood affluence – with poor housing conditions and unequal access to coping strategies such as urban green spaces or climate-resilient infrastructures (Allegretto et al., 2022; Baró et al., 2019; Wong et al., 2022). Given that, in this study, we consider as “vulnerable” those who, due to social positions and structural inequalities, are temporarily more exposed and susceptible to and less able to cope with climate threats and intersectional precarity, hence our adoption of the term “intersecting vulnerabilities”.

To help further theorize vulnerability with a particular focus on temperature extremes and its inherent connections with intersecting social positions and structural inequalities, we introduce the concept of intersectional thermal (dis)comfort. We build upon Rodó-Zárate (2022) feminist conceptualizations of “comfort” as embodied emotions derived from experiences of privilege and relief, and “discomfort” as related to oppressed positions in power structures, which (re)produce social relations of inequality. We expand Rodó-Zárate’s notion of (dis)comfort by considering thermal (dis)comfort as the relation between embodied experiences of heat and cold, household and socioeconomic conditions, and access to refuge spaces. This approach contributes to ongoing discourses on the connections between embodied intersectionalities of emotions and lived experiences (in this instance, thermal (dis)comforts), sociopolitical differences (such as gender, class, and migrant status) and

spatialities (in our case, access to climate shelters) (Sultana, 2020), and their broader implications for climate justice in cities.

An intersectional lens enables climate justice approaches to analyze the differential impacts of climate change (and the responses to those impacts), addressing the resulting injustices in more equitable ways (Amorim-Maia et al., 2022; Mikulewicz et al., 2023; Sultana, 2022). In the absence of a universally-accepted definition of climate justice, we apply Schlosberg's (2001) three-pillared framework of environmental and ecological justice – distributive, procedural, and recognitional – to a climate change context to theorize which groups benefit, participate, and are recognized (or not) in climate-adaptive interventions. In urban adaptation, distributive justice is concerned with the distribution of material and social benefits and costs of adaptation responses; procedural justice relates to the fair inclusion of different voices, values, and needs in adaptation decision-making; and recognitional justice pertains to the legitimization of diverse social and cultural identities in adaptation processes and its outcomes (Chu & Michael, 2019a; Mohtat & Khirfan, 2021). While we acknowledge recent scholarly calls to expand the scope of justice towards abolitionist, postcolonial, and emancipatory approaches (Anguelovski et al., 2020; Ranganathan & Bratman, 2021; Robin & Castán Broto, 2020), we hold to the foundational three pillars as they help to analyze the distributive, accessibility, and inclusivity issues encountered by marginalized populations in relation to climate shelters in Barcelona.

To carry out this analysis, we consider climate shelters as critical urban built infrastructures meant to protect populations who are vulnerable to extreme temperatures. Critical urban built infrastructures are comprised of human-made networks, systems, and everyday spaces that produce and deliver services that are essential for protection, safety, and basic comfort in cities (Hendricks & Van Zandt, 2021). They shape and are shaped by urban landscapes, as well as by historical processes of power, control and access (e.g., segregation, racial zoning, gender division of labor), inequitably providing environmental protection for some while exacerbating hazards and vulnerabilities for others (Steele & Legacy, 2017). Thus, the distribution and accessibility of critical urban infrastructures have acute distributional effects on environmental conditions, public health, and community vulnerability (Hendricks & Van Zandt, 2021; Steele & Legacy, 2017). In this study, we use an intersectional lens to empirically observe and theoretically reflect on the climate justice outcomes (i.e., distributive, recognitional) of one form of adaptive urban infrastructure (i.e., climate shelters) for a community deemed vulnerable to climate change in Barcelona.

3. Methods

This study employed mixed methods and citizen science approaches, integrating archival analysis, a focus group, a neighborhood-level survey, and interviews. Adopting an intersectional perspective, we examined the interplay between historical evidence, lived experiences, and quantitative data, considering various social identities and positions to understand intersecting vulnerabilities in La Prosperitat, a neighborhood in Barcelona's Nou Barris district. We followed feminist approaches by centering the voices of marginalized residents and prioritizing their everyday lived, private, and embodied experiences to capture unique forms of vulnerability through a combination of research methods.

From January 2021 to April 2022, we conducted archival analysis at the Historical Archive of Roquetes-Nou Barris and virtual searches of the municipal archive of Nou Barris and the City Council's websites. This research aimed to provide a historical overview of the development of the neighborhood, contextualize the case study analysis, and inform the survey. The list of inspected documents and books can be found in Appendix 1.

We then designed a needs assessment survey with 36 questions to understand residents' lived experiences, perceptions, and needs related to climate change, particularly heatwaves and episodes of extreme cold.

Questions were guided by prior climate change-related surveys by global organizations and research institutions (e.g., Carmin et al., 2012; University of Oxford & UNDP, 2021), adapted to the realities of the neighborhood, and informed by community input and feedback. To this end, in February 2021, we conducted a focus group with ten women residents of La Prosperitat, employing citizen science principles and a feminist perspective to collaboratively design the survey in ways that resonated with their everyday realities (Listerborn, 2008).

Specifically, the survey aimed to understand residents' (1) self-reported experience of extreme heat and cold; (2) use of cooling and warming refuges – both indoor and outdoor; (3) awareness of the "Climate Shelter" network; (4) use of municipal Climate Shelters; (5) ideal Climate Shelter characteristics; (6) climate change concerns; (7) current and future climate change impacts; (8) support of climate policies; (9) availability of home cooling/heating systems; (10) demographic information; and (11) experience with discrimination. Survey questions are available in Appendix 2. Section 5 of the survey aimed to gain insight into how residents' ideal climate shelter would integrate into the urban fabric – from the physical space, including outdoor greenspace characteristics like ventilation and shading, to further benefits that these spaces could provide, such as socioeconomic and care-related activities. With multiple choice and open-ended questions, this section was a central aspect of the citizen science approach. In section 11, we were interested in learning about how participants' experiences of discrimination related to other potential intersecting vulnerabilities. To gauge that, we asked whether and how often participants felt that they were treated unfairly due to their gender/sex, country of origin or habitual previous residency, age, race/ethnicity/skin color, religion, or sexuality.

