Equitability of Policies to Address the Urban Heat Island Effect

A Comparison of Portland and Vancouver

Supervised Research Project

In partial fulfillment of the requirements for the Master of Urban Planning degree

School of Urban Planning

Submitted by:

Marie de Froidmont - 261141920

Supervisor:

Madhav Govind Badami

August 2025

Abstract

Urban heat island effects raise temperatures in cities, creating particularly harsh conditions for vulnerable populations. This study compares the approaches of Portland, USA and Vancouver, Canada, in mitigating the urban heat island effect, drawing on a literature review, spatial analysis, critical policy review and a discussion of policy findings. Both cities experienced devastating heatwaves in 2021, which accelerated policy responses and heightened attention to equity.

Spatial analysis revealed inequities in access to green space and cooling infrastructure, with the highest vulnerability found in older, denser and less-vegetated neighborhoods. Policy analysis indicated partial alignment with United Nations guidelines but identified persistent gaps, including limited adoption of materials-based cooling measures, unstable funding and weak integration of cooling requirements into zoning and development codes.

The findings highlight the need for a comprehensive, justice-oriented approach that combines physical cooling interventions with socially inclusive planning and stable, cross-sector governance. Embedding these principles into core urban policy frameworks can reduce heat exposure and help ensure that no community is left behind as cities work to adapt to rising urban temperatures.

Key words: Urban Heat Island, Equity, Sustainability, Climate Change.

Résumé

Les effets d'îlot de chaleur urbain augmentent les températures dans les villes, créant des conditions particulièrement difficiles pour les populations vulnérables. Cette étude compare les approches de Portland (États-Unis) et de Vancouver (Canada) pour atténuer l'effet d'îlot de chaleur urbain, en s'appuyant sur une revue de littérature, une analyse spatiale, une évaluation critique des politiques et une discussion des résultats de cette analyse. Les deux villes ont connu des vagues de chaleur dévastatrices en 2021, ce qui a accéléré les réponses politiques et renforcé l'attention portée à l'équité.

L'analyse spatiale a révélé des inégalités dans l'accès aux espaces verts et aux infrastructures de rafraîchissement, la vulnérabilité la plus élevée se trouvant dans les quartiers plus anciens, plus denses et moins végétalisés. L'analyse des politiques a montré un alignement partiel avec les lignes directrices des Nations Unies, mais a mis en évidence des lacunes persistantes, notamment le faible recours aux mesures de rafraîchissement fondées sur les matériaux, l'instabilité des financements et la faible intégration des exigences de rafraîchissement dans les règlements de zonage et les codes de construction.

Les résultats soulignent la nécessité d'une approche globale et axée sur la justice, combinant des interventions physiques de rafraîchissement avec une planification socialement inclusive et une gouvernance intersectorielle stable. Intégrer ces principes dans les cadres politiques urbains fondamentaux peut réduire l'exposition à la chaleur et garantir qu'aucune communauté ne soit laissée pour compte dans l'adaptation des villes à la hausse des températures urbaines.

Mots-clés : îlot de chaleur urbain, équité, durabilité, changement climatique.

Acknowledgements

Firstly, I would like to thank Professor Madhav Badami for his invaluable guidance, constructive feedback and encouragement throughout this research.

I am also grateful to the faculty, staff and fellow students, whose insight and collaboration have only deepened my passion for urban planning.

My heartfelt thanks go to my family and friends, who have shown me support.

This project has been a meaningful experience for me, both as an academic achievement and as a small step toward addressing important challenges in our cities. It represents my interest in supporting the creation of urban environments that are resilient, inclusive and fair for everyone.

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List of Abbreviations

Abbreviation	Definition
BC	British Columbia
CT	Census Tract
CUHI	Canopy Layer Urban Heat Island
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GHG	Greenhouse Gas
GIS	Geographic Information System
HAPs	Heat Action Plans
HVAC	Heating Ventilation and Air Conditioning
OR	Oregon
OSHA	Occupational Safety and Health Administration
PBEM	Portland Bureau of Emergency Management
PCEF	Portland Clean Energy Fund
PWB	Portland Water Bureau
SUHI	Surface Urban Heat Island
UHI	Urban Heat Island
UN	United Nations
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples

1. Introduction

Climate change is one of the most pressing challenges of our time, with its impacts becoming increasingly severe and widespread. Rising global temperatures and extreme weather events pose significant risks to both natural ecosystems and human societies (Mohajerani et al., 2017). The scientific consensus shows that human activities, particularly the burning of fossil fuels and deforestation, have significantly increased greenhouse gas (GHG) concentrations in the atmosphere, leading to global warming. As a result, the frequency and intensity of extreme weather events (i.e. heatwaves, hurricanes, wildfires and heavy rainfall) have risen dramatically. These changes threaten biodiversity, disrupt agricultural productivity and exacerbate existing social inequalities, disproportionately affecting marginalized communities that have fewer resources to adapt for this change (Mitchell & Chakraborty, 2018).

Urban areas, where most of the global population resides are especially vulnerable to the effects of climate change (Sachindra et al., 2015). Cities are not only hotspots of economic activity but of environmental challenges as well. The dense built environment, high energy consumption and extensive impervious surfaces contribute to temperature increases, intensifying the urban heat island (UHI) effect (Irfeey et al., 2023). This phenomenon where urban areas experience higher temperatures than their rural surroundings, has serious implications for public health and overall urban livability. These risks are particularly more significant for vulnerable populations (i.e. the elderly, low-income communities and individuals with pre-existing health conditions) (Irfeey et al., 2023; UN, 2022). Without proactive mitigation strategies, the growing intensity of heat stress in urban environments will continue to compromise public health, infrastructure stability and overall quality of life.

1.1. *Research Question and Objectives*

The primary research question guiding this study is:

How can cities better integrate UHI mitigation strategies into urban planning and policy frameworks to ensure both effectiveness and equity in addressing UHI impacts?

To answer the question, this report uses two case studies (Vancouver in British Columbia, Canada and Portland in Oregon, USA) and explores whether current policies and interventions in these cities effectively address the needs of all residents, particularly those most vulnerable to extreme heat. It also seeks to assess whether disparities exist in the distribution of cooling infrastructure, green spaces and heat resilience measures across different socio-economic and demographic groups.

To make the analysis more manageable, the study focuses on a limited set of publicly available indicators and selects only a few key policies deemed most relevant to the topic, which will be further discussed later on. It is acknowledged that a more comprehensive assessment would require the inclusion of more policies and indicators to fully capture the complexity of the issue, a recommendation for future research.

This research will focus on the following key objectives:

- Assess the distribution geographically of UHI factors (i.e. green canopy and built environment).
- Examine socio-economic disparities in heat exposure and resilience.
- Evaluate the existing policies in promoting equitable heat resilience.
- Identify best practices and potential areas for improvement.

By integrating these diverse objectives, the study combines empirical spatial analysis with policy review and comparative governance perspectives. This multi-faceted approach not only enables an evaluation of Vancouver and Portland's urban heat challenges and responses but also promotes a replicable method useful to other cities struggling with similar issues.

Basing it on publicly available data from municipal open portals, the study uses the GIS software techniques to link environmental characteristics (e.g. canopy cover, urban density) with vulnerability indicators (income levels, age distribution, disability, renter status). This methodology highlights inequities in exposure and resource allocation and supports evidence-based planning.

Ultimately, this research contributes both to scholarly understanding and practical policymaking by demonstrating how focused data analysis and cross-jurisdictional comparison can inform the development of equitable and effective urban heat mitigation strategies.

1.2. *Relevance of study*

This research is relevant given the escalating impacts of climate change and the increasing population in urban areas worldwide. As more people move to cities, urban areas are becoming focal points of climate vulnerability such as extreme heat events. The UHI effect worsens heat-related risks disproportionately affecting low-income populations, seniors and individuals with pre-existing health conditions who may have limited access to cooling resources (Irfeey et al., 2023; UN, 2022). Ensuring that urban heat mitigation strategies are equitably distributed is therefore essential for promoting climate justice and protecting public health.

Portland and Vancouver were selected as case studies based on different factors. Firstly, both cities have made a lot of improvements in urban sustainability and climate sustainability in the last few years, as shown by new climate action plans, targeted investments in heat mitigation infrastructure and a growing amount of strategic policy documents (Portland – CNCA, n.d.; SmartCitiesWorld, 2024). Secondly, each city has a comparable population size, 615,267 for Portland and 687,933 for Vancouver in 2025 (World Population Review, n.d.), and both share similar climates and urban infrastructure profiles. Importantly, both cities possess sufficient financial and institutional capacity to design and implement large-scale mitigation strategies, ensuring that the analysis focuses on contexts where interventions are plausible and scalable.

Convenience and data accessibility indeed also played a role in the case selection process. However, choosing cities on either side of the Canada and USA border brings valuable comparative insight. Despite the similarity in their sizes and environmental contexts, Portland and Vancouver operate within distinct institutional and cultural settings. This allows the study to examine how “similar” cities may adopt divergent or convergent approaches to UHI mitigation in response to different governance settings and policy environments.

By analyzing policies related to UHI in these cities based on the UN's cooling recommendations for cities, this study will provide insights into the successes and shortcomings of their approaches, offering valuable lessons for other cities aiming to enhance urban resilience related to UHI in an equitable manner. By examining the intersection of UHI mitigation and equity, this study aims to highlight the importance of inclusive and climate policies that leave no community behind. The findings of this research can inform policymakers, urban planners and community organizations on how to develop strategies that are both effective and socially equitable. The urgency of climate action cannot be overstated and it is crucial that solutions not only reduce temperatures but also promote social equity and resilience.

2. Methodology

This study employs a multi-faceted approach, integrating a background and literature review, spatial analysis and a critical policy review to comprehensively assess UHI mitigation strategies in Vancouver and Portland. The insights from the spatial and policy analyses are then used to conduct a policy analysis that evaluates the alignment between existing strategies and the spatial distribution of heat vulnerability. By combining these methods, the study aims to provide a deeper understanding of the factors driving heat exposure and assess the effectiveness and equity of current and potential mitigation measures.

2.1. *Background & Literature review*

The first stage of the study involves an extensive review of existing research on the UHI effect, mitigation strategies and urban resilience. This review establishes a foundational understanding of the issue and helps us to give better insights on this project's research. The main themes to be explored are:

- What causes the UHI effect, including both natural and human-made factors.
- How it affects people and the economy, especially in terms of health impacts.
- Why the impacts are unequal, with a focus on planning decisions and social factors.
- What solutions are currently used, looking at useful technologies, policies and programs.

The literature review provides context for understanding the issue at hand and the various mitigation approaches and identifying best practices that can potentially be applied in cities around the world.

2.2. *Spatial Analysis*

A GIS-based spatial analysis was conducted to evaluate environmental and demographic factors contributing to heat vulnerability in both Portland and Vancouver. This multilayered approach integrates several key components to assess risk distribution and identify priority areas for intervention:

- Heat Vulnerability Mapping: Heat vulnerability was assessed using different indicators, including income levels, age distribution, renter population and the proportion of residents with disabilities. These were found on the cities' respective open data portals.

    - Income levels: Number of residents with incomes below the city's median.
    - Age distribution: Number of residents aged over 65 or under 14.
    - Renter population: Number of residents who are renters.
    - Disability prevalence: Number of residents who report a disability.

    As will be discussed in the Background and Literature Review, these groups are more likely to experience severe impacts during extreme heat events, hence the need to map them out. The indicators were then mapped and combined to generate a vulnerability score for each neighbourhood/CT in Portland and Vancouver. Each indicator was normalized using the formula:

$$\frac{x - min}{95^{th} - min} \times 10$$

    Where x represents the actual value of a given indicator in a specific neighbourhood/CT and min and 95^{th} refer to the minimum and 95^{th} percentile values of that same indicator across the entire city. Each indicator was normalized using the formula above at the neighbourhood/CT level. The 95^{th} percentile was chosen as the upper reference point to reduce the distorting influence of extreme outliers: if the maximum had been used, a very small number of neighbourhoods/CTs with extreme values would dominate the scale and compress the distribution of all others toward the lower end. By anchoring the scale to the 95^{th} percentile instead, areas with high (but not extreme) values remain distinguishable as relatively more vulnerable, rather than appearing artificially close to the city-wide average.

With this approach, most neighbourhoods fall within the 0 to 10 range, while those above the 95^{th} percentile exceed 10. The values above 10 are deliberately retained at the indicator level to highlight the ones with exceptionally high vulnerability. The four normalized indicators are then averaged to produce a composite vulnerability score for each neighbourhood/CT. For purposes of presentation this composite score is rescaled and capped at 10. This rescaling facilitates comparability across neighbourhoods/CTs and simplifies communication.

However, it is important to note the limitations of this approach:

- The choice of the 95^{th} percentile was pragmatic. A stricter definition (e.g., the 90^{th} percentile) or a looser one (e.g., the 99^{th}) would change the relative scaling. This introduces some subjectivity.
- While using the 95^{th} percentile reduces the leverage of extreme values, it does not eliminate it. Outliers above the 95^{th} still stretch the distribution, and when the final composite is rescaled to 0–10, this may slightly compress values for the rest of the neighborhoods.
- By capping the composite at 10, the ability to distinguish between "just above" and "far above" the 95^{th} percentile across multiple indicators is lost. In effect, all neighborhoods with extremely high scores are treated as equally vulnerable. This communicates urgency but also masks variation within the upper tail. Additionally if the sample size is not large enough or the outliers are far off the cap, the mean and median of the scores may not truly represent the distribution of vulnerability, areas with very high vulnerability may appear only moderately different from those just above the threshold, masking the true variation across neighborhoods.
- Since the indicators are based on raw counts rather than proportions, larger neighborhoods with more people may be classified as more vulnerable than smaller neighborhoods with comparatively higher rates of vulnerability.

