The Urban Heat Island Effect - SDG 11 and 13 Proposal

1. Introduction

Phoenix, Arizona, is a city notoriously grappling with extreme heat, often seeing summer temperatures rise above 110°F (43°C). This relentless heat impacts residents, particularly those in low-income neighborhoods who have limited access to air conditioning and cooling centers, diminishing the quality of life and increasing environmental risks. Additionally, the city's water quality suffers as higher temperatures exacerbate thermal pollution, affecting both aquatic ecosystems and the quality of drinking water. The relentless heat also accelerates the wear and tear on infrastructure, resulting in higher maintenance costs and more frequent repairs. However, it is not just Phoenix that is experiencing this crisis; extreme heat is a growing concern for cities around the globe, and the reason for these issues stems from the phenomena called the Urban Heat Island (UHI) effect. The urban heat island effect is when urban areas become significantly warmer than their rural surroundings due to human activities and development. UHI significantly impacts vulnerable communities, exacerbating heat-related illnesses, deteriorating water quality, and degrading infrastructure. This phenomenon can be compared to a thermal blanket trapping heat within cities. Just as a thermal blanket retains body heat by preventing it from escaping into the cooler surrounding air, urban areas retain heat due to their dense concentration of buildings, roads, and other infrastructure. These structures absorb and store heat from the sun during the day and release it slowly at night, preventing the city from cooling down. This continuous heat retention creates a layer of warmth over the city, much like a thermal blanket keeps the heat in, leading to persistently higher temperatures compared to rural areas. To address this, we must implement targeted urban planning strategies that increase green spaces, enhance building materials, improve energy efficiency, and promote sustainable transportation.

By adopting these strategies, cities like Phoenix can mitigate the effects of The Urban Heat Island Effect, improve the quality of lives, and create more sustainable environments.

2. Summary of Key Findings and Identification of Gaps

2.a) Key Findings from Existing Research

Research consistently shows that UHI intentsidies heat waves within urban areas, leading to higher temperatures compared to surrounding rural areas. The U.S Environmental Protection Agency states this “phenomenon is exacerbated by the concentration of impervious surfaces such as asphalt and concrete, which absorb and re-radiate heat more effectively than natural landscapes” (EPA, 2023)

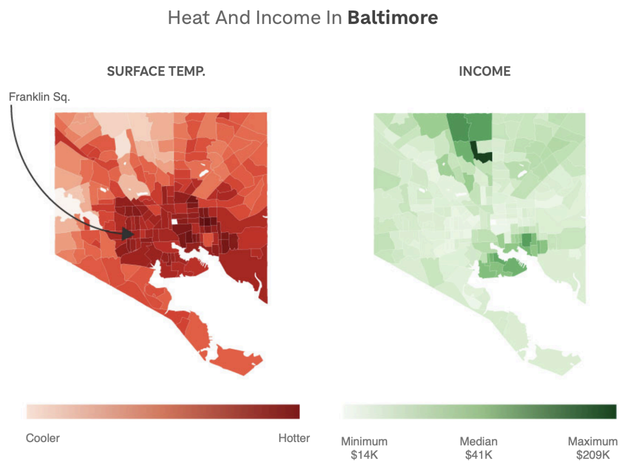
Second, this intensification of the UHI disproportionately impacts low-income and marginalized communities. The populations often reside in areas with fewer green spaces and less access to cooling infrastructure, which exacerbates health risks during extreme heat events. (Harlan & Ruddell, 2011). These communities tend to live in neighborhoods with older, and less energy - efficient housing that offers little protection against extreme temperature. Due to this, residents face higher energy bills to maintain between paying for cooling or other essential needs. Additionally, these areas are more likely to lack adequate healthcare services, making it harder for residents to seek treatment for heat related illness. According to a 2021 report by the Maricopa Association of Governments, states that heat-related emergency room visits in West Valley communities lead to an estimated annual increase in health care expenses of $1.2 million, disproportionately affecting low-income residents who are less likely to afford these additional costs.

Furthermore, the UHI has been linked to thermal pollution in urban water bodies, raising water temperatures and affecting aquatic ecosystems. “Higher water temperatures reduce oxygen levels, threaten biodiversity, and increase the presence of harmful bacteria, which can compromise water quality” (Mohajeri et al, 2021). This in turn impacts vulnerable populations the most as low-income communities, which may already face challenges in accessing clean and affordable water, are disproportionately affected by the degradation of water quality due to UHI-induced thermal pollution. These communities might rely on urban water bodies for various purposes, including fishing, bathing, and even as a source of drinking water when access to treated water is limited. The decline in water quality due to elevated temperatures can exacerbate health risks, leading to higher rates of waterborne diseases and other health issues related to contaminated water. Moreover, these communities are less likely to have access to alternative water sources or the financial means to mitigate the impact of degraded water quality, further entrenching their vulnerability