Our survey included adult residents (18+) of La Prosperitat, and sampling strategy relied on a preliminary demographic study to identify the main socioeconomic characteristics of the neighborhood. Table 1 shows the relationship between key demographic indicators reported in municipal sources and those reported by the population included in the survey. We attempted to survey participants in ways that closely represented the composition of the neighborhood while acknowledging limitations. Following this goal of representativeness, we strived to include a diversity of participants across genders, countries of origin, age, and education.

We surveyed a total of 380 adult residents of La Prosperitat from February to May 2022, aiming for a sampling confidence level of 95% and a margin of error of 5% for the neighborhood's adult population. The survey was conducted in Spanish (314), Catalan (65), and English (1), and collected both in person (220) and online (160) using Kobo-Toolbox. Online surveys were recruited through community associations and networks, while in-person surveys were collected on tablets by a team of six individuals. The collection area was identified in collaboration with local partners and included three focal points in the neighborhood (Plaça Àngel Pestaña, Plaça de les Treballadores i Treballadors de la Harry Walker, and Plaça de la Zona Verda de La Prosperitat) along with a one-block radius surrounding those points (Fig. 1).

Table 1

Key demographic data for La Prosperitat showing categories reported by municipal sources (total and percentage) and those reported by our survey participants (percentage). Source: Barcelona City Council Statistics Department, 2022, and survey data.

Category		Total	Percentage	Surveyed
Gender	Female	14,357	53%	62%
	Male	12,646	47%	35%
Country of origin	Spain	20,215	75%	75%
	Foreigners	6,788	25%	23%
Age	18–50	11,044	48%	53%
	50+	12,025	52%	47%
Education	No univ. degree	19,520	85%	64%
	University degree	3,149	14%	31%



Fig. 1. Survey anchor points in La Prosperitat. Source: Google Earth (2020) Scale: 300 m. Perimeter and markers: author.

We conducted thirty surveys at the local senior's social center to ensure representation of older residents who had reduced presence in the streets. In addition, we placed posters with QR codes pointing to the online versions of the survey in strategic locations in the neighborhood (e.g., bus stops, street poles, shop entrances), distributed flyers with the QR code, and organized four events to collect responses. Participants provided informed consent, and the study received ethics approval from our university's ethics board.

We analyzed survey results using descriptive statistics, bivariate analysis, and multivariate logistic regression modeling in R (version 4.2.1). All models were adjusted for gender, age, region of origin, level of education and income, and set statistical significance at p -value < 0.05 . We applied an intersectional approach to the interpretation of our results, considering the associations and relationships found between different demographic variables and outcomes as indicators of intersecting social inequalities. Acknowledging that there is no commonly agreed quantitative method for empirically analyzing intersectionality that captures the intricacies of the theory (Guan et al., 2021), we interpret our results as proxies for social and historical systems of power and oppression. We then apply mixed methods to move beyond proxies and contextualize our results within broader structures and power relations that create intersecting vulnerabilities. Even though survey questions tracked various categories for the variables above, those were dichotomized to form binary variables to facilitate statistical analyses. Region of origin was dichotomized into Global North and Global South following IMF's "advanced economies grouping" and "emerging and developing economies" respectively, as well as aid flows, as suggested by Hickel et al. (2022). We also draw on recent studies which highlight how immigrant status intersects with structural racism and day-to-day discrimination (Viruell-Fuentes et al., 2012) to constitute a category of continued vulnerability over time in Europe (Hemminki, 2014) and Barcelona, particularly in poorer districts such as Nou Barris (Anguelovski et al., 2018). Level of income was dichotomized into "high" for residents who reported living comfortably and "low" for residents who

reported finding it hard to make ends meet or having just enough to survive. Questions about climate change concerns and impact perception were assessed using a 5-point Likert scale and were also dichotomized to compare "positive" to "negative" responses. Probabilities were calculated based on logistic regression results for statistically significant responses.

Lastly, we conducted six semi-structured interviews with emblematic local actors, including neighborhood association members and participants in social movements, as well as four informal conversations with climate shelter staff (library and civic center workers). The objective of these interviews was not to provide a parallel source of qualitative data but to provide contextual information and triangulate survey findings through oral histories and lived experiences. They also allowed us to gather additional targeted information from key residents with deep knowledge of the neighborhood and stakeholders familiar with climate shelters and the policies that underpin them. Interviews with residents focused on socioeconomic and environmental struggles, while conversations with climate shelter staff covered protocols, preparedness, and personnel matters.

Methodological limitations include potential interviewer bias or misrepresentation due to most in-person surveys being conducted by foreigners (all of whom spoke fluent Spanish and/or Catalan). Online surveys may have led to non-response of selection bias, omitting populations who do not have or feel comfortable using electronic devices. Some level of spectrum bias was also present with an overrepresentation of women and individuals with a university degree. Moreover, the study did not account for the length of time immigrants from Global South countries have been in Barcelona, limiting understanding of their changing socioeconomic background and vulnerability, although gathering such data would also involve its own set of assumptions and generalizations (e.g., about time of residence, integration, and vulnerability). Despite these limitations, as we seek an intersectional feminist approach, we still believe that our results present a reliable and representative portrayal of local needs and preferences.