- Green Space: The spatial distribution of green space was analyzed to identify areas benefitting from natural cooling and those lacking green infrastructure. Green space per capita was calculated by neighbourhood (Portland) or CT (Vancouver) to evaluate whether residents have equitable access to vegetation. This metric was used to assess alignment with international benchmarks, such as the recommended minimum of 9 m² and ideal of 50 m² of green space per person for effective urban cooling (Czesak and Różycka-Czas, 2025; Badiu et al., 2016; Russo and Cirella, 2018). For simplicity, green space was attributed to the neighbourhood/CT in which it is located. It is acknowledged, however, that this approach does not fully account for actual accessibility. Some green spaces located just outside a CT boundary may still be easily accessible to nearby residents, while others within a CT may not be equally accessible to all due to barriers such as road infrastructure, topography or limited entrances. Additionally, while it is expected that denser areas will have less green space per capita, as the number of residents and the proportion of land covered by buildings and infrastructure are both higher, it remains an important indicator because lower availability of green space in these areas can exacerbate heat vulnerability. Even though this pattern is somewhat inherent to urban density, it should not be overlooked or ignored; recognizing it is essential to develop targeted strategies and adaptations that address the specific challenges faced by residents in dense, less green environments. Future research could benefit from incorporating additional metrics and accounting for accessibility barriers to better capture equitable access to green infrastructure.

- Distribution of Cooling Facilities: The location of cooling centers, libraries and other air-conditioned public facilities was mapped with the green space per capita. It still is compared and studied with the vulnerability map to assess whether high-risk populations have adequate access to public cooling resources, highlighting spatial mismatches between need and service provision.

- Urban Density and Built Environment: In Portland, the built environment analysis includes building height, age and density, factors that influence heat retention and airflow. Older and taller buildings in denser urban cores are associated with greater thermal mass and reduced ventilation, exacerbating urban heat island effects. The median height of the buildings per neighbourhood was depicted and was combined by having the building footprints to show when it was built. In Vancouver, due to data limitations, the analysis only examines building age and density by showing the building footprints.

In summary, the spatial analysis demonstrates how to systematically uncover inequities in heat exposure and resource distribution. Even though the data is specific to Portland and Vancouver, the approach itself is replicable in other cities. By showing how environmental factors (green space, urban density) intersect with social factors (income, age, disability, renter status), the analysis becomes a model for identifying priority areas in any urban context. This depth is essential not only for evaluating current policies, but also for illustrating a methodology that policymakers elsewhere can adapt to ensure their UHI mitigation strategies are evidence-based and equity-focused. All data used in this analysis were retrieved from the cities' open data portals (City of Vancouver, n.d.; City of Porland, n.d.).

2.3. *Critical Policy Review*

A comprehensive policy review was conducted for both Portland and Vancouver, drawing from their most recent climate-related strategic documents; Portland's *Emergency Climate Action Plans* and Vancouver's *Climate Change Adaptation Strategy* (City of Portland, 2024; City of Vancouver, 2024a). The review focused on key sectors across different municipal departments, specifically tree planting and landscaping, green infrastructure and buildings, emergency preparedness and energy consumption. These sectors were selected based on their direct or indirect influence on UHI dynamics:

- Tree planting and landscaping play a critical role in mitigating UHI effects by increasing shading and evapotranspiration, which can significantly reduce surface and ambient temperatures in urban areas as will be discussed later.

- Green infrastructure and building design were included due to their potential to reduce heat absorption through reflective surfaces, green roofs, permeable materials and thermally efficient construction. These features not only lower localized temperatures but also reduce dependence on mechanical cooling, which in turn helps limit anthropogenic heat emissions.

- Emergency preparedness was examined for its importance in reducing health risks during extreme heat events, particularly for at-risk groups such as seniors, children, low-income households and renters. Effective preparedness strategies are essential for addressing the high heat exposure and social vulnerability. By ensuring access to cooling centers cities can reduce avoidable heat-related illnesses and fatalities while promoting climate equity in the face of intensifying heat events.

- Finally, other relevant initiatives such as energy consumption were reviewed as a cross-cutting issue. Policies that promote energy efficiency, distributed renewables and passive cooling technologies are crucial to breaking the feedback loop of rising temperatures and growing energy use. By examining how these sectors are addressed in each city's plans, the policy review aims to assess whether strategies are spatially targeted, equity-informed and aligned with current knowledge on urban heat mitigation.

2.4. *Policy Analysis*

The policy analysis builds directly on the findings of the spatial analysis and critical policy review, using those insights as a lens to evaluate the relevance and effectiveness of each city's strategies. This section examined how well the existing policies address the specific spatial patterns of vulnerability and heat exposure identified earlier and whether they align with best practices outlined in the UN's *Sustainable Cooling Handbook for Cities*.

Each policy was evaluated not just on its stated objectives, but on how well it responds to the actual conditions within the city, particularly in neighborhoods/CTs facing higher levels of heat exposure and social vulnerability. Special attention was given to whether policies were equity-driven: for example, whether they explicitly prioritize low-income areas for tree planting, cooling interventions or retrofitting programs. The analysis also assessed the degree of cross-departmental coordination, implementation progress and whether the strategies are spatially targeted or too generalized to address localized UHI risks.

By comparing local plans to the UN's cooling framework, which emphasizes reducing heat at the urban scale, improving building thermal performance and ensuring equitable access to cooling, the analysis determined whether each city's approach is reactive, proactive, or transformational. Ultimately, the policy analysis aims to understand not only what cities are planning, but how strategically and equitably they are doing so in the face of growing heat risks.

By integrating these three methodological approaches, the study provides a comprehensive assessment of the UHI challenges facing Vancouver and Portland, offering evidence-based insights to guide future planning and policy decisions for many cities experiencing the UHI effect.

3. Background and Literature review

3.1. *Urban Heat Island effect*

As cities grow and develop, they replace natural landscapes with impervious surfaces such as asphalt, concrete and buildings, which absorb and retain heat, leading to higher temperatures compared to their surroundings (Mohajerani et al., 2017). This temperature disparity creates what is known as an urban heat island, where urban areas are most of the times warmer. Even smaller towns and cities exhibit the UHI effect and the severity of it is should not only be based on the size of the city, as it can be misleading (Brabant et al., 2024).

The UHI effect manifests in two main forms: Surface UHI and Atmospheric UHI (Roth, 2020). Surface UHI occurs when roads, pavements and rooftops absorb and store heat throughout the day; this effect is most intense during daylight hours (Roth, 2020). The retained heat continues to be released into the night, increasing the temperature disparity and the Atmospheric UHI. Atmospheric UHI refers to the warming of the air in urban areas relative to rural surroundings (Roth, 2020). Atmospheric UHI is again divided into the Canopy Layer UHI (CUHI), which extends from the ground up to below the tops of trees or roofs and the Boundary Layer UHI, which extends from the rooftops or treetops to a height of approximately 1.5 km, where the influence of most contributors become significantly diminished as they are less present (Oke, 1982; Roth, 2020). CUHI is the most seen and studied of the two types as it is the most concerning for humans. The timing and intensity of Atmospheric UHI depends on factors such as the properties of the urban area, the season and the geolocation (Roth, 2020). However, it is often most pronounced at night when heat stored in urban infrastructure during the day begins to be released.

3.1.1. Physical Drivers

While many elements contribute to the UHI effect, its intensity is determined by both the physical characteristics of the city (i.e. its size, population density, building layout) and external conditions (i.e. local climate, topography, weather patters, seasonal variations) (Filho et al., 2017).

The type of material used for construction is one of the main contributors to UHI. There are three key properties of the material that play a role in the UHI's intensity (Bhargava et al., 2017):

- Albedo: the ratio of solar energy that a surface reflects and the energy it absorbs. Surfaces with high albedo reflect more solar energy and absorb less heat, thereby contributing less to UHI. Dark-colored materials (often used in urban areas) absorb more energy during the day and radiate more heat at night, contributing to the UHI effect.

- Heat capacity: a material's ability to store heat. Steel and concrete (common materials in urban areas) have high heat capacities, meaning they can absorb and store heat throughout the day, gradually releasing it during the night. As a result, cities tend to retain heat longer than rural areas, causing nighttime temperatures to remain higher and contributing to UHI.

- Thermal emittance: the ability of a material to release the stored infrared radiation (heat). Materials with high thermal emittance release heat more efficiently and stay cool. Most common construction materials, such as concrete and asphalt, have relatively high thermal emittance, while metals typically exhibit lower thermal emittance, causing them to retain heat for a longer period of time increasing the SUHI.

Urban geometry, defined by the size, shape and spacing of buildings, directly affects wind flow and energy absorption within cities. Due to the building density, wind velocity is reduced hence the natural cooling effect by convection is decreased as well (Priyadarsini et al, 2008). Buildings obstruct wind circulation, leading to reduced air movement and higher temperatures. For instance, streets lined with tall buildings or commonly called canyon streets, trap heat as the building walls absorb the heat (Voordeckers et al., 2021). While taller buildings can provide shade during the day, they also absorb and reflect sunlight, further lowering the albedo of the city, thereby increasing its overall temperature.

The reduction in vegetation cover, a common consequence of urbanization is another important factor. Natural areas in rural settings provide cooling through processes like evapotranspiration, where plants release water into the air, lowering ambient temperatures. In cities, however, impervious surfaces such as concrete and asphalt replace greenery, leading to reduced evapotranspiration and higher temperatures. Furthermore, the lack of permeable surfaces in urban areas increases runoff, which, in turn, contributes to higher temperatures by reducing the moisture available for cooling. It has been reported that each 10% vegetative cover of the city can reduce the city's overall temperature by 0.6 K (Oke, 1982).

3.1.2. Anthropogenic Heat

Human activities are a major contributor to the UHI effect, particularly in densely populated areas where energy use and emissions are concentrated. High levels of pollutants with positive forcing, such as carbon dioxide, are released through human activities and energy consumption, all of which are more pronounced in urban centers (Bhargava et al., 2017). This concentration of emissions traps heat in the atmosphere, raising local temperatures. Air pollution in these areas especially from vehicle exhaust and industrial processes, not only degrades air quality but also enhances the UHI effect by trapping solar radiation and reducing heat dissipation (Nuruzzaman, 2015).

An ironic contributor is the use of air conditioning. As air conditioners cool the inside of buildings, they release the absorbed heat into the surrounding environment, further warming the atmosphere (Okwen et al., 2011). The growing reliance on air conditioning, especially during summer, amplifies the UHI effect by adding additional heat to the already elevated temperatures of urban centers.

3.2. *Impacts*

Higher urban temperatures and air pollution from UHI directly affect human health (Irfeey et al., 2023). These include heat stress, respiratory problems and heat-related illnesses, such as heatstrokes (Mayo Clinic, n.d.). Vulnerable populations, such as children and the elderly are at an increased risk. The rise in temperatures and poor air quality can lead to a higher incidence of heat-related deaths, especially during heatwaves (Irfeey et al., 2023).

The UHI effect disproportionately impacts lower-income areas, as they usually have fewer resources for cooling and infrastructure with better insulation. Higher energy costs and health-related expenses can strain both individuals and public services, further deepening socio-economic disparities and increasing financial burdens. A study by the International Labour Organization estimated that productivity losses due to heat stress could result in a global economic loss of $2.4 trillion by 2030 (UN, 2019). These statistics emphasize the urgent need for effective urban heat mitigation strategies to alleviate both social and economic burdens.

This unequal distribution of heat exposure is known as thermal inequity, a condition driven by urban planning decisions, socio-economic disparities and environmental injustice. Communities most affected by this inequity are often the least equipped to respond and without targeted interventions, the gap between vulnerable populations and the rest of the urban population will continue to grow. Addressing these disparities is essential not only for public health and environmental sustainability but also for advancing social equity in the face of a changing climate.

Higher temperatures also lead to increased energy consumption during the summer due to higher demand for air conditioning and cooling. And as mentioned previously, this actually only worsens the whole situation. The additional energy demand not only results in higher electricity bills but also requires more electricity production, which has significant environmental impacts. The process of generating electricity releases large amounts of pollutants into the atmosphere (and exhaust heat), contributing to climate change and deteriorating air quality, ultimately worsening public health (Bhargava et al., 2017). While this topic in itself is very important, it is too complex to be fully explored here.

As urban surfaces heat up, they transfer heat to stormwater runoff during rainfall. This raises water temperatures in rivers, lakes and streams, disrupting aquatic ecosystems. The increase in water temperature can impair the metabolism and reproduction of many aquatic species, leading to imbalances in ecosystems and negatively impacting biodiversity (Roa et al., 2003).

3.2.1. Causes of Thermal Inequity

The reason for thermal inequity can be divided into two categories. First, the lack of social resources and adaptive capacity to respond to temperature change. And second, historical planning practices such as redlining which have shaped urban heat exposure.

a) Socio-Economic

A community's adaptive capacity is its ability to anticipate, respond to and recover from environmental stressors (i.e. extreme heat) (Norris et al., 2007; Liu et al., 2022; Rosner, 2023). While infrastructure improvements (e.g., green spaces, cooling centers and energy-efficient housing), which will be discussed in further detail later on this report are essential, social factors significantly impact a community's ability to implement and benefit from these measures (Norris et al., 2007).

Income levels have a direct influence on vulnerability to thermal inequity. Low-income households often lack the financial resources to afford air conditioning, energy-efficient housing or access to heat-resilient infrastructure (Rosner, 2023). These disparities also extend to healthcare access, the ability to reach cooling centers and the capacity to respond to heat-related emergencies, leaving certain communities disproportionally affected. Residents in low-income neighborhoods may also experience weaker political representation and limited trust in institutions, reducing their ability to advocate for and benefit from adaptation measures (Rosner, 2023).

Awareness and education also play an important role in shaping a community's resilience to climate change. Higher levels of education are associated with greater awareness of climate risks and better health outcomes (Solecki et al., 2013). Communities with more educational attainment are generally better informed about the dangers of extreme heat and more capable of understanding and acting on early warnings, health advisories and long-term planning strategies (Rosenthal et al., 2014). Education can also enhance individual decision-making, encourage civic participation and support the adoption of sustainable behaviors and technologies that improve resilience.

Social capital refers to the networks, norms and trust that facilitate collective action within communities (Liu et al., 2022). Research has demonstrated a strong correlation between social capital and a community's ability to prepare for, respond to and recover from disasters (Aldrich & Meyer, 2015). Communities with higher levels of social capital tend to have better access to information, stronger support systems and an increased capacity to implement adaptation measures. Active community participation and strong social ties help disseminate early warnings, coordinate emergency plans and build trust between residents and institutions (Lo et al., 2015). Kerstholt et al. (2017) argue that communities with higher levels of social participation are better prepared for disasters because they can mobilize resources more efficiently. During and after a disaster, social capital plays a vital role in emergency response and recovery. Strong social networks improve access to critical resources such as financial aid, shelter and healthcare services. Communities with higher levels of trust and cohesion tend to organize more effective evacuation and relief efforts (Matsumoto & Madarame, 2018). In addition, social capital supports psychological resilience by reducing stress and fostering a sense of belonging during crises (Araya et al., 2006). Communities with strong social networks are also more likely to organize local cooling initiatives, check on vulnerable residents and push for policy interventions that address heat inequities (Paton & Buergelt, 2019).

In short, differences in income, education and social capital all contribute to the uneven distribution of adaptive capacity. Understanding these social dimensions is key to developing urban heat mitigation strategies that are inclusive, effective and equitable.

b) Past Planning Practices

Past urban planning decisions have contributed to thermal inequalities. In North America, historically redlined neighborhoods, where financial and housing discrimination excluded racial minorities, continue to experience higher heat exposure due to limited green space and a high concentration of impervious surface (Nowak et al., 2022). These communities were often denied investment in public infrastructure, including parks, street trees and modern housing. As a result, these areas continue to bear the consequences of outdated planning policies that prioritized wealthier areas for environmental benefits (Wilson, 2020). Even in contemporary planning, disparities persist, with lower-income neighborhoods often receiving fewer resources for climate adaptation measures (Rosner, 2023). Exclusionary zoning, referring to the regulation of economic and racial diversity by land-use in the USA is another form of practice that was once used, which drove the excluded communities to move to areas with less greenspaces and more impervious surfaces (Harlan et al., 2006; Wilson, 2020). Additionally, the industrial zoning has concentrated polluting factories, warehouses and highways in lower-income communities, which intensify the heat stress, by releasing heat but also due to the high usage of impervious surfaces. Urbanization itself as mentioned has been playing a role as people started to live in the city center, which meant a higher population density leading to an increase in human activities that are energy consuming leading to an increase of positive forcing energy. This increase in density also led to the creation of larger and taller buildings which in turn contributed to wind breakers, contributing to UHI.

Urban sprawl has favoured car-dependent urban design, which contributed to heat stress in multiple ways: increased emissions lead to higher temperatures, while extensive road networks, parking spaces and the sprawling suburban development create heat-retaining landscapes. Poorer communities, often situated near highways and industrial zones, experience intensified heat exposure due to these factors (Harlan et al., 2006). Additionally, residents in car-dependent cities face greater challenges in accessing cooling resources, as essential services may be located further away from residential areas (Rosner, 2023). Public transportation infrastructure often lacks shade or climate-controlled waiting areas, exposing commuters to extreme temperatures for extended periods.

The history of urban development has prioritized economic expansion and industrial efficiency over equitable environmental planning. The legacy of these decisions continues to shape the present-day landscape, where marginalized communities disproportionately suffer from heat-related stress, economic burden and poor health outcomes.

3.3. *Existing Solutions*

UHI is a critical issue for cities worldwide, that will only worsen if no changes are made. As this issue has been going on for a while, urban planners, policymakers, engineers and many others involved in urban development have found and implemented various technological infrastructure, policy frameworks and community engagements to respond to UHI.

3.3.1. Technological and Built Solutions

Technological adaptation is a primary means of directly mitigating the UHI effect. Advances in monitoring and mitigation technologies provide crucial data for urban planners, allowing for precise interventions (Shi et al., 2023). Remote sensing, geographic information systems (GIS) and real-time climate monitoring can help cities identify and respond to heat stress hotspots more effectively (Fu et al., 2024). One of the most effective mitigation strategies involves integrating green infrastructure into urban environments. Using this data, cities can decide where to plant trees, install green roofs or use cooler materials. Nature-based solutions (i.e. urban forests, street trees, vegetative barriers etc.) provide shade and facilitate evapotranspiration, reducing ambient temperatures while improving air quality and biodiversity (Parker & Simpson, 2020). Additionally, green roofs and living walls serve as insulative barriers for buildings, reducing indoor temperatures and consequently reducing energy consumption for cooling systems (Irfeey et al., 2023). Parks and blue-green infrastructure contribute to cooling by increasing moisture levels in the air and fostering local microclimates that counteract heat accumulation. Blue infrastructure elements, particularly those designed to work in conjunction with vegetation, are increasingly recognized as cost-effective and multi-functional solutions for mitigating UHI (Fu et al., 2024). Reflective and high-albedo materials are essential in reducing heat absorption in urban areas as well (Nuruzzaman, 2015). Cool roofs and pavements, which incorporate reflective coatings and materials, prevent heat retention and minimize the radiative heating of urban surfaces (Boyd et al., 2015). Additionally, permeable pavements improve water infiltration and reduce surface temperatures, enhancing both stormwater management and urban cooling effects.

Akbari and Kolokotsa (2016) highlight newer materials like thermochromic coatings that change reflectivity depending on temperature and retroreflective surfaces that bounce heat directly back to the sky, which can be especially effective in dense cities. Still, these technologies are only as effective as the policies that support them.

3.3.2. Policy Frameworks and Community Engagement

Cities need zoning rules and building codes that require or encourage passive cooling, tree planting and heat-reflective surfaces. For example, setting standards for building orientation, spacing between structures and minimum requirements for shaded areas can reduce heat build-up in the first place (Akbari & Kolokotsa, 2016). Planning decisions about materials and building layout also affect wind flow and shade, which can either help cool an area or trap heat. That is why the UN and researchers stress the need for cities to combine technology and planning if they want to manage urban heat in a way that is both effective and fair.

Some urban planning policies such as zoning regulations and building codes mandate climate-responsive construction practices, compelling developers to integrate heat-mitigating features into new developments (Akbari et al., 2001). Common recommendations include the use of energy-efficient materials, high-albedo surfaces and passive cooling designs that minimize heat absorption. Traditionally, building codes have been developed based on historical climate patterns to address localized risks and hazards (Rosner, 2023; Lenzholzer et al., 2020). However, with the accelerating impacts of climate change, new construction must now be designed to withstand anticipated future climate conditions, ensuring long-term adaptability and resilience (ICC, 2021).

Heat action plans (HAPs) have been successfully implemented in cities such as New York, Los Angeles, Ahmedabad and Paris where extreme heat poses significant public health risks (Rosner, 2023). These plans provide structured responses to heat events by integrating early warning systems, emergency cooling centers and targeted interventions for vulnerable populations, such as the elderly and low-income residents. By proactively addressing extreme heat, HAPs help reduce heat-related illnesses and fatalities, demonstrating the importance of coordinated urban heat adaptation strategies.

Governments have also employed financial incentives, such as tax credits, grants and policy adoptions, to promote the implementation of UHI mitigation strategies while addressing thermal inequities (Therrien & Normandin, 2020). These incentives encourage the adoption of cooling technologies and sustainable urban solutions. For instance, in Portland, Oregon, residents earning 60% or less of the Area Median Income are eligible for cooling devices to help regulate indoor temperatures during extreme heat events (Rosner, 2023). Additionally, carbon offset programs are increasingly being used to fund urban greening initiatives by redirecting resources from polluting industries to sustainable projects. Some cities, such as London, Bogotá and Paris, have even implemented policies that limit car usage, further contributing to UHI mitigation and air quality improvements (Brown, 2009).

Community engagement remains a critical yet often underutilized component of UHI mitigation. Grassroots organizations and local advocacy groups play a significant role in promoting tree-planting campaigns, urban gardens and the establishment of local cooling centers. These community-based adaptation programs empower residents to take an active role in shaping their urban environment, fostering social cohesion and localized resilience against extreme heat events. Awareness is a key factor in addressing heat-related risks, as increasing knowledge among both community members and urban planners about adaptation strategies strengthens community-driven efforts and ensures long-term sustainability (Lenzholzer et al., 2020; Rosner, 2023; EEA, 2012).

3.3.3. Constraints and Challenges

Despite the effectiveness of technological, built and policy solutions for mitigating the UHI effect, several challenges hinder their implementation. High costs associated with research, construction and maintenance present significant barriers, particularly for municipalities with limited financial resources. Additionally, integrating cooling infrastructure into existing urban landscapes requires careful planning to avoid conflicts with other land uses and urban development priorities (Lenzholzer et al., 2020). Regulatory measures, such as building codes, play a crucial role in ensuring climate-responsive construction, but their enforcement varies widely across jurisdictions. The absence of standardized regulations often limits their widespread adoption, leading to inconsistent implementation and reduced impact. Similarly, some municipalities lack the necessary funding, administrative capacity or coordination frameworks to maintain robust heat response systems. Schmeltz et al (2023) highlight that current planning efforts often fail to adequately address the needs of at-risk communities, reinforcing existing social and environmental inequalities. While community-driven initiatives have demonstrated success in promoting tree planting, urban gardens and local cooling centers, they frequently encounter challenges related to sustained funding and policy support (Sousa-Silva et al., 2023). Without institutional backing, many grassroots efforts remain limited in scale and struggle to achieve broader, systemic impact. Policymakers can enhance the effectiveness of these initiatives by formally integrating community perspectives into urban planning processes and providing long-term financial and technical assistance to support locally driven adaptation strategies (EEA, 2012).

Overcoming these challenges requires a holistic approach that combines strong regulatory enforcement, equitable financial support and inclusive governance. By addressing gaps in funding, policy coordination and community engagement, cities can create more resilient urban environments capable of mitigating extreme heat impacts for all residents.

3.4. *Synthesis*

The literature reviewed underscores that the urban heat island effect is shaped by the interaction of physical drivers (i.e. impervious surfaces, building form and green space) and social factors (i.e. income, age, health status and historic planning practices). These insights guided the selection of metrics used in this study. Green space per capita and the age and density of buildings are included because they directly reflect the physical determinants of heat retention and dissipation highlighted in the literature. The presence and accessibility of cooling facilities are examined because policy and planning studies consistently emphasize the importance of equitable access to public cooling infrastructure for vulnerable populations during extreme heat events. On the social side, indicators such as income, renter status, disability and age distribution are selected because prior research shows that these groups consistently face heightened exposure, reduced adaptive capacity and disproportionate health risks. The combination of environmental and social dimensions enables the metrics to represent how physical heat risks intersect with patterns of vulnerability. This allows the case studies of Portland and Vancouver to be situated not only in relation to their physical risk profiles but also in terms of how policies respond to patterns of social vulnerability. In doing so, it bridges the gap between technical solutions and questions of justice, aligning the analysis with calls for urban climate policies that are both effective and equitable.

4. Case Study 1: Portland

The City of Portland has been working across ten municipal bureaus to develop its 2025 Emergency Climate Action Plans, which include the implementation of 47 key strategies (City of Portland, 2022). This coordinated effort was largely prompted by the city's experience with extreme heat, particularly during the 2021 heatwave, which exposed the city's vulnerability to the UHI effect and its lack of preparedness. During that single week, 111 heat-related deaths were reported statewide, with 72 occurring in Multnomah County alone. Many of these people were elderly, lived alone and did not have access to air conditioning (Ashbaugh & Kittner, 2024).

Extreme heat events in Portland are becoming more frequent and more intense (City of Portland, 2022). Between 1961 and 1990, Multnomah County experienced an average of 6.3 days per year above 32°C (U.S. Federal Government, 2025). Figure 1 shows that by 2050, that number is projected to rise to 18.5 to 23.4 days annually (U.S. Federal Government, 2021). Thus, the number of very hot days will at least triple per year if the county does not put its climate plans into action. This only underscores the urgency of implementing mitigation measures swiftly, yet strategically, to protect not only vulnerable populations but also the broader economy. The longer these interventions are delayed, the higher the social, environmental and economic costs are likely to be.

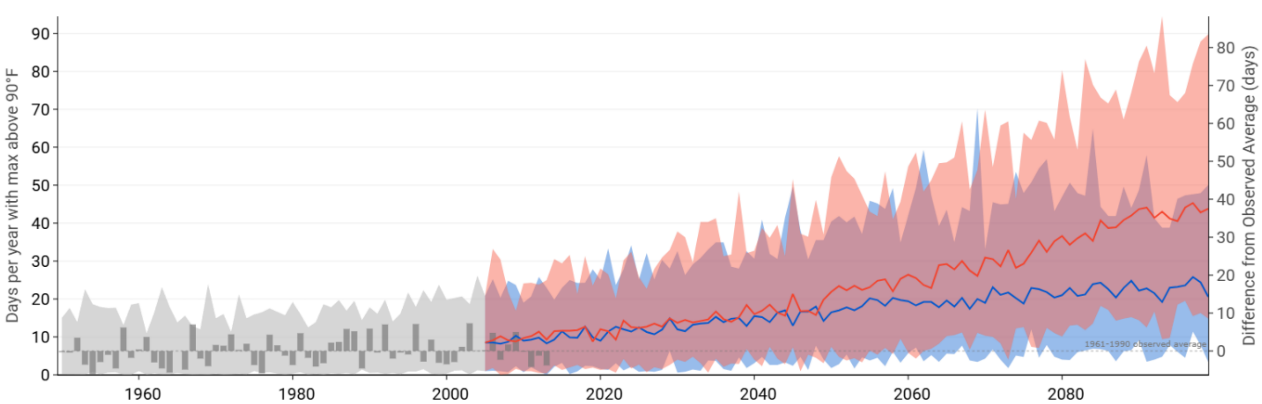

Figure 1: Predicted days per year above 32°C in Portland (U.S. Federal Government, 2025).