3.1. La Prosperitat, Barcelona, a neighborhood at the center of climate vulnerability

Barcelona is a densely populated Mediterranean city with a historic lack of accessible greenspaces, particularly in centrally located areas (Barcelona, 2020). In 2022, the city experienced its hottest summer on record, with an average temperature of 28.2 °C (+3.9 °C compared to the 1961–1990 average) and exceptional heatwaves that started earlier, ended later, and lasted longer through the year compared to historical trends (Meteocat, 2022a, 2022b, 2022c). Extraordinary heatwaves are expected to increase in frequency, duration, and intensity (Altava-Ortiz & Barrera-Escoda, 2020; Meteocat, 2023). Vulnerability assessments indicate that the central district of Ciutat Vella and the peripheral district of Nou Barris, where La Prosperitat is situated, are among the most vulnerable areas to climate change, due to socioeconomic factors, limited access to greenspaces, and old, energy-demanding buildings (Barcelona Regional, 2017; IERMB, 2022). Fig. 2 illustrates the climate change vulnerability index for Barcelona at the census tract level, displaying the high vulnerability of Ciutat Vella (south) and outlining Nou Barris (in blue), and the La Prosperitat neighborhood (in black). The index is on a scale of 0–100, where higher values indicate greater vulnerability.

Barcelona is acutely affected by extreme heat during the summer but also episodes of extreme cold during the winter. In both cases, marginalized populations struggle the most to maintain comfortable temperatures in their homes and afford cooling/heating bills. Limited access to refuge spaces further compounds the issue. A report by Barcelona’s Public Health Agency revealed that 11.1% of the population cannot

afford to maintain adequate temperatures during warm months and 9.4% during cold months, although cold weather has a greater impact on mortality than heat (Mari-Dell’Olmo et al., 2022). Women, seniors, and residents originally from Global South countries are particularly affected; and low-income neighborhoods present a high percentage of residents without heating/cooling systems or the ability to use them when needed (Mari-Dell’Olmo et al., 2022).

In 2019, Barcelona established a network of “Climate Shelters” with the aim to provide thermal comfort to vulnerable groups. This initiative repurposes existing public facilities to not only serve their usual functions and services but also provide spaces of refuge from extreme temperatures. Barcelona’s Climate Shelters include specially-conditioned indoor facilities (such as public libraries, civic centers, and schools) but also a wide network of green infrastructures with sufficient greenery, shade, water resources, and resting areas (Barcelona, 2021c). Thus, climate shelters are tightly woven into (yet not limited to) the notion of increasing urban greening in the city (Barcelona, 2021b). Recently, the city expanded the scope of the program beyond heat refuges to use some of the spaces (indoor facilities, particularly) as refuge from cold spells – acknowledging that residents’ vulnerabilities are not only related to heat but also cold. As of Spring 2023, the City of Barcelona has a total of 202 Climate Shelters, covering 95% of the population with a shelter within 10 min on foot from their homes. Additionally, the Metropolitan Area of Barcelona (AMB) has 43 Climate Shelters in seven other cities, as part of its 2018–2030 Climate Change Adaptation Plan (AMB, 2018). Besides climate shelters, Barcelona has other measures in place to address high temperatures such as the Action Plan to Prevent the Effects of Heatwaves on Health (ASPCAT, 2022); a new plan to increase the

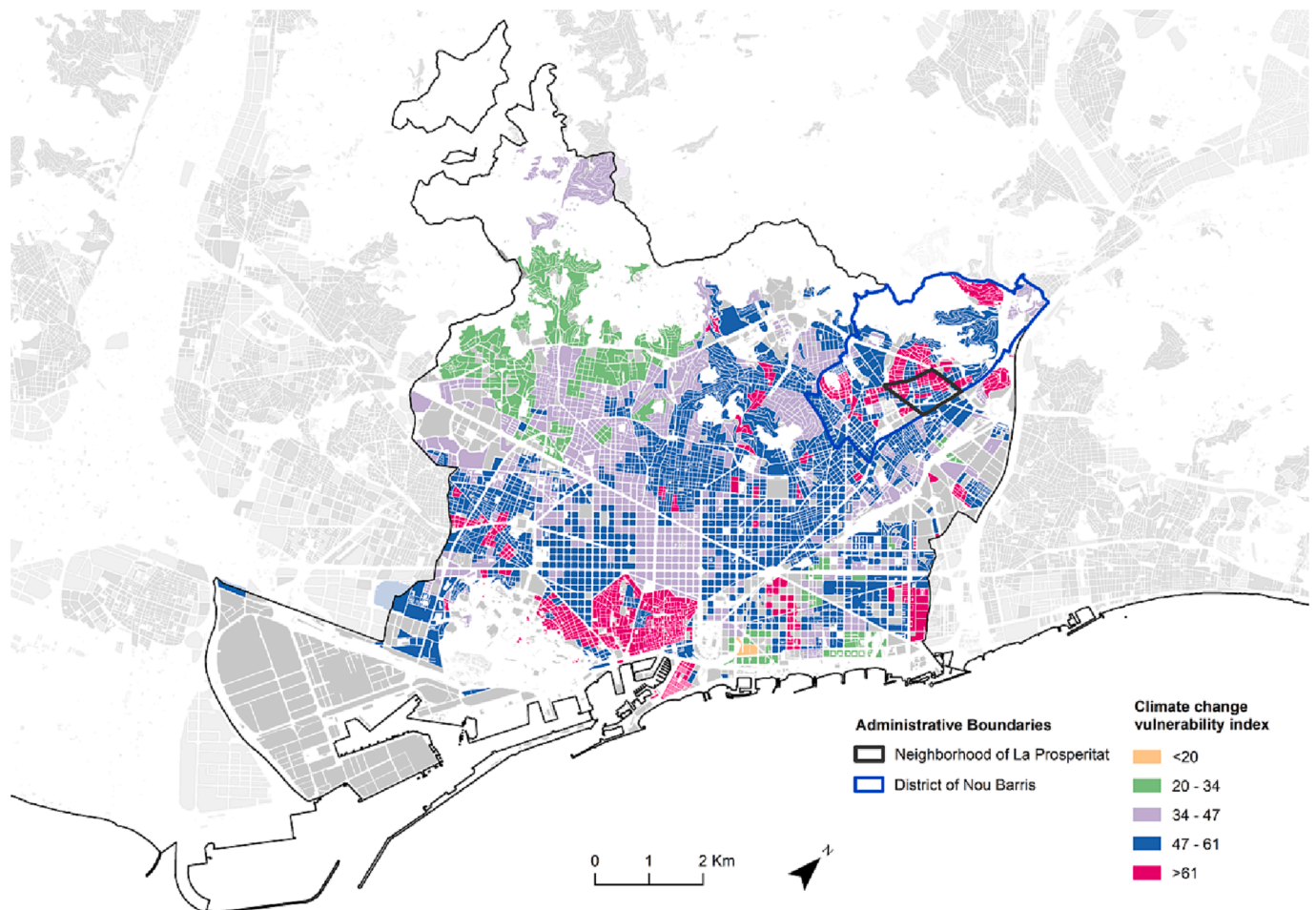


Fig. 2. Barcelona climate change vulnerability index. Source: Garcia-Sierra, M. and Domene, E. (2022). Heat in the future: Climate change vulnerability index (IVAC). Bellaterra, Barcelona Institute of Regional and Metropolitan Studies.

amount of shade in public spaces; a mobile application to locate and track public drinking fountains; and the Energy Advice Points, which offer information and technical advice to support the energy rehabilitation of homes and guarantee universal access to electricity.

La Prosperitat, located in the northeastern part of Barcelona (see Fig. 2) is a densely populated working-class neighborhood (444 people/hectare) with a history of underservice and limited infrastructure access. As of 2023, it has a diverse population of around 27,000 inhabitants, comprised of historically marginalized yet strongly mobilized residents. One quarter of residents come from abroad, with significantly more immigrants from middle/low-income countries (such as Honduras, Armenia, Ecuador, Peru, and Romania) and significantly fewer immigrants from high-income countries (such as Sweden, Switzerland, Belgium, the USA, and UK) than the Barcelona average (Barcelona, 2022b). It is a socially and culturally active neighborhood, with most activity congregating at the civic center, *Casal de Barri La Prosperitat*. Other noteworthy facilities include the neighborhood association, youth center, and a senior's daycare center. In comparison with Barcelona demographic indicators, La Prosperitat has a low percentage of people with a university degree (13% vs. 33% for Barcelona) and a high percentage of older people (65+) living alone (55% vs. 44% for Barcelona) (Barcelona, 2022a). Of particular interest is also the female profile of

unemployment (55%) and precarious employment, with a notable presence of young people, foreigners, and workers with little academic qualification undertaking part-time jobs and temporary contracts. The surface area of the homes is lower than the city average, the housing density is higher, and the buildings are on average 49.5 years old (Barcelona, 2021a). The topography of the neighborhood is marked by narrow streets and a lack of buildable lots and green spaces. There are no climate shelters in La Prosperitat. To access green or less densely urbanized areas, residents need to go to adjacent neighborhoods, where access can be hindered by the local hilly topography.

Our archival and secondary data analysis revealed recent urbanization and infrastructural developments in La Prosperitat. The neighborhood emerged in the 1920 s, through the settlement of migrants from southern Spain, who constructed informal settlements and barracks in an area lacking basic street and housing infrastructure. Throughout the decades, the neighborhood continued to grow through self-construction, unaccompanied by sufficient facilities or public services, thus remaining largely unserved and poorly connected with the rest of the city. Throughout most of La Prosperitat's history, neighborhood mobilizations played a crucial role in obtaining infrastructure and service improvements to meet the needs of the growing community (Abeyà, 2019; Barcelona, 2019). This historical context is crucial for understanding the



Fig. 3. Key land features. Clockwise: Plaza Angel Pestaña, the central square in La Prosperitat, with the civic center at the back; Plaza de la Zona Verda; Plaza de les Treballadores y Treballadors de la Harry Walker; Sant Francesc Xavier Street, on the southwest flank of the central square. Photos by the author.

roots of the social and cultural strengths of the neighborhood, which has a cohesive associative fabric still vibrant today. Fig. 3 shows the main squares and a typical street in La Prosperitat.

4. Results

4.1. Intersecting experiences of discrimination and unfair treatment

According to our survey analysis, the historic marginalization of the neighborhood is expressed today through feelings of discrimination reported by residents. Those who reported being most discriminated against were Global South and low-income residents, particularly due to their country of origin ($p < 0.001$; 0.004), skin color ($p < 0.001$; 0.012), and religion ($p = 0.003$; 0.048), respectively. Women reported higher rates of unfair treatment based on gender ($p < 0.001$) compared to men. Open-ended responses highlighted unfair treatment related to accent, physical appearance, and disability. Notably, Nou Barris (the district where La Prosperitat is located) has the highest rate of people with disabilities in the city (10,3 %). This experience of unfair treatment reported mainly by Global South, low-income, and women residents highlights the intersecting nature of social identities and positions in La Prosperitat, which overlap to create different experiences of discrimination and marginalization in the neighborhood.

4.2. Lived experiences of extreme heat and cold at home

The historic and discriminatory trend is superposed to an overall poor access to climate regulating mechanisms and the role that social differences play in how extreme climate conditions are managed in La Prosperitat. Fig. 4 shows the frequency with which homes were reported to be too hot or cold to stay inside during recent events of extreme heat/cold and usage of heat/cold refuges. Responses suggest that most houses are ill-prepared to handle extreme heat at least some of the time. In terms of usage of heat refuges by population, immigrants from the Global South were more likely to use open green spaces ($p = 0.017$), and less likely to use indoor spaces with air conditioning ($p = 0.042$) than Global North residents. Women were more likely than men to stay at home ($p = 0.032$). Open-ended questions revealed that residents generally also go to the beach (the nearest being 6 km away), the swimming pool (at Can Dragó Sports Center, 750 m away from the Square Àngel Pestaña), and to the mountains to seek refuge from extreme heat. Seven people also mentioned going to bar and café terraces, as they offer shade and refreshments.