4.1. *Spatial Analysis*

4.1.1. Vulnerable Population

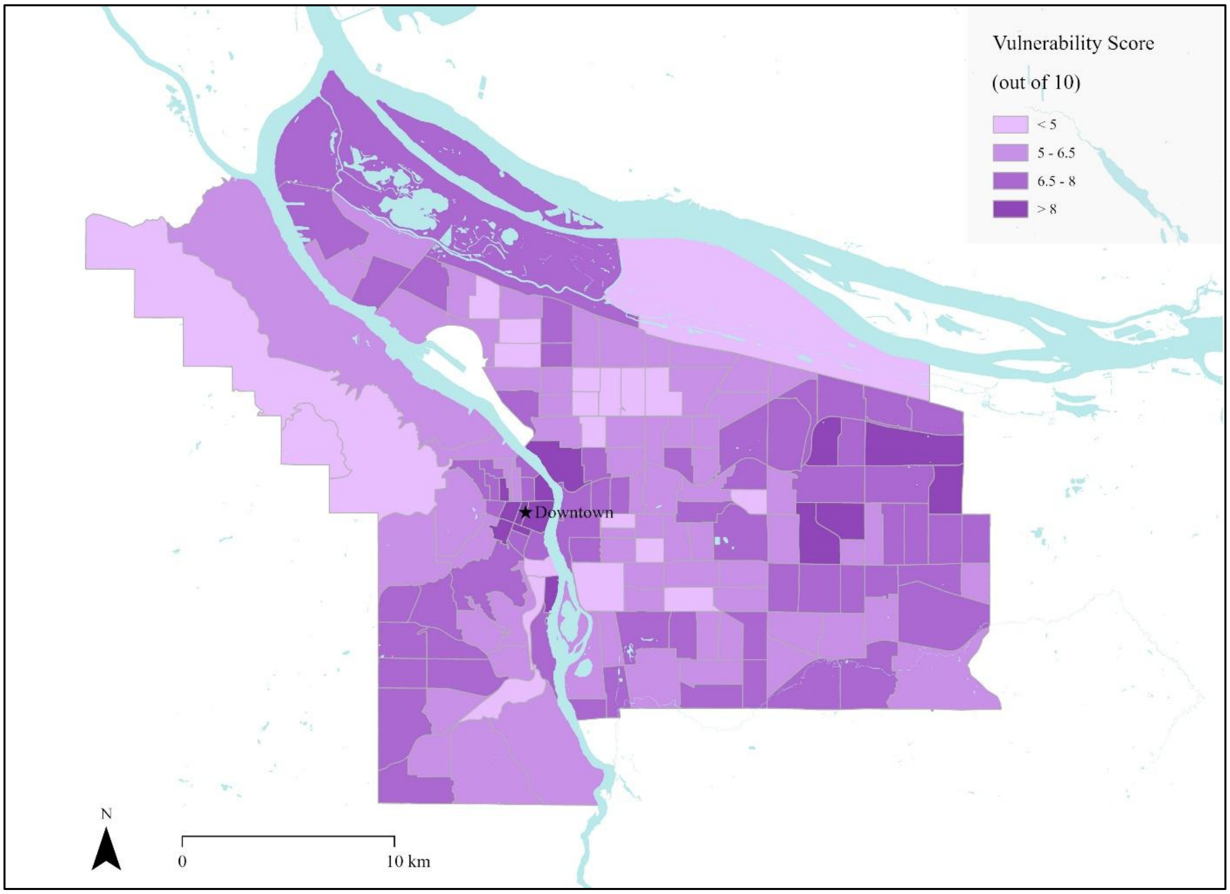

Figure 2: Vulnerability population in Portland. Source: Portland Open Data Portal.

As mentioned in the methodology section, this map displays the heat vulnerability score for each Portland neighborhood, ranging from 0 (lowest vulnerability) to 10 (highest). Scores are based on the average of normalized total counts for four indicators: residents over 65 years old, children under 14, renters and people with disabilities. A higher score means a higher concentration of vulnerable residents in that neighborhood. Full details on the calculation method are provided in the methodology (pp. 5–6).

From Figure 2 there does not appear to be a sharply defined spatial pattern in this map, except in the central part of the city around the river, where the downtown area is located many neighborhoods fall in the 6.5 - 8 range, with a couple of neighborhoods scoring above 8. These zones are home to higher concentrations of older adults, young children, renters and low-income residents, making them more vulnerable to extreme heat. As will be explored further later on but can already be inferred, the central area is also the city's most densely built environment and busiest. This makes the vulnerable population more at risk during periods of extreme heat.

The central-eastern part of the city also contains pockets of higher vulnerability, with a few surrounding neighborhoods scoring below 6.5. While the differences in scores across the city are not drastic, the eastern areas still tend to show relatively higher vulnerability and this should not be overlooked. In contrast, some neighborhoods scoring below 5 are located more on the outskirts, with a few appearing in more central areas as well.

Overall, this map provides a valuable starting point for understanding the social dimensions of heat vulnerability in the city. It helps identify priority areas for intervention, particularly in eastern and central neighborhoods, where vulnerable populations and built conditions intersect.

It was seen that the median and mean are quite close to each other indicating a somewhat normal distribution of vulnerability scores with no significant outliers (6.6 for the mean and 6.4 for the median). This indicates that most neighborhoods fall near the middle of the vulnerability scale, with fewer areas at the extreme high or low ends, which helps ensure that vulnerability patterns and differences can be interpreted more clearly. Additionally, only two neighbourhoods got a final score above 10 prior to capping. Given the sample size of 165 neighbourhoods and the highest being at 15.2, the impact of capping on the mean and median is considered negligible.

4.1.2. Green Coverage

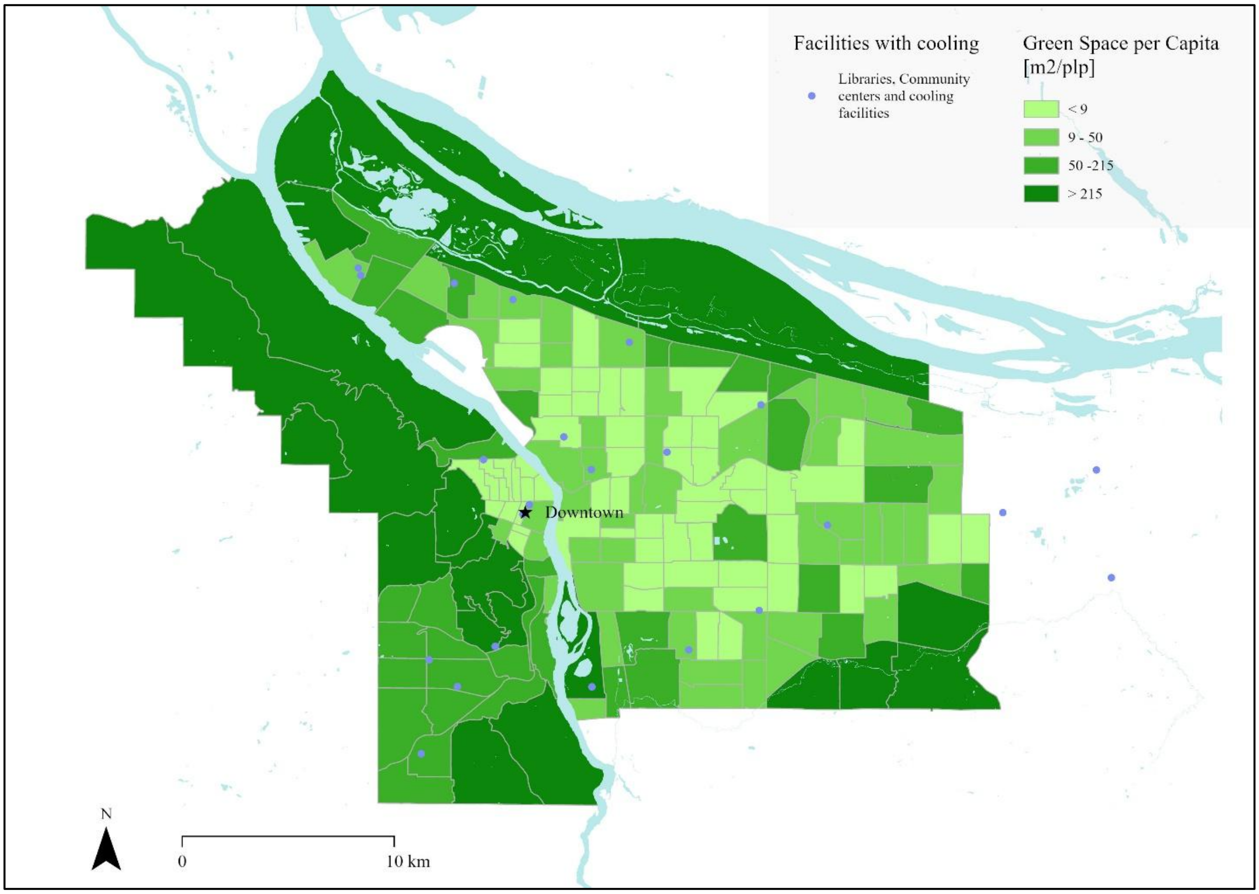

Figure 3: Green Space per Capita per neighbourhood with public facilities with cooling in Portland. Source: Portland Open Data Portal.

This map shows the distribution of green space per person (m^2 per capita) across Portland neighborhoods, alongside the location of public facilities with cooling (libraries, community centers and designated cooling facilities). Green space availability was calculated by dividing the total green area in each neighborhood by its residential population. The data was classified into four categories: less than 9 m^2 per person, 9–50 m^2 per person, 50–215 m^2 per person and more than 215 m^2 per person. These thresholds align with the benchmarks for urban cooling: a minimum of 9 m^2 per person to provide basic thermal comfort and an ideal target of 50 m^2 per person for optimal cooling benefits (Russo & Cirella, 2018).

The map of green space per capita reveals a pronounced spatial gradient: outer areas of the city, particularly in the north, exhibit the highest green space per capita, largely due to lower population densities and the presence of extensive parks and natural areas. The west side of the Willamette River also contains substantial green space, with the notable exception of the downtown core, which is markedly deficient in canopy and parkland. In contrast, many central neighborhoods, where population density is highest, fall below the minimum benchmark of 9 m^2 per person, with several well under the ideal value of 50 m^2 per person. While the citywide mean is approximately 275 m^2 per person, the median neighborhood value is only 15 m^2, meaning at least half of Portland's residents have access to over 260 m^2 less green space than the average. Although this gap is partly explained by sparsely populated areas containing large tracts of reserved or undeveloped land, it nevertheless represents a substantial disparity in access to green spaces. The uneven spatial distribution of cooling facilities further compounds this inequity, leaving some high-need neighborhoods with limited access to temperature-moderating resources.

Even if some residents can visit green areas in nearby neighborhoods, the issue remains: in many central neighborhoods, where people live close together, the cooling benefits of green space are missing. While the city-wide average seems impressive, the distribution of green space is highly uneven. Another concern is the placement of cooling facilities (i.e. libraries and community centers), most are located in the city center, but there is a noticeable gap on the eastern side, where vulnerable populations may struggle to find relief from the heat. Given the high population density in the central area, there is clearly a need to add more cooling spaces for those most at risk.

Table 1: Portland, Green Space.

	Less than 9 m^2	Between 9 and 50 m^2	Above 50 m^2
Number of neighbourhoods	60	50	55
Population affected	231,625	204,823	213,407
Average Vulnerability Score	6.49	6.80	6.40

Table 1 helps put these spatial patterns into perspective. Of the three categories of green space distribution, the largest share of the population (over 231,600 people across 60 neighborhoods) live in areas with less than 9 m^2 of green space per person. When combined with the 204,800 residents living in neighborhoods that have between 9 and 50 m^2 per person, this means that more than two-thirds of Portland's population falls short of the recommended 50 m² threshold for optimal cooling. Interestingly, the highest average social vulnerability score (6.80/10) is found not in the lowest green-space tracts, but in those with 9 to 50 m² per person. Approximately 17% of Portland's total land area is devoted to green spaces. While this figure demonstrates a commitment to green infrastructure, the uneven neighborhood-level distribution means that many residents, especially in dense, vulnerable central neighborhoods, still face significant deficits in accessible green space. This underscores the need to not only expand green space citywide but also ensure its equitable placement and access.

The correlation coefficient between green space per capita and vulnerability is –0.10, indicating a very weak negative relationship: neighborhoods with less green space are slightly more likely to be socially vulnerable. In other words, while low access to green space often overlaps with vulnerability, the relationship is shaped by additional factors.

When we look again at the vulnerability map, the issue becomes even more urgent. There is a visible pattern in the central neighborhoods, where many residents are low-income, older adults, young children, or renters. These groups are more vulnerable to heat and have fewer resources to cope with extreme weather. The eastern neighborhoods also show signs of high vulnerability and lack nearby cooling facilities, which puts residents at higher risk. Although the Willamette River may offer some natural cooling to the downtown area, this benefit does not extend to the east, where the problem is worse. Together, the maps show that both central and eastern parts of the city need more attention, with better access to trees, green space and cooling infrastructure to protect vulnerable people during heatwaves.

4.1.3. Built Environment

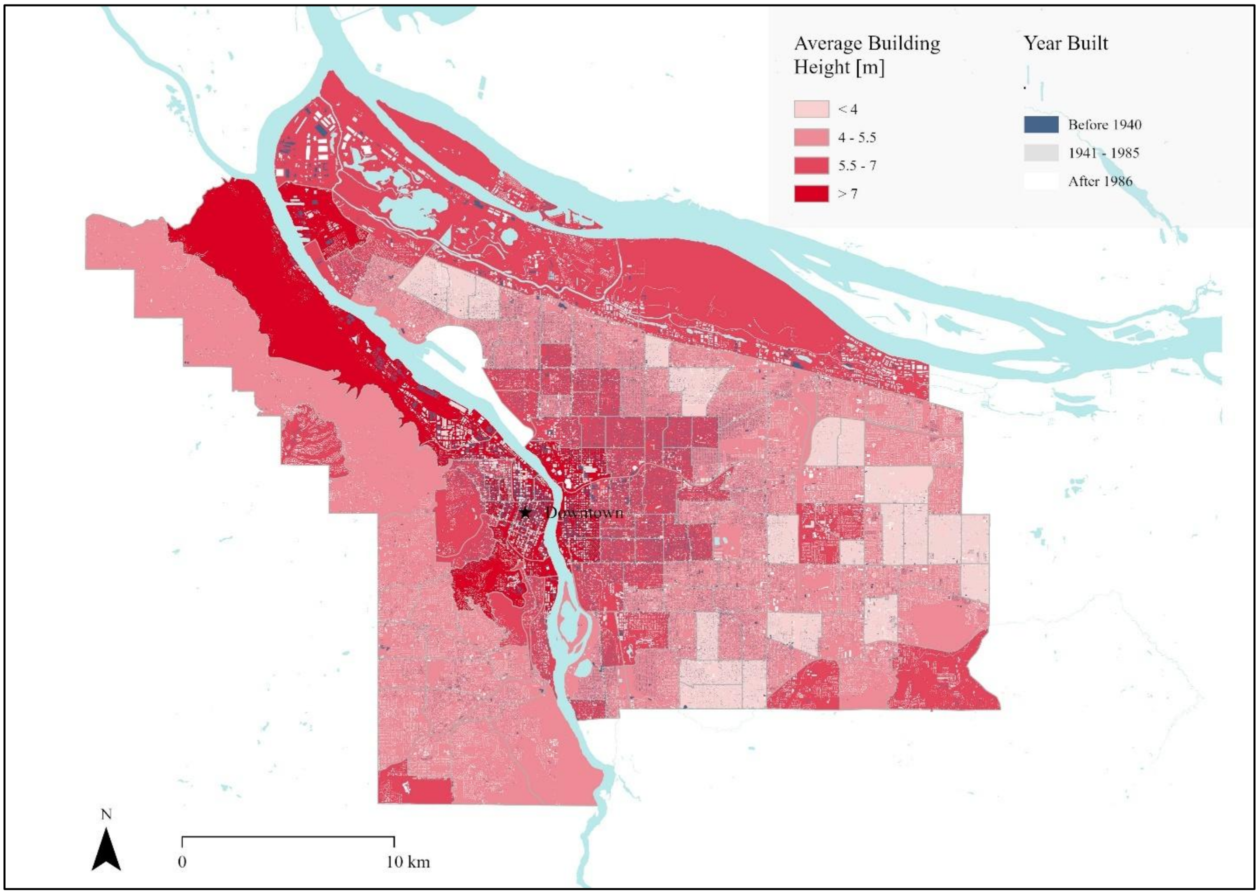

Figure 4: Built Environment of Portland. Source: Portland Open Data Portal.

This map categorizes building footprints by predominant construction era: pre-1940 buildings, which often have low insulation and high heat retention; buildings from 1941–1986, which vary in quality but often lack modern cooling features; and post-1986 buildings, which are more likely to meet updated energy efficiency standards. The analysis also incorporates the median building height for each neighbourhood, providing an indication of the predominant building height in that area. Taller buildings tend to trap more heat and can contribute to higher indoor temperatures during extreme heat events, making height an important factor in assessing heat risk.

Figure 4 shows that Portland's city center has a noticeable concentration of taller buildings, many of which were constructed before 1940. The eastern side of the city features more recent construction, mainly from 1940 to 1985, but these buildings still carry the challenges of aging infrastructure and may lack modern insulation. It is also worth noting that many of these structures are generally smaller, with most under 5.5 meters, typically no more than two floors, which may lessen their contribution to localized heat buildup.

Table 2: Portland, Built Environment.

	Less than 4 m	Between 4 and 7 m high	Above 7 m high
Number of neighbourhoods	21	119	25
Population affected	89,931	490,789	69,135
Average Vulnerability Score	6.58	6.30	7.75

Table 2's results show that the majority of residents (nearly 491,000 across 119 neighborhoods) live in areas with buildings averaging 4 to 7 m in height, where the mean vulnerability score is 6.3. However, the most striking finding emerges in the tallest building category where the average vulnerability score rises significantly to 7.75/10, the highest of the three. This indicates that residents living in high-rise environments are considerably more vulnerable to heat-related risks compared both to those in low- and mid-rise areas. The correlation coefficient used in Excel between building height and vulnerability is +0.49, indicating a moderate positive relationship: as building height increases, so does the level of social vulnerability. While the correlation partly reflects the fact that taller apartment buildings are disproportionately rental housing, the value of the correlation coefficient still highlights an equity concern.

When this urban form is viewed alongside the vulnerability map, the city center stands out as an area of concern. It not only hosts a higher share of vulnerable residents but is also the busiest part of the city, with more traffic and human activity, factors that contribute to anthropogenic heat emissions and increase the UHI effect. The dense and tall built environment further traps heat within the canopy layer, compounding the risk for residents, especially those who may already face social or economic disadvantages. That said, the proximity of the Willamette River may offer some natural cooling benefits in certain parts of the downtown area. On the eastern side, while the built form is less dense and buildings are generally lower, the presence of vulnerable populations and a lack of cooling infrastructure make it an important area to monitor and support through targeted interventions. Other parts of the city appear to be less pressing in terms of combined risk, but these insights highlight the need for ongoing attention to both social and physical factors in order to create a more heat-resilient Portland.

4.2. *Critical Policy Review*

4.2.1. Tree Planting and Landscaping

Portland's urban heat island strategy continues to prioritize expanding tree canopy coverage in the city's most heat-vulnerable neighborhoods. Policy T-3 supports this effort by targeting areas like East Portland for large-scale planting through PCEF's Equitable Tree Canopy (SP8) program. The program aims to plant and establish at least 15,000 trees by 2029, beginning with the planting of the first 1,000 trees during the 2024–25 season. Planting target areas are prioritized in areas with elevated surface temperatures and in communities historically underserved by greening and heat-mitigation efforts. The city works with local organizations to ensure meaningful community involvement, inviting residents to help determine planting locations, select species and decide on maintenance plans that reflect their lived experiences and neighbourhood needs. In addition to planting, the city is shifting the responsibility for maintaining its 240,000 street trees from individual property owners to the Urban Forestry division within Portland Parks and Recreation. This transition is backed by a $65 million PCEF investment and includes systematic inspection, pruning and replacement cycles to ensure long-term tree health. An additional $5 million will fund sidewalk widening and street tree installation along the busiest avenue (82^{nd}). While these efforts are promising, the program remains in its early stages, requiring significant coordination among city bureaus, community partners and residents. Long-term funding and maintenance systems must be carefully designed to withstand budget pressures and evolving climate conditions.

Within the next year, Portland is also planning changes to its tree-related regulations to better protect existing trees and direct more resources toward neighborhoods that need them most. Policy T-2 is intended to set a stronger foundation for how the city manages trees in both public and private spaces, ensuring more equitable outcomes and enhancing resilience to rising temperatures. Together, these initiatives reflect a more comprehensive and long-term approach to urban forestry, connecting community needs, regulatory reform and the evolving challenges of climate adaptation.

4.2.2. Green Infrastructure and Buildings

Portland has embedded climate resilience in the built environment through green infrastructure and building decarbonization policies. Policy B-1 proposed the adoption of climate and health standards for multifamily and commercial buildings to reduce emissions and enhance indoor conditions. A draft policy was released and a pilot with multifamily buildings is moving forward, but full council consideration has been delayed due to a city charter transition and broader economic uncertainties. In contrast, Policy B-3 is actively progressing. Through PCEF community grants, more than 343 homes have already received energy retrofits, primarily involving heat pumps. Over the next five years, the program will deliver clean energy upgrades to 4,815 affordable multifamily units and over 3,000 low- and moderate-income homes. Meanwhile, the NR-4 policy initiated the development of a citywide green infrastructure systems plan. Although the plan itself has been delayed due to lack of resources and a lead agency, over $232 million has already been invested in bioswales, depaving, urban canopy expansion and other green infrastructure across various city bureaus and nonprofit partners. While much of the infrastructure work is ongoing, coordination and strategic alignment remain areas of need for broader citywide impact.

The Green Building Policy, under section 1.1.H, mandates that city-owned buildings must cover their entire roof area with an ecoroof, except where technical constraints apply. Additionally, all existing city buildings undergoing roof replacements are required to install ecoroofs as part of the upgrade. Any exemptions to this requirement must be formally approved by the commissioner overseeing the responsible bureau (City of Portland, 2015).

Additionally, the HEART (Health, Equitable Energy, Anti-Displacement, Resilience, Temperature) building standards integrate equity-driven energy efficiency requirements in rental properties, addressing both climate resilience and affordability (Ashbaugh & Kittner, 2024). However, there is a gap in mandating landlord-provided cooling and sustained funding for retrofitting older buildings remains uncertain (ECOnorthwest, 2025).

Portland has also linked UHI mitigation with stormwater management through initiatives such as the *Grey to Green* program, which has increased urban vegetation while improving stormwater absorption (Friends of Trees, 2012). This multi-benefit approach demonstrates how green infrastructure can simultaneously address heat resilience and flooding risks.

4.2.3. Emergency Preparedness

Portland's emergency preparedness efforts span infrastructure, planning, equipment and regional coordination, although progress is uneven. Policy E-1, which aims to ensure continuity of operations for transportation infrastructure during extreme events, is not yet funded, though agencies like Portland Bureau of Transportation (PBOT) have begun identifying needs and applying for grants, such as for mobile floodwall systems. Similarly, Policy E-2 seeks to improve citywide emergency response equipment but has yet to receive dedicated funding. Nonetheless, some bureaus have taken independent steps: PBOT and Portland Water Bureau (PWB) have restocked emergency kits, acquired communication radios and updated response plans, such as those used during the 2023 Camp Creek Fire. Policy E-3 supports the revision of continuity of operations plans, with PBOT leading the charge despite delays caused by software issues. Federal Emergency Management Agency (FEMA) training is now mandatory for all staff involved in winter weather response. Lastly, Policy E-4 extends beyond city boundaries to strengthen regional climate resilience. Portland Water Bureau has participated in national networks like the Water Utility Climate Alliance and represented the city at the White House Summit on Climate Resilience. PBOT and Portland Bureau of Emergency Management (PBEM) continue to collaborate with Metro, the regional government organization that oversees land use planning, transportation and environmental issues across the Portland metropolitan area, on regional evacuation strategies and emergency transportation routes (Metro, n.d.). While each policy has seen some progress, limited funding and the scale of coordination required present ongoing challenges.

4.2.4. Planning and Energy/Other

Portland's long-term climate planning is underpinned by policies focused on decarbonizing the city's energy supply and integrating climate risk into infrastructure investment. Policy E-1 (under electricity supply), which aimed to enroll the city in a community-wide green electricity tariff, has encountered major delays. Portland General Electric ultimately declined to proceed with the tariff due to high market costs and the city agreed that the proposed terms were not favorable for ratepayers. Despite this, discussions continue around alternative pathways to clean grid access. Policy E-2 (under electricity supply) has progressed more steadily. PCEF has invested nearly $400 million in renewable energy initiatives (Dodge, 2024). These efforts include both on-site solar for homes and community-scale installations that build local resilience. Finally, Policy IP-1 ensures that capital investments are evaluated for climate risks such as flooding, heat and drought. The Portland Water Bureau has adopted a climate-smart checklist for project planning, while the Bureau of Environmental Services has incorporated climate change into its modeling and project design processes. The city is also contributing to national discussions on climate-related infrastructure financing through EPA partnerships. These efforts signal meaningful, if incremental, shifts toward embedding climate considerations across the entire urban planning process.

The Cooling Portland initiative under Policy H-1 is a centerpiece of this approach, aiming to distribute 15,000 high-efficiency heat pumps to low-income households by 2027. As of mid-2024, the program has already exceeded its early benchmarks, with more than 1,700 installations completed. Additional funding has supported upgrades to community centers that act as cooling and clean air refuges, although not all efforts have been successful. For example, Portland's attempt to secure FEMA funding for solar and battery backup at East Portland Community Center was unsuccessful.

For outdoor workers, Policy H-2 has institutionalized Oregon Occupational Safety and Health Division's (OSHA) permanent rules regarding extreme heat and wildfire smoke, including mandated breaks, shade, hydration and protective equipment. These safety measures are now fully incorporated into city bureaus' standard training and construction contracts. Additionally, the H-2 advocates for reducing outdoor work during extreme heat events, recognizing the heightened risks faced by outdoor laborers (Xiang et al., 2014). Policy RH-1 complements these efforts by transforming the East Portland Community Center into a full-fledged resilience hub for climate emergencies. HVAC upgrades are proceeding through an energy savings performance contract and design work continues despite unmet funding needs for additional infrastructure. Collectively, these policies represent Portland's most equity-driven efforts, focused not only on physical improvements but also on long-term community capacity building.

Portland's transportation policies advance climate goals by promoting active mobility and reducing vehicle dependence. Policy T-1 has resulted in significant improvements in low-carbon travel infrastructure and services. With multimillion-dollar PCEF funding, PBOT has expanded bike lanes, pedestrian crossings and transit services (*PBOT Programs and Projects Funded Through PCEF*, n.d.). The Portland Streetcar, powered entirely by renewable electricity, reported a 12% ridership increase over the previous fiscal year. Bike-share and e-scooter usage also continue to grow, with over 665,000 and 1.18 million trips respectively. Programming like *Safe routes to school* and *BIKETOWN for All* is reaching more Portlanders than ever (*Safe routes to school*, n.d.; *About BIKETOWN*, 2025). Policy T-2, which sought to reduce vehicle miles traveled through pricing strategies, faced setbacks. The regional road pricing project was not pursued further, though PBOT continues to integrate the equitable pricing principles into its parking management work. In contrast, Policy T-4 has made significant progress. The Transportation Wallet: Access for All program, which offers free or subsidized access to transit, e-bikes and ride-shares for low-income residents, has more than tripled its outreach since its 2021 pilot (*The Transportation Wallet: Access for All program – Bing*, n.d.). Over 1,300 wallets were distributed in six months and PCEF has committed $25 million over five years to expand the program. These transportation efforts reflect a strong alignment between infrastructure investment and equity-based mobility access.

Citywide policies are increasingly prioritizing vulnerable communities, particularly in East Portland, which experiences both high temperatures and socioeconomic disadvantages. However, gaps persist in ensuring long-term cooling affordability and addressing the disproportionate energy burden on renters, who are 2.4 times less likely than homeowners to have air conditioning (Voelkel et al., 2018).