A large majority of residents also reported experiencing extreme cold at home (see Fig. 4). Our analysis revealed that low-income residents and those from the Global South experience colder conditions compared to high-income ($p = 0.014$) and Global North neighbors ($p = 0.034$),

highlighting inequalities in home insulation and energy poverty faced by these groups. Residents originally from the Global South were significantly less likely to use indoor spaces for protection from the cold compared to those from Global North countries ($p = 0.040$). Open-ended questions indicated that bars and cafes are also used as refuges from cold weather, pointing to the important role that these spaces play for socialization and even public health in the neighborhood.

Regarding heating and cooling systems, half of the surveyed residents have air conditioning, but low-income residents are less likely to have it than high-income residents ($p = 0.012$). Global South ($p = 0.029$) and low-income residents ($p < 0.001$) are half as likely to have heating systems at home (i.e., heat pumps and central heating) compared to Global North and high-income residents. Low-income residents are also more likely to have no heating or cooling systems at all compared to high-income residents ($p = 0.031$).

4.3. Experience and perception of climate change impacts

The conditions reported above occur within the context of a neighborhood where residents already feel the impacts of climate change in their daily lives, mainly in terms of higher cooling and heating bills and increased food costs. Survey results and interviews revealed that residents expect these conditions to worsen in the future. Women and low-income residents are particularly affected by current climate hazards, and women express greater concern about future impacts. Women are three times more likely to be impacted by rising food prices ($p = 0.002$) and twice as likely to experience increased health effects and diseases compared to men ($p < 0.001$). They also express more apprehension about potential damage to their homes ($p < 0.001$). Low-income residents, especially younger individuals ($p = 0.001$), are more likely to consider relocating due to housing inadequacy. From an intersectional perspective, people who identified as women *and* low-income were significantly more affected by climate impacts, particularly related to the cost of living (e.g., heating bills, food prices) and health issues. Table 2 shows the differences by gender, region of origin, and income level for current climate impacts.

In terms of governmental policy support, residents in La Prosperitat prioritize: (1) the creation of more public green spaces, (2) increased investment in wildfire prevention, and (3) improved energy efficiency of houses and buildings. Women show higher levels of support than men across all categories. Other than gender, no group showed relevant statistical differences for climate policy support.

4.4. Awareness and use of public refuge spaces

Reflective of the lack of climate shelters in the neighborhood, most survey respondents (85%) were unaware of the municipal climate

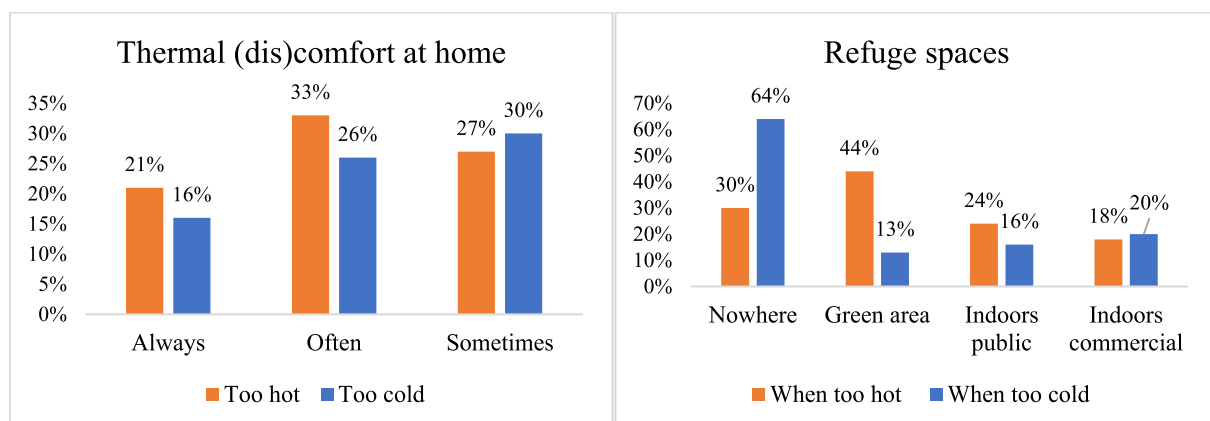


Fig. 4. Frequency of thermal (dis)comforts experienced at home due to extreme heat and cold and used spaces of refuge from extreme heat and cold.

Table 2

Climate impacts reported by La Prosperitat residents with frequencies, odds ratio coefficients, confidence intervals and p-values from the logistic regression models for the responses that presented statistical significance.

Climate Change Impact	Frequency	Group	Coef.	95% CI	P-value
Higher cooling bills	F: 201; M: 105	Gender	3.13	(1.28, 8.04)	p = 0.014
Higher heating bills	L: 196; H: 80	Income	0.36	(0.17, 0.75)	p = 0.006
	F: 201; M: 107	Gender	2.62	(1.02, 6.97)	p = 0.047
More expensive food	F: 199; M: 103	Gender	3.32	(1.56, 7.30)	p = 0.002
Increased health effects and diseases	F: 173; M: 77	Gender	2.83	(1.65, 4.89)	p < 0.001
	L: 163; H: 62	Income	0.57	(0.33, 0.10)	p = 0.048
Increased risk of heat injuries	N: 177; S: 42	Region	2.00	(0.43, 3.70)	p = 0.027
	F: 183; M: 98	Gender	2.04	(1.01, 4.14)	p = 0.046
Damage to home	N: 251; S: 63	Region	2.58	(1.40, 4.87)	p = 0.028
	F: 152; M: 71	Gender	2.78	(1.58, 4.92)	p < 0.001
Damage to infrastructures	F: 134; M: 64	Gender	1.85	(1.12, 3.05)	p = 0.016
Relocations or considerations on moving house	L: 99; H: 68	Income	0.40	(0.23, 0.68)	p = 0.001

Legend: F = Female; M = Male; N = Global North; S = Global South; L = Low-income; H = High-income.

shelter network. Residents originally from the Global North were seven times more likely to be aware of the program than those from the Global South ($p = 0.005$). Immigrant women and individuals with lower academic qualifications were particularly less likely to know about the network. After being provided with information about the climate shelter network and its nearby locations, 81% of surveyed individuals reported never having used a climate shelter for protection from extreme weather. Despite that, 75% of respondents had used the shelters for other purposes, such as recreation, indicating that these spaces are known and used by residents in general. Furthermore, 59% reported that they would use a climate shelter in the future to seek protection from extreme weather. Younger residents ($p < 0.001$), those with a university degree ($p = 0.012$), and low-income individuals ($p = 0.028$) were more likely to consider using the shelters compared to their counterparts.