5. Case Study 2: Vancouver

Vancouver uses several specific plans led by experts to make sure the city focuses on the most important climate issues that will be mentioned in section 5.2. Like Portland, Vancouver went through the extreme 2021 heatwave, when temperatures broke records and went over 40°C. Across BC, 619 people died due to the heat, 117 of them in Vancouver (City of Vancouver, 2024a). In 2023, the Fraser River, which runs through the city, hit its lowest stream flow ever because of very high temperatures (City of Vancouver, 2024a). While this is mainly due to climate change, it is made worse by the UHI effect, which adds to overall warming (IPCC, 2021).

In the 1990s, Vancouver had only about one day each year where the temperature went above 30°C (City of Vancouver, 2024a). By the 2050s, that number is expected to rise to between 6 and 29 days every year, with at least a 50 % chance of getting more than 9 (City of Vancouver, 2024a). Nights with temperatures above 16°C used to happen around 6 times a year (City of Vancouver, 2024a). By the 2050s, that could jump to between 43 and 92 nights (City of Vancouver, 2024a). The number of heatwaves per year is also expected to rise dramatically, from 9 to 46 (City of Vancouver, 2024a). These numbers are alarming and show why strong action on heat and climate is urgently needed.

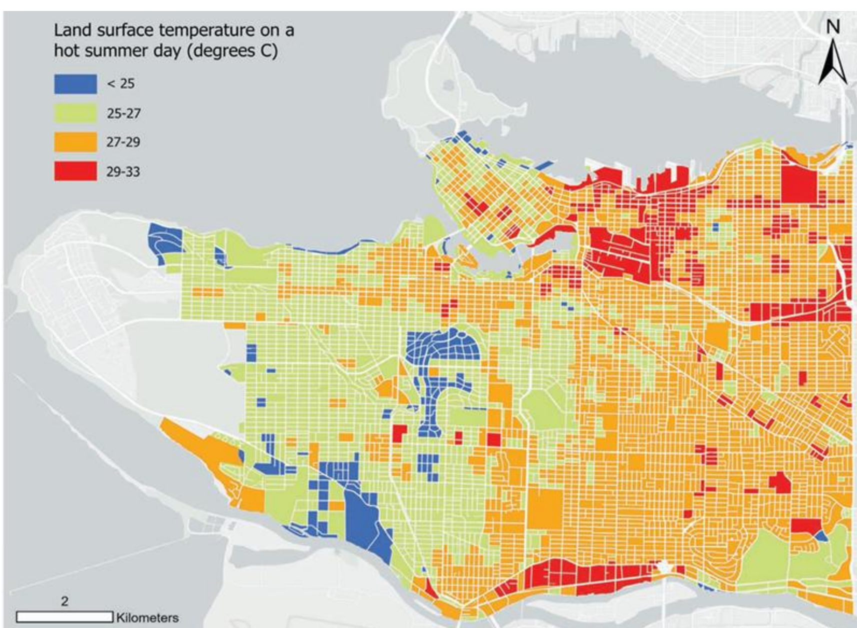

Figure 5: Land surface temperature on a hot summer day in Vancouver (City of Vancouver, 2024a).

The map above shows land surface temperatures in Vancouver during the summer. As seen, the city centre has the highest surface temperatures, highlighting it as a key area that needs attention and targeted cooling strategies.

5.1. *Spatial Analysis*

5.1.1. Vulnerable Population

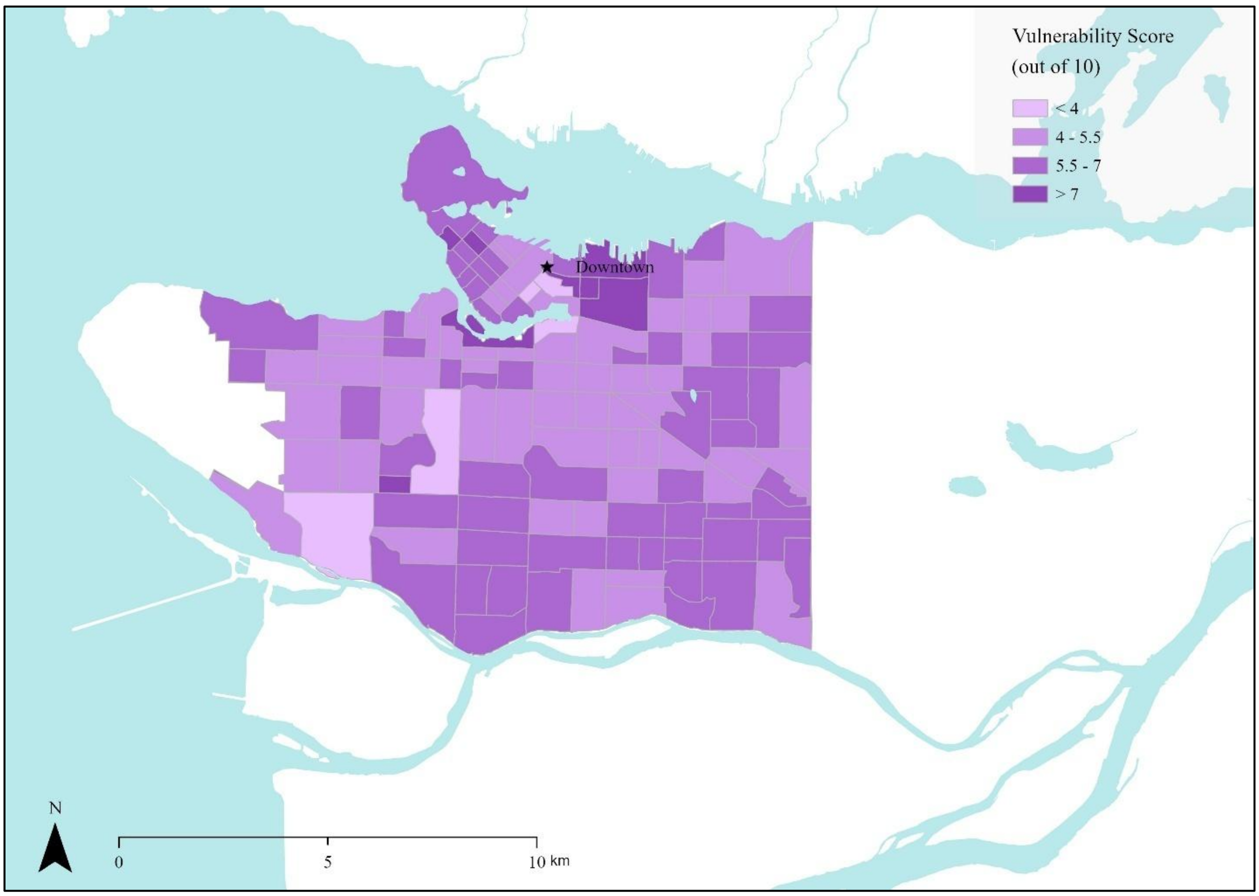

Figure 6: Figure 2: Vulnerability population in Vancouver. Source: Vancouver Open Data Portal.

The vulnerability map of Vancouver (Figure 6) shows that the city centre has a high concentration of vulnerable populations. This is concerning because, as shown in the previous map (Figure 5), this area also experiences the hottest surface temperatures during summer heatwaves. This overlap raises serious concerns for residents' health and safety. Interestingly, one census tract (CT) in the city centre actually has one of the lowest vulnerability scores (under 4/10), while the other two low-scoring CTs are located on the west side of Vancouver.

Using GIS's spatial join and statistical summary tools, the vulnerability scores were calculated for all CTs and produced descriptive statistics. CTs with scores between 4 and 7 are scattered throughout the city with no clear spatial pattern. The statistical results showed the vulnerability scores follow an approximately normal distribution, with the mean (5.6) and median (5.5) close in value and no extreme outliers evident on the histogram. Similar to Portland, only one CT reached a final score above 10 (10.2), with 138 CTs in total, its effect on both the mean and median is also considered negligible.

5.1.2. Green Coverage

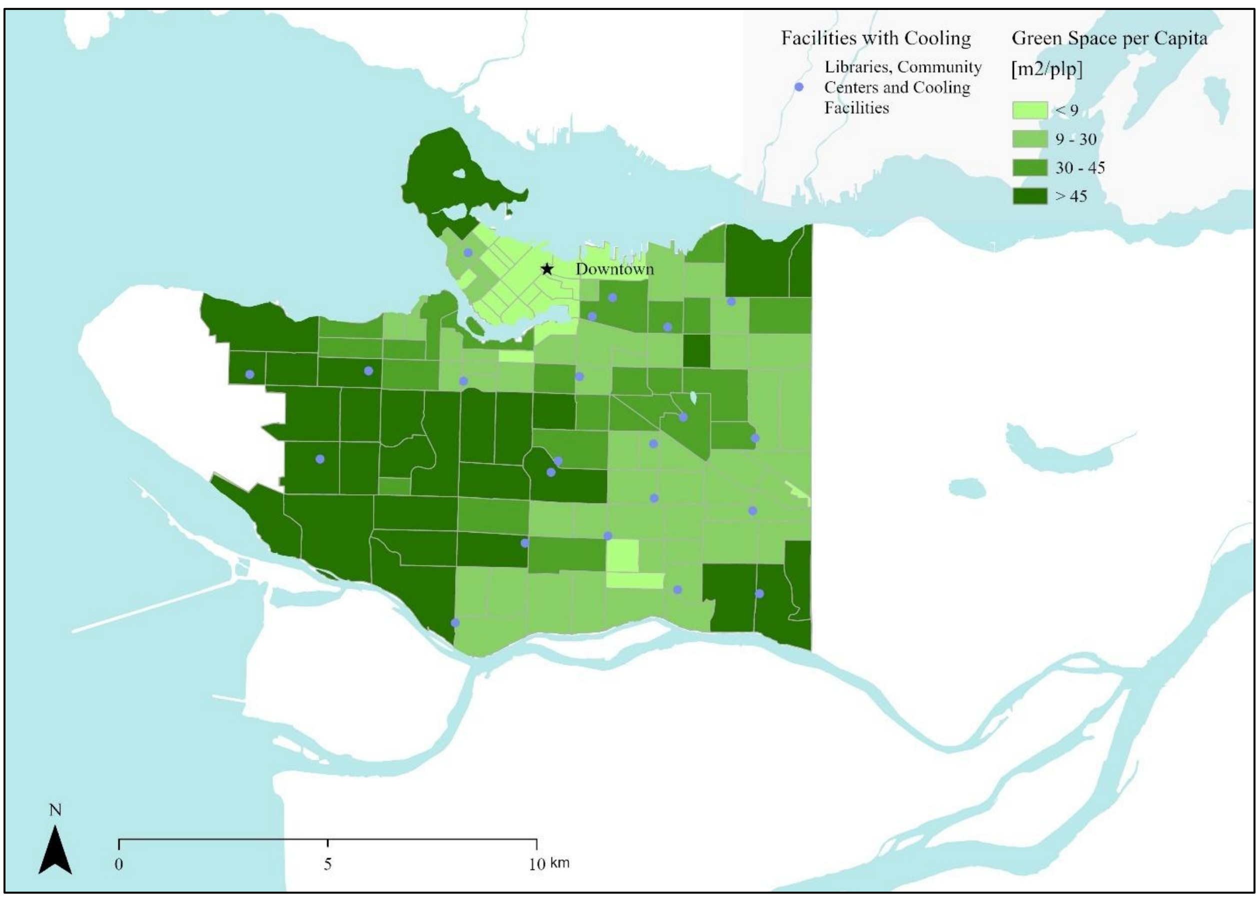

Figure 7: Green Space per Capita per CT with public facilities with cooling in Vancouver. Source: Vancouver Open Data Portal.

Figure 7 illustrates the distribution of green space per capita alongside the location of cooling facilities in Vancouver. It shows that the west side of the city generally has more green space per person, while many eastern neighborhoods have far less vegetation in relation to their population, with only a few greener zones in the far south and southeast. The downtown core stands out as having the lowest green space per person, falling below the recommended minimum of 9 m^2 per capita, with two additional CTs in the south also below this threshold. Although some low–green-space CTs are adjacent to heavily vegetated areas, these spaces may not always be equally accessible due to distance, infrastructure barriers or lack of shade along walking routes. The white area at the far west of the map represents Pacific Spirit Regional Park. This area has extensive vegetation but is excluded from the analysis because it lies outside residential zones.

Looking at the GIS's statistical analysis, Vancouver's mean green space per capita is 44 m^2, but the median is only 21 m^2. While this shows some disparity, it is a lot less extreme than in Portland, which had an average of 275 m^2 and a median of just 15 m^2 as discussed in section 4.1.2.. Vancouver's values range from 0 to 643 m^2, reflecting a wide variation that includes highly populated industrial/commercial zones with minimal vegetation as well as CTs made up almost entirely of forested land without many residents.

Cooling facilities (blue dots on the map) are generally well distributed but tend to cluster in the east, where green space is rarer. While the central downtown area is short on such facilities, residents there are close to the waterfront and forested parks, which can provide some natural cooling, though the high vulnerability and small amount of accessible greenery in the core remain areas of concern.

Table 3: Vancouver, Green Space.

	Less than 9 m^2	Between 9 and 50 m^2	Above 50 m^2
Number of CTs	31	79	28
Population affected	172,313	403,218	144,049
Average Vulnerability Score	5.34	5.76	5.33

About 172,000 residents live in CTs with less than 9 m^2 per capita and a much larger share (over 403,000 people and 79 CTs) have between 9 to 50 m^2 per capita. In total, this means that roughly two-thirds of Vancouver's population resides in areas below the “ideal” 50 m² per capita benchmark. The highest mean vulnerability (5.76) appears in the 9–50 m² per capita bucket, while both the lowest and the highest end of the green space spectrum record nearly identical values (5.34 and 5.33, respectively). This suggests that while low green space can exacerbate heat exposure, it is not a consistent predictor of social vulnerability across the city. Correlation analysis confirms this: the coefficient between green space access and vulnerability is –0.01, essentially indicating no statistical relationship. Vancouver stands out with about 25% of its urban area considered green space. However, as shown, high total green coverage does not automatically guarantee neighborhood-level accessibility, especially in the dense city center and eastern CTs where green spaces are sparse and less accessible to vulnerable populations. This highlights the importance of pairing overall green space provision with targeted strategies to improve access where it is needed most.

Overlaying this information with the city’s heat vulnerability map highlights two priority areas for concern. First, the eastern portion of Vancouver has comparatively low vegetation, lies further from the ocean and therefore lacks the natural cooling effect and contains several CTs scoring between 4.0 and 5.5 out of 10 on the vulnerability index. Second, the central area also contains CTs with vulnerability scores around 4.0, combined with extremely low green space per capita, further increasing residents’ exposure to heat risk.

5.1.3. Built Environment

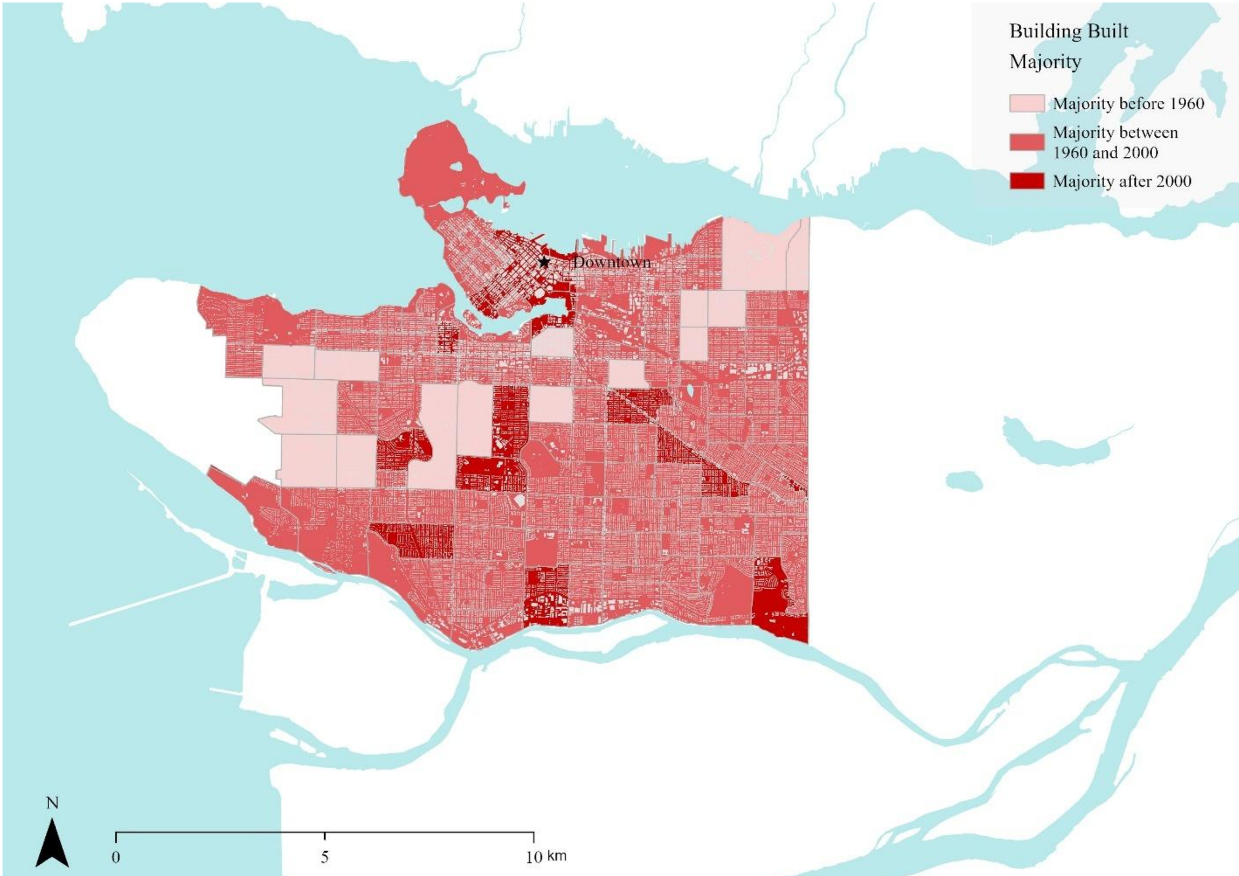

Figure 8: Built Environment of Vancouver. Source: Vancouver Open Data Portal.

Figure 8 shows the predominant age of building construction and its concentration in Vancouver by CT. Unfortunately, due to data limitations, building height information was unavailable. Even so, it can be seen that in the city centre, most buildings were constructed before 1960. This dense urban fabric, with its concentration of older, multi-storey buildings create conditions likely to intensify the UHI effect. As mentioned previously, these can be named “street canyons” and they can trap heat and limit airflow.

This aging building stock in central Vancouver presents several challenges. Combined with high population density and very limited green space, residents are at higher risk. Older buildings are more likely to have poor insulation, lack air conditioning and offer little opportunity for individuals to implement cooling adaptations due to rental restrictions or financial limitations.

Beyond the centre, the map shows a more mixed distribution of building ages. Most CTs are dominated by structures built between 1960 and 2000, spanning the city except for the far southeast and a small area where post-2000 development is clustered. However, the fact that most buildings city-wide were built between 1960 and 2000 suggests that a significant portion of Vancouver's residential stock may still lack modern energy efficiency standards and heat-resilient features.

Spatially, there is no strong pattern outside the central and southeast areas, indicating diverse development histories across neighbourhoods. However, the centre stands out as uniquely challenged by the combination of dense, older buildings and low vegetation.

Overall, when overlaid with the green space and cooling facility data, this map reinforces the conclusion that the most at-risk areas, particularly the central and eastern neighbourhoods combine dense, older construction with low green space availability, limited airflow and high heat vulnerability. These overlapping disadvantages underscore the need for targeted adaptation and retrofit strategies to better protect residents from extreme heat.

5.2. *Critical Policy Review*

Vancouver's Climate Change Adaptation Strategy is supported by several interconnected plans that address specific priorities (City of Vancouver, 2024a). The Vancouver Plan is a long-term land use vision focused on livability, sustainability and climate protection (City of Vancouver, 2022). The UNDRIP Strategy, developed in collaboration with local First Nations, focuses on Indigenous rights and self-determination (City of Vancouver, 2024b). The Equity Framework aligns city operations around fairness and inclusion (City of Vancouver, 2021). Resilient Vancouver focuses on preparing for shocks like earthquakes and climate risks, while the Hazard & Risk Explorer helps identify and address vulnerabilities (City of Vancouver, n.d.; City of Vancouver, 2025a). Other plans like the Climate Emergency Action Plan, Rain City Strategy, Healthy City Strategy, Urban Forest Strategy and Groundwater Strategy target specific areas such as emissions, water, health, ecosystems and natural infrastructure (City of Vancouver, 2020; City of Vancouver, 2019; City of Vancouver, 2014; City of Vancouver, 2025b; City of Vancouver, 2018). Together, these plans guide coordinated, equitable and climate-resilient city planning. To provide a more comprehensive understanding of the equity in the current mitigation strategies for the UHI effect in Vancouver, this report focuses on the policies introduced in the Climate Change Adaptation Strategy.

The strategy also includes a prioritization matrix to assess the urgency and feasibility of each proposed action. Each criterion is scored from 1 to 4, with 4 being the highest, allowing the City to systematically prioritize actions based on a balanced assessment of equity, feasibility and effectiveness. This matrix evaluates each action across several dimensions, including its response to equity concerns, alignment and mutual benefits with the goals of other levels of government and local communities and the City's own capability (financial, technical and operational) to implement it. It also considers whether the action falls within the City's jurisdiction, the clarity of its accountability structure with a clear implementation pathway, the urgency in terms of immediate climate risks and finally, its potential impact on intended beneficiaries. This structured approach demonstrates a well-thought-out plan with clear implications for implementation.

5.2.1. Tree Planting and Landscaping

The city has committed to increasing the tree canopy to 30% by 2050, with a specific focus on neighborhoods that currently have below-average canopy cover and high proportions of paved surfaces (City of Vancouver, 2024a). Policy H3.1 outlines the city's continued efforts to advance tree planting on public land, specifically targeting heat-vulnerable communities. The explicit equity outcome attached to this action recognizes that these neighborhoods experience more intense heat due to historical disinvestment in green infrastructure.

Complementing this commitment, Policy H3.2 mandates the installation of 20–40 new tree pits per year in low-canopy areas. Like H3.1, the equity outcome associated with H3.2 identifies that these interventions are most beneficial for residents exposed to higher urban heat levels, where canopy gaps intersect with socio-economic disadvantage.

To ensure the long-term resilience of its urban forest, Vancouver has also introduced Policy H3.3, which involves the implementation of three pilot tree-planting projects that assess the performance of climate-adapted tree species. The results from these pilots will inform future citywide planting decisions, helping to reduce tree mortality during extreme heat and drought events. Again, the equity outcome highlights that this approach benefits neighborhoods with lower canopy coverage and less adaptive capacity, reinforcing the city's commitment to targeted, data-informed planning.

Vancouver also recognizes the critical role that private land plays in the urban forest. Policy H3.4 focuses on identifying priority areas for tree planting and retention on private land, which comprises over 35% of the city's canopy (City of Vancouver, 2024a). Existing trees on these lands are at risk due to increasing development pressures. The equity implications are clear: canopy cover on private property is unevenly distributed, reflecting patterns of historical exclusion and unequal land use planning. Understanding where canopy is being lost and where it can be expanded, will help guide future interventions. To this end, Policy H3.5 calls for the development of a monitoring system to track changes in private land canopy due to permitted tree removal, informing both retention targets and best practices for urban forestry management.

5.2.2. Green Infrastructure and Buildings

Vancouver's climate adaptation strategy places significant emphasis on its building stock, particularly in light of rising temperatures and the vulnerability of residents in aging, poorly insulated, or unequipped structures. Policy H1.2 initiates work to assess the feasibility (technically, economically and legally) of reducing indoor temperatures in existing multi-family residential buildings. These buildings, which often lack cooling systems, house many of the city's most heat-vulnerable populations, including seniors, renters and socially isolated individuals. This shows that the City recognizes its residents are not only more likely to be exposed to extreme heat but also have fewer personal or financial resources to cope with it.

To address this gap more directly, Vancouver has introduced Policy H1.3, which commits to launching a multi-family heat pump incentive and owner support program in 2024. Developed in collaboration with BC Hydro, the Province of BC and the Zero Emissions Innovation Centre, the program aims to shift the focus of financial incentives, traditionally available mostly to single-family homeowners, toward multi-family buildings. Directing public funds toward rental and non-profit housing ensures life-saving cooling technologies reach those most at risk, rather than those with the most resources.

These efforts are bolstered by retrofit programs aimed at rental and non-profit housing. Policy H1.4 supports the implementation of the Rental Apartment Retrofit Accelerator and Non-Profit Resilient Retrofit Grant programs, which aim to upgrade approximately 30 buildings. These retrofits will improve cooling and reduce emissions, while producing case studies and insights for broader policy reform. The associated equity outcome recognizes that renters often lack control over indoor temperatures and are more vulnerable to heat-related health risks. These programs aim to make cooling more accessible without triggering rent increases or displacement.

While long-term retrofits are necessary, short-term research is equally vital. Policy H1.5 outlines the city's plan to complete a study on cooling measures in existing multi-family buildings, in partnership with Metro Vancouver and the City of North Vancouver. The study will explore retrofit strategies that avoid carbon increases, prevent displacement and address housing inequity, recognizing that solutions must protect the environment but the community as well.

Forward-looking building standards are also being enacted. Policy H1.6 introduces a mandatory cooling requirement for new multi-family buildings under the Vancouver Building By-law (VBBL), effective in 2025. It also explores extending similar requirements to 1–3 story residential buildings. This policy seeks to standardize access to thermally safe homes, which is especially significant for residents of rental and social housing, where mechanical cooling has historically been less common. By embedding cooling into future development standards, Vancouver is pre-emptively addressing equity gaps in thermal safety.

Lastly, Policy H1.7 focuses on advocating for changes to provincial regulations (specifically the Strata Property Act and Residential Tenancy Act) that currently limit cooling installations in many buildings (Chang, 2022). These legislative barriers often prevent tenants from accessing essential cooling measures. Enabling residents to cool their homes safely is a critical step toward preventing heat-related illness and death, particularly among those who have little agency over their housing conditions.

5.2.3. Emergency Preparedness

Vancouver's emergency preparedness policies focus on providing immediate and equitable support to those most at risk during heat events. A cornerstone of this strategy is Policy H1.1, which expands upon the 2022–2023 Cool Kit project. Delivered in partnership with community organizations and Vancouver Coastal Health, the initiative wants to provide 6,500 kits to residents lacking mechanical cooling. The kits are designed to help people remain safe in their homes during heatwaves, especially those who cannot travel to public cooling centres. The program ensures that the most vulnerable populations are not left behind during extreme heat events. The strong community partnerships demonstrate thoughtful collaboration and essential support. This targeted intervention not only reduces health risks but also fosters trust and resilience within communities.

Policy H1.8 furthers this work by analyzing data from the Measuring Indoor Temperature Initiative. Conducted in partnership with public health agencies, this initiative investigates how outdoor temperatures translate into dangerous indoor heat, particularly in older or poorly ventilated buildings. Its findings will guide future heat response strategies and building policies. The associated equity outcome recognizes that high indoor temperatures were the primary cause of mortality during the 2021 heat dome. By linking building type and social vulnerability, this policy equips the city to respond more effectively to future emergencies. This data-driven and equity-focused policy not only enhances emergency preparedness but also lays the groundwork for long-term improvements in housing quality and public health outcomes.

5.2.4. Planning and Energy/Other

Vancouver's broader planning efforts include targeted investments in civic infrastructure and initiatives focused on highly vulnerable populations. Policy H2.2 involves retrofitting two community-use facilities and one civic operation building with mechanical cooling.