4.5. Ideal climate shelter

Based on residents' elected priorities, the ideal climate shelter for La Prosperitat is deeply connected to the greenspace network of the city. It is a mostly outdoor space that provides access to nature and protection from extreme heat and cold through natural thermal comfort and shading designs (e.g., vegetation, water). It would also serve as a venue for recreational, cultural, and social activities to be enjoyed with family and friends. Fig. 5 shows a graphic representation of the "Ideal Climate Shelter" for La Prosperitat, prepared by a prominent member of the neighborhood association and civic center and based on the neighbors' needs and envisioned characteristics expressed by survey participants. The percentages indicate the proportion of individuals who selected a particular option out of all of those who responded to that question. Participants could choose multiple options per question. Colors represent responses to the same question.

While there was a general preference for outdoor spaces, women were more inclined than men to prefer indoor spaces ($p = 0.045$). Women also expressed a preference for using these spaces with family members ($p = 0.048$), especially younger women, whereas men, particularly from the Global North, were more likely to go with colleagues ($p = 0.001$). Open-ended responses commonly mentioned the desire for water features such as fountains, sprinklers, and pools, as well as spaces for sports and urban gardens.

Survey results did not address the spatial distribution of ideal climate shelters, which is particularly challenging in densely urbanized neighborhoods with limited available undeveloped or green spaces. Thus, the location and distribution of climate shelters in neighborhoods like La Prosperitat is a matter worth exploring in future research, as it would require more creative and resourceful approaches. This could involve utilizing existing privately owned or community-operated spaces that meet the criteria of climate shelters, such as community centers, sports centers, schools, food and beverage outlets, and local urban gardens. Moreover, the neighborhood could benefit from tactical urbanism

initiatives in public spaces, such as planter boxes, benches, and gazebos, to create mini-refuges in harder-to-reach locations.

4.6. Continued processes of socio-ecological improvements

Interviews with key stakeholders elicited important themes regarding past and present neighborhood mobilizations in La Prosperitat to combat intersecting social and environmental injustices. These mobilizations have been historically intersectional, with various movements (e.g., housing, labor, anti-fascist) coalescing around the neighborhood association to advocate for improved living conditions for all residents, often led by women. Residents especially highlighted the historic struggle for clean water (driven primarily by women over the decades) and a remarkable 62-day strike for workers' rights at the Harry Walker factory, which mobilized the entire neighborhood in 1970. They also spoke about the fight against polluting industries, including a chemical plant which was shut down following local complaints of contamination and an asphalt plant which was forced to close after strong neighborhood mobilizations, and which was later transformed into a community-run sociocultural center (*Ateneo Popular 9 Barris*). Interviewees also emphasized the demand for green areas, including years of struggle to open the first "Green Zone of La Prosperitat", where residents blocked the construction of a condominium by camping on site, and the opening of the central square, Àngel Pestaña, in 1986, following 10 years of neighborhood mobilization to turn an area occupied by shacks into a community square. As the president of the association of elderly residents of La Prosperitat puts it, "we had to start from scratch. Schools, squares, green areas, nurseries... we had nothing, nothing. And everything was conquered through neighborhood struggles, with solidarity". Her words are complemented by those of a neighborhood historian, "I would say that every square in the neighborhood has been the product of a struggle. There was no free square, not one. In fact, almost all the services and infrastructures were products of struggles. They didn't give us anything".

Current demands include more green spaces and shade, a new public complex for a library, an auditorium, and a new space for the youth center. The historic movements and contemporary demands of La Prosperitat residents emphasize opportunities for climate shelters to address intersecting social-ecological needs (beyond protection from extreme heat), including more access to nature, and community spaces to conduct recreational and cultural activities. Moreover, despite the lack of climate shelters in the neighborhood, interviewees pointed to the resourceful usage of existing infrastructures and facilities as refuge. As the president of the Center for Popular Studies and Historical Archive of Roquetes-Nou Barris explains, "People already use many spaces as climate shelters, without knowing the name, 'shelter'. But they already use them, of course they do. If you want to know where the climate shelters are, you just need to follow the path of the *yayos* (grandparents)".

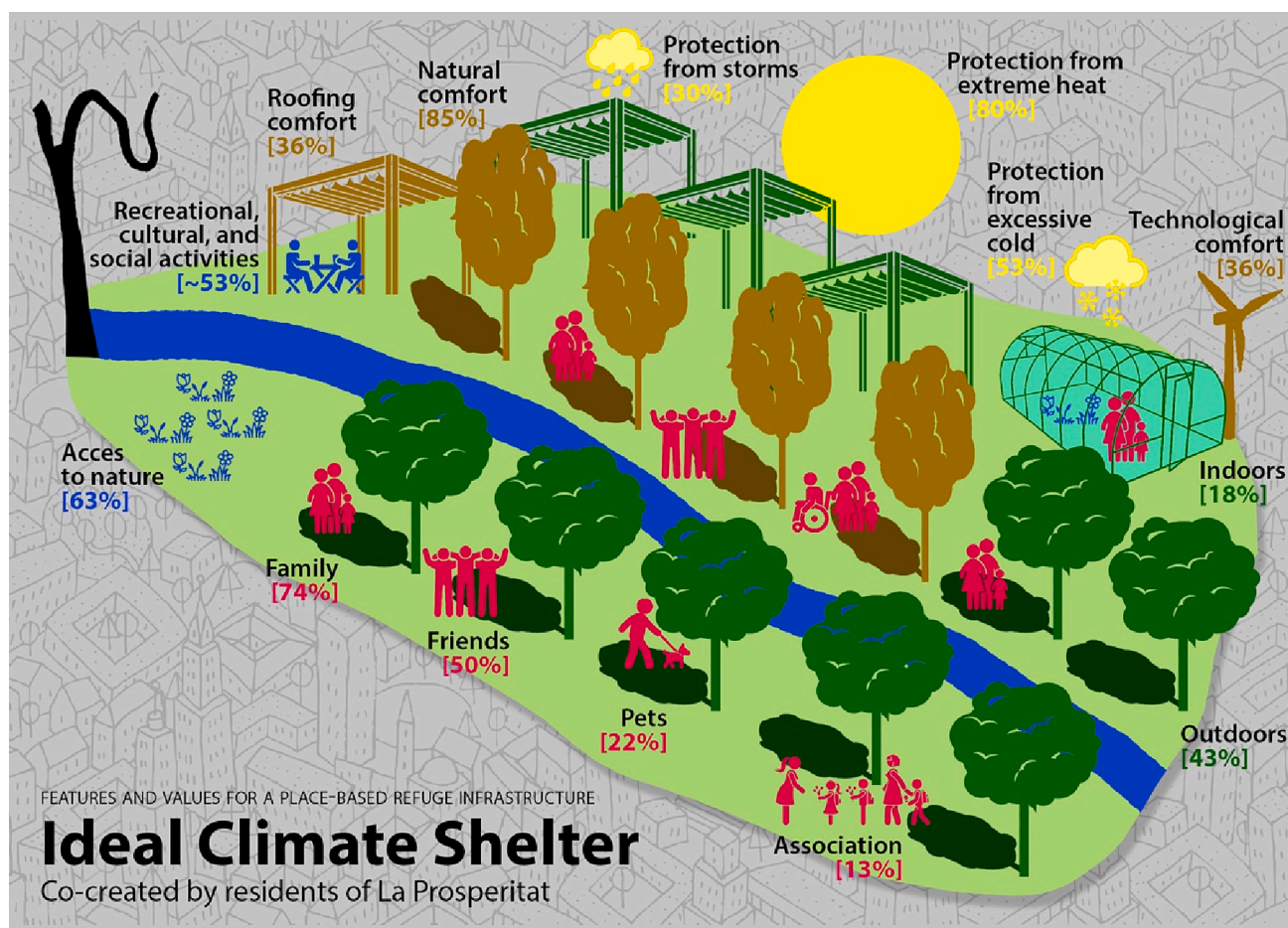


Fig. 5. Ideal Climate Shelter as per residents of La Prosperitat. Prepared by Roger Costa Puyal, member of the Neighborhood Association of La Prosperitat and Casal de Barri La Prosperitat, based on survey responses.

Finally, responses from the climate shelter staff evoked important considerations about the commitment to the program but lack of training and protocols. In nearby libraries and civic centers, staff reported that facilities had been designated as “Climate Shelters” by the City Council based on their existing characteristics, but without substantial investment or staff training to effectively handle potential heat emergencies. For instance, a civic center worker reported having “nothing to offer” for shelter-seekers to spend the time and staff at two libraries reported receiving no protocol, training, or material beyond reusable cups and stickers. Moreover, many shelters had reduced opening hours during the summer holidays of 2021, which coincided with the hottest period of the year. This seems to have been addressed by the summer of 2022 when climate shelters had extended opening hours from June to September as well as clearer protocols in place for staff.

5. Discussion: Addressing heat and cold inequalities with critical urban infrastructures

This study analyzed experiences of thermal (dis)comfort – or the unequal lived experiences of heat and cold – as well as climate risk perceptions, needs, and expectations of a community deemed vulnerable to climate change (La Prosperitat), using an intersectional climate justice lens and a citizen science approach. The analysis revealed how different social identities and positions influence residents’ adaptive capacity and informed the extent to which existing adaptive urban infrastructures address intersecting vulnerabilities.

Thermal (dis)comforts in La Prosperitat disproportionately affected women, low-income residents, and immigrants from Global South

countries. Our intersectional analysis attributed these thermal (dis) comforts to structural vulnerabilities related to housing precariousness and energy poverty and compounded by the effective unavailability (until recently) of adaptive built infrastructures – i.e., indoor and outdoor climate shelters – in the neighborhood. Our findings underscored the critical role of the city’s greenspace network in addressing the needs of those most affected by thermal (dis)comforts. The high number of elderly residents living alone compounded by the findings that a third of respondents – particularly women – prefer not to leave their homes in case of extreme heat and that women are especially impacted by rising costs of living show how vulnerability in La Prosperitat is the result of intersecting social and economic factors. In fact, research shows that risk of death due to extreme heat is higher among women and older adults in Barcelona (Ingole et al., 2020) and among residents of areas with little green space (Xu et al., 2013), which is the case in La Prosperitat. Notwithstanding, our results also point to cold (dis)comforts experienced mostly by low-income and immigrant residents, with two-thirds of residents preferring not to go anywhere in case of extreme cold. This is concerning considering that cold temperatures have a greater impact on mortality in Barcelona than warm temperatures (Marí-Del-Olmo et al., 2019, 2022). This is possibly reflected in the historic conditions of Barcelona, which have seldom been faced with extended cold weather. Thus, because it was not a necessity, lower income households did not account for cold, but higher income households did as a matter of accessing higher degrees of comfort. This may point toward an important strand of thinking for climate shelters in cities wherein those with intersecting vulnerabilities are especially disadvantaged when it comes to conditions that shift from being questions of

(dis)comfort to questions of basic wellbeing and survival that have long remained invisible. This underlines the need to invest in home retrofitting and energy efficiency incentive programs to prevent disadvantaged residents from being further isolated if refuges are inaccessible or do not respond to their intersecting needs and vulnerabilities. While Barcelona is supporting associations of neighbors in their application to EU Next Generation funds for energy-retrofit and solar panel programs, the administrative burden and time commitment of such applications tends to discourage people from applying.