Even though it is only two buildings, these retrofits are located in underserved areas to ensure they are accessible to residents who lack cooling at home. In addition to benefiting community members, these upgrades also support the health and safety of city staff during heat events.

Policy A1.1 directs the city to work with partners to address the unique needs of unhoused residents and those experiencing housing precarity during climate-related events. Vancouver acknowledges that these individuals are disproportionately exposed to environmental hazards such as heat, smoke and flooding. This policy initiates the development of more low-barrier, indoor respite spaces to ensure that unhoused people have safe, dignified places to shelter during emergencies. This approach prioritizes the safety of residents who are most often excluded from traditional safety frameworks.

Although transportation plays a smaller role in Vancouver's UHI mitigation strategy, it includes a critical equity intervention: Policy H2.1 launches an extreme heat transportation pilot for seniors and individuals with disabilities. During the 2021 heat dome, these populations experienced disproportionate mortality while sheltering in place. The program provides taxi vouchers that enable vulnerable residents to access cooling centres when public transit or walking is not a viable option. By addressing the mobility barriers that often leave these communities isolated during emergencies, the policy aims to improve health outcomes and reduce avoidable deaths. This initiative exemplifies a low-cost, high-impact adaptation strategy that centers vulnerable populations. It also highlights the importance of integrating transportation planning into climate resilience work, ensuring that infrastructure and services are accessible during times of crisis.

6. Policy Analysis

6.1. *Discussion*

Both cities respond to many of the core recommendations outlined in the UN's Sustainable Cooling Handbook for Cities: they use data to identify vulnerable areas, they coordinate across sectors and they aim to reach communities most impacted by urban heat (UN, 2022). However, while they demonstrate many best practices in policy design, they face shared challenges around funding, materials-based cooling interventions and implementation timelines.

Both cities have prioritized tree planting and urban forestry as central elements of their UHI strategies. In Vancouver, this is embedded in a suite of policies that target tree canopy expansion specifically in low-income, low-canopy areas. The city also monitors private tree removal and invests in climate-adapted tree species, showing a long-term, data-informed approach. Similarly, Portland's *Equitable Tree Canopy* Program is focused on East Portland, where vulnerability and heat exposure are highest (PCEF, 2024). These actions directly reflect UN recommendations to use localized data to prioritize green infrastructure in heat vulnerable population zones and to ensure that the cost burden of climate resilience does not fall on those least able to afford it. However, such green infrastructure recommendations face practical space constraints in high-density areas, where land for planting is limited and maintenance costs can be a barrier to sustained canopy coverage.

In terms of building design and retrofits, both cities have made progress, but Vancouver's policy structure is notably more comprehensive. Policies like H1.2 to H1.6 support cooling retrofits in existing multifamily buildings, launch heat pump incentive programs and introduce mandatory cooling requirements for new construction, all while centering renters and residents of non-profit housing (City of Vancouver, 2024a). This addresses the UN's call to reduce cooling demand in buildings through regulation, particularly in housing for marginalized groups. Portland, through HEART standards and its Clean Energy Fund (PCEF), has installed heat pumps in over 1,700 homes (City of Portland, 2024). Yet the recommendation to integrate cooling into building codes and retrofit policies carries its own limitations; retrofitting older buildings can be technically and financially challenging and there is a risk that costs may be passed on to tenants unless strong anti-displacement safeguards are enforced.

Both cities also prioritize emergency preparedness, recognizing that many deaths during heat events stem from indoor overheating and lack of access to cooling. Vancouver's *Cool Kit* distribution program, developed with public health agencies, is an innovative and low-barrier intervention. It reflects the UN's emphasis on "last-mile cooling", bringing adaptation resources directly to people who cannot leave their homes. Vancouver's data partnerships also allow it to track indoor temperatures in older buildings, helping refine future building and emergency policies. Portland, meanwhile, has invested in upgrading cooling shelters and clean air refuges and has expanded OSHA protections for outdoor workers. These efforts align with the UN's call to tailor heat preparedness to specific at-risk groups, including laborers, seniors and those living alone or in poor housing conditions.

Vancouver's Cool Kit program, temperature monitoring efforts, Portland's improved cooling shelters and protections for outdoor workers all focus on bringing cooling help directly to the people who need it most, especially those who cannot easily access AC or cooling centers. However, recommendations to expand emergency readiness face coordination and outreach challenges, especially in ensuring that measures reach socially isolated individuals and linguistically or culturally diverse groups who may not access mainstream communication channels.

Transportation and accessibility policies also intersect with UHI mitigation, though the two cities approach them differently. Portland's Transportation Wallet: Access for All program offers low-income residents access to transit, e-bikes and car-share services, improving their ability to reach cooling facilities or green spaces. Vancouver's senior-focused transportation pilot offers heatwave taxi vouchers to mobility-impaired residents. Both policies respond to the UN's recommendation to reduce physical and financial barriers to cooling access, especially for vulnerable populations who may otherwise remain in overheated spaces.

A critical strength shared by both cities is their commitment to interdepartmental coordination and community engagement, with tools like Vancouver's equity-feasibility-impact prioritization matrix and Portland's embedded climate goals across bureaus. These align with UN guidance on cross-sector governance. However, even with this commitment, better cross-department teamwork is still held back when departments work in isolation, have different priorities, or when frequent changes in leadership disrupt ongoing plans.

An often-overlooked challenge lies in busy city centers, which are among the hottest zones due to density, traffic, heat-retaining surfaces and minimal green space. These districts are often deprioritized because of land constraints, high economic activity and the disruption caused by major interventions. Yet they see some of the most concentrated daily human activity, making tailored strategies essential for meaningful inclusion in cooling plans. Tailored strategies will be essential if downtowns are to be meaningfully included in future cooling plans.

Yet despite these strengths, both cities fall short in a critical area long recognized as a major contributor to the UHI effect: materials-based cooling solutions. Measures such as reflective or cool roofing, light-colored pavements, permeable surfaces and passive building design are largely absent from current planning frameworks. These interventions are high-impact and have proven effective in cities like Los Angeles and Ahmedabad to significantly reduce surface and ambient temperatures (UN, 2022), but can be costly, technically complex to retrofit and slow to deliver visible results. Given that many buildings in both cities are older and may face demolition or redevelopment, there is a clear opportunity to embed such solutions into new projects from the outset. Integrating reflective and permeable materials, along with passive design features, into building codes and planning requirements would gradually shift the urban fabric toward cooler outcomes, particularly in dense areas where tree planting is limited. Portland's ecoroof mandate for city-owned buildings represents modest progress, but broader adoption remains limited. Beyond individual materials, urban form and building geometry must also be considered as part of a holistic approach to UHI mitigation. New developments should be evaluated not only for how much heat they retain internally, but also for how their shape, materials and positioning influence the microclimate of surrounding areas. This approach considers both the heat retained by the building itself, but also its impact on the surrounding environment, making it vital for future progress. Without it, cities risk overlooking the full potential of design to reduce urban heat exposure across entire communities.

However, realizing these and other cooling ambitions will depend on long-term funding. While both cities have well-articulated strategies and ambitious targets, several programs remain underfunded or delayed. In Portland, multiple policies have stalled due to budget gaps. Vancouver's retrofit and resilience programs, while carefully designed, depend heavily on partnerships with senior levels of government and may be difficult to scale citywide without stable, long-term funding. Sustainable finance is important to ensure that cooling policies move beyond planning and into full-scale implementation.

6.2. *Contribution of the research to urban planning*

This research contributes to urban planning by showing how data-informed, place-based strategies are essential for building resilient and equitable cities. The comparative analysis of Vancouver and Portland demonstrates that localized planning, supported by tools like GIS mapping and climate modeling, allows planners to identify high-risk zones and prioritize interventions accordingly. These tools reveal patterns in heat exposure, green space distribution and social vulnerability, helping cities move beyond one-size-fits-all planning approaches. Every neighborhood is different and urban planning must adapt to these differences in a targeted and responsive way.

Another major contribution of this work is its emphasis on cross-sector collaboration. The case studies show that effective urban heat mitigation requires coordination between planning departments, public health agencies, community organizations and infrastructure teams. This kind of collaboration ensures that technical solutions, such as green infrastructure or building retrofits, are also socially equitable and aligned with real community needs.

A third contribution is the integration of equity as a guiding principle. This research highlights how cooling strategies can be designed to directly address historical patterns of exclusion. This means embedding equity into zoning, building codes and emergency response ensuring that new developments include mandatory green infrastructure and that existing buildings in high-risk areas have access to retrofitting programs. As the UN Sustainable Cooling Handbook also notes, equitable access to cooling is a key pillar of climate resilience (UN, 2022).

Overall, this research offers practical insights for urban planners looking to design cities that are not only environmentally sustainable and energy-efficient, but also socially just. By analyzing real-world examples and aligning them with global recommendations, the project helps identify how cities can implement cooling strategies that are both grounded in data and responsive to people's lived realities.

6.3. *Future research directions and recommendations*

A major policy gap lies in the role of urban materials and form. While most policies today emphasize tree planting or building efficiency, materials like dark asphalt and black rooftops continue to worsen urban heat. Lighter, reflective materials and permeable surfaces can significantly reduce surface temperatures, yet they are largely missing from current strategies in Vancouver and Portland. Cities like Los Angeles and Ahmedabad show that cool roofs and reflective pavements can work, especially in low-income areas where heat exposure is highest. Future policies must prioritize these low-cost, high-impact solutions (UN, 2022).

Urban design and building geometry also need more attention. The height, shape and layout of buildings affect airflow, shading and how heat circulates in dense areas. Without good design, cities create "urban canyons" that trap hot air and worsen heat exposure. The UN recommends that cities model wind and sun patterns when planning new developments (UN, 2022). Cities like Singapore and Tokyo already do this and their methods could be adapted in places like Vancouver and Portland. Yet this approach is missing from both cities' current policies.

Funding is another area where attention is needed. Many good policies are delayed because of limited budgets or unclear priorities. Both cities publish annual progress reports, which provide useful data for asking: Where is the funding going? Are there delays because of low prioritization, or are budgets simply too tight? Could cities shift funding from other areas to support UHI mitigation more effectively? Research into city budget structures could help identify where more investment is needed and how it can be achieved without undermining other services.

This study also shows that collaboration across departments is essential. Vancouver and Portland both work across planning, health, housing and emergency services to deliver more effective responses. But more policy is needed into how other cities can build similar models. Governance structures that encourage joint action can help cities avoid unintended consequences, like increased energy use or the displacement of vulnerable residents. Community involvement is also key. Policies work best when residents, NGOs and local organizations are involved in shaping them. Future policies should look at how to make this engagement meaningful and continuous, not just one-off consultations.

In short, future policies should focus on materials, urban design, funding priorities and governance models. UHI mitigation must be integrated into how cities are built, funded and governed and always with equity at the center.

7. Conclusion

This study has explored how two cities, Vancouver and Portland are responding to the growing threat of urban heat through policies, planning strategies and on-the-ground actions. The research looked closely at how urban heat affects different neighborhoods and how each city is using data, planning tools and community-focused programs to reduce those effects. By comparing their efforts and evaluating how they align with the UN's Sustainable Cooling Handbook for Cities, the study provides a clear picture of what is working, what is missing and what can be improved.

The central question of this research was: *How can cities better integrate UHI mitigation strategies into urban planning and policy frameworks to ensure both effectiveness and equity?* The findings show that both Vancouver and Portland are making important progress, but in different ways. The experience of these two cities shows that even constrained, phased improvements can yield important benefits if guided by spatial evidence and community engagement. For future-oriented urban resilience planning in other cities, the lesson is that, while the starting point may be uneven and the challenges complex, the path forward is achievable if actions are targeted, sustained and equity-led.

To address the persistent inequities in heat resilience identified in this study, cities should start by prioritizing interventions in neighborhoods that combine high heat exposure with socio-economic vulnerability. These priorities must also include busy city centers, where high density, traffic and minimal green space create acute heat risks but where interventions are often delayed by land constraints and economic activity. This means that tree planting, reflective surface treatments, shading infrastructure and building retrofits should first be directed toward those areas most at risk, as shown by spatial and demographic analysis. Where new developments replace older building stock, as seen in both case study cities, there is a cost-effective opportunity to embed materials-based cooling and passive design from the outset. Heat resilience must also be embedded within the core planning processes of the city: zoning codes, land-use permits and infrastructure design guidelines should explicitly integrate cooling requirements so that climate adaptation becomes a standard outcome of development rather than an afterthought.

Equally crucial is the preservation, expansion and interconnection of green infrastructure. Cities should protect mature trees through strong canopy retention bylaws, create new green corridors and ensure public shaded spaces connect into broader cooling networks. At the same time, building adaptation measures must account for housing equity. Retrofit incentives for installing heat pumps, improving insulation, or adding shading devices should specifically target low-income and renter-heavy neighborhoods, with safeguards to prevent passing retrofit costs onto tenants or triggering displacement.

Emergency heat readiness needs to be expanded, with investments in local cooling refuges, mobile relief services and outreach tailored to cultural and linguistic needs so that all residents can access protection during extreme weather. Achieving this will require breaking down policy silos by formalizing collaboration between climate adaptation, housing, public health and transportation departments, ensuring that interventions complement one another and provide compounded benefits.

Finally, progress should be tracked using open, spatially detailed datasets. While recognising implementation challenges such as funding gaps and the complexity of retrofitting dense built environments, a targeted, phased and equity-led approach can deliver meaningful progress. Transparent monitoring of metrics such as land surface temperature, green space and heat-related illness rates, broken down by neighborhood, will allow both policymakers and the public to evaluate the impact of implemented measures and hold institutions accountable. By combining targeted action, integrated governance and transparent measurement, cities can steadily close the gap between current realities and the equitable, climate-resilient urban futures they aspire to build.

In conclusion, this research shows that effective and equitable UHI mitigation requires more than planting trees or handing out ACs. It requires thoughtful, integrated planning that uses data, crosses departments and centers the needs of vulnerable communities. As climate change intensifies, cooling cities will become not just a technical challenge but a key part of creating fair, livable and resilient urban environments.

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