We also unveiled unequal patterns of usage and accessibility of existing refuge infrastructures, with certain populations, especially immigrants from the Global South, being less aware of and/or willing to use these spaces compared to others. We relate that difference to inadequate promotion, unequal distribution, and insufficient accessibility, including in terms of cultural appropriateness, of climate shelters for La Prosperitat residents. In Barcelona, immigrant groups have been less vocal, recognized, or formally organized than working-class Spanish residents, which could explain a possible reduced sense of belonging and participation in certain contexts and settings (Kotsila et al., 2021; Oscilowicz et al., 2020). Municipal documents also acknowledge the limited participation of residents from diverse origins and cultures in the organized community fabric of La Prosperitat (Barcelona, 2021a). This finding more broadly reveals the presence of social divides in people's accessibility and familiarization with refuge infrastructures, suggesting that the mere presence of a climate shelter may not do much for those with entrenched intersecting vulnerabilities. These groups require much more specific, regular, and culturally- or socially-adapted engagement in the context of a new adaptation program like a climate shelter.

Our results illustrate patterns of intersecting climate vulnerabilities with important implications for the different dimensions of climate justice (Chu & Michael, 2019b; Schlosberg, 2001). In terms of distributive justice, the unequal allocation of climate shelters and uneven patterns of usage across social tracts suggest that these spaces may not be reachable or welcoming enough to groups facing intersecting vulnerabilities. With respect to recognitional justice, our study brings attention to feminist epistemologies through, for instance, embodied knowledges that translate awareness of environmental and climate changes (i.e., thermal (dis)comforts) and everyday experiences of climate impact and vulnerability (Chu & Michael, 2019b; Fricker, 2017; Hamstead, 2023). Moreover, the significant socioeconomic and gendered differences in perception of climate risk, experience of impact, and policy support, compounded by the reported experiences of discrimination against these populations, underscore the importance of considering whose identities, cultural values, and perspectives are prioritized in the design of climate-adaptive infrastructures and to better support those who are often invisibilized and marginalized.

Finally, our empirical results outline a place-based, grassroots proposal for climate shelters to address the intersecting environmental and social needs of historically marginalized residents. As per their stated preferences, these infrastructures of refuge must provide access to nature and protection from extreme heat and cold, while also addressing other social, cultural, and recreational needs. This citizen-science driven exercise responded to recent calls for engaging with the diversity of everyday lives and accommodating multiple forms of knowledge, cultural norms, and identities in urban transformation (Romero-Lankao et al., 2018). Moreover, these findings more broadly contribute to recent discourses on the design of climate-adaptive built environments (Liu et al., 2023), and green infrastructure planning practices focused on inclusion, community consent (Grabowski et al., 2023), and citizens as expert knowledge holders (Anguelovski et al. 2020). Fundamentally, this practice highlighted the importance of facilitating citizen science methods that focus on operationalizing feminist intersectional principles to identify social-ecological needs and co-create place-based solutions to address intersecting climate vulnerabilities.

6. Conclusion

This study aimed to understand how urban communities deemed as climate-vulnerable are experiencing climate change – particularly their lived experiences of thermal (dis)comfort and access to spaces of refuge – in order to evaluate the extent to which climate-adaptive infrastructures simultaneously provide protection from extreme events and address entrenched intersecting vulnerabilities. By applying an intersectional climate justice perspective, we unveiled uneven experiences of thermal (dis)comfort and access to coping mechanisms, with some social groups significantly more impacted than others. Moreover, existing climate shelter infrastructures were found to be ineffective and underutilized by La Prosperitat residents – at least for the purpose of finding refuge from climate extremes. We suggest ways for climate shelters to fulfil the potential to address intersecting vulnerabilities through place-based and community-led approaches. We draw attention to the need for future researchers and city planners to better address the different barriers to accessibility (distributive, recognitional, physical) of climate-adaptive infrastructures and to explore the ways in which their potential benefits can be more inclusively distributed.

Beyond La Prosperitat and Barcelona, our paper highlights a general need for cities to conduct deeper analyses of intersecting vulnerabilities in the delivery of climate-adaptive urban infrastructures, to better understand and tackle the entrenched barriers faced by marginalized populations in adapting to extreme climate. By examining the local dynamics of one city, this case study provides valuable insights into the challenges and opportunities that other early-adopter cities may face in tackling similar issues. Although this case is focused on Barcelona, it highlights how class, gender, and migrant status intersect as compounded characteristics of vulnerability, as shown in prior urban climate justice studies (e.g., Sultana, 2020). The Barcelona case refers to a particular historic, social, and political trajectory of immigration, racialization, and gendered-driven discrimination and vulnerability, but its broader characteristics are reminiscent of other urban contexts of climate vulnerability in global cities.

The study highlights the potential for climate shelters and related infrastructures to address and link up with historic intersecting vulnerabilities by offering culturally-appropriate and welcoming spaces of refuge from extreme temperatures that meet other social needs of vulnerable residents. This shift is necessary to protect the most heat- and cold-vulnerable groups and tackle other intersecting vulnerabilities brought on by inadequate housing conditions, unequal access to spaces of refuge and socioeconomic inequalities. This way, climate-adaptive urban infrastructures can more effectively and strategically address intersecting climate and social vulnerabilities and move cities towards greater climate justice.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.landurbplan.2023.104836>.

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