2.a.1) Key Data Visualizations

The Correlation between the UHIE and Income

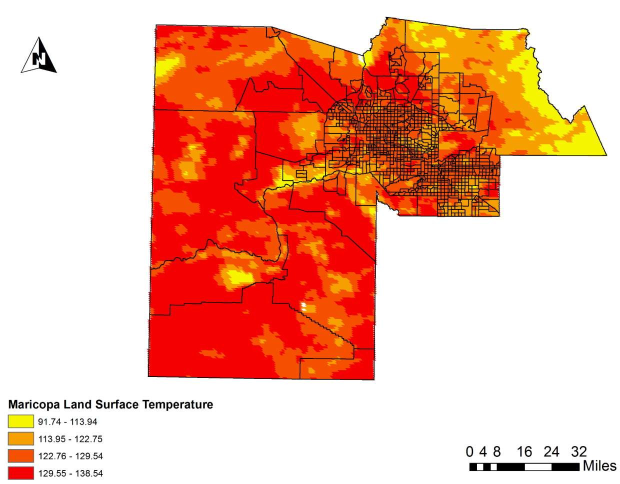
Figure 1



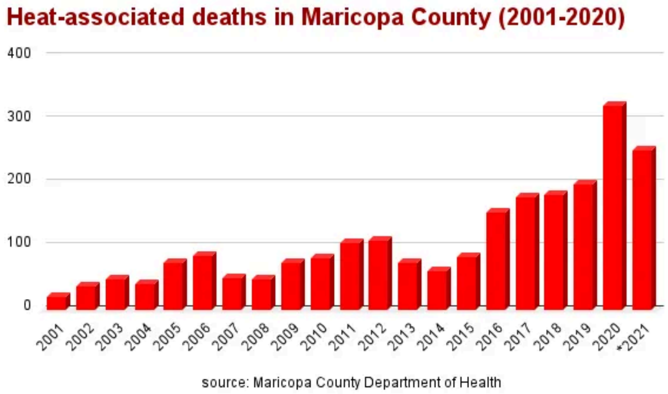
Note: Income measured as median household income per census tract

Source: NASA/U.S. Geological Survey, Census Bureau

Credit: Sean McMinn/NPR



Source: Maricopa County Department of Health



Source: Maricopa County Department of Health

2.b) Identification of Research Gaps

1. Although the UHI effect is well-documented, there is a gap in research on how to effectively integrate UHI mitigation strategies into existing urban planning frameworks. More studies are needed to understand the barriers to implementation and how these strategies can be systematically applied across diverse urban environments.

2. There is a lack of comprehensive economic analysis of the costs and benefits of UHI mitigation strategies. More research is needed to quantify the economic savings from reduced healthcare costs, lower energy consumption, and decreased infrastructure maintenance due to UHI mitigation efforts.

3. Despite the recognition that low-income and marginalized communities are disproportionately affected by UHI, there is insufficient research on how to ensure these communities benefit equitably from UHI mitigation efforts. It is needed to explore how UHI interventions can be tailored to meet the specific needs of vulnerable populations and how barriers such as financial constraints, lack of political influence, and limited access to resources can be overcome. Additionally, research should examine the potential unintended consequences of UHI mitigation, such as the risk of "green gentrification," where improvements in urban infrastructure lead to increased property values and displacement of low-income residents

2.c) Purpose of the Proposed Research

To address these gaps, this research will focus on creating an urban planning framework that integrates UHI mitigation strategies with objectives of Sustainable Development Goals (SDGs) 11 and 13. This research aims to develop actionable guidelines for integrating UHI mitigation strategies into urban planning practices, with a focus on overcoming implementation barriers and ensuring that these strategies are adaptable to various urban contexts.

3. Guided Research Question

3.a) Primary Research Question: What are the most effective urban planning and policy strategies to mitigate the Urban Heat Island (UHI) in cities, particularly in low-income neighborhoods?

This question will help identify and evaluate existing strategies, understand the impact on low-income neighborhoods, develop recommendations, and explore the integration into urban planning frameworks.

4. Existing Policies and Proposed Improvements

5.a) Existing Policies in Different Cities

Phoenix Arizona:

1. Cool Roofs Program: The city has incentivized the installation of cool roofs, which are designed to reflect more sunlight and absorb less heat than standard roofs (City of Phoenix, 2020).

Effectiveness of this policy: Research has indicated that cool roofs in Phoenix can reduce rooftop temperatures by up to 30°F (16.7°C), which translates into a decrease in indoor cooling energy demand by about 15% to 20% (City of Phoenix, 2020). However, the implementation of cool roofs has been uneven, particularly in low-income neighborhoods where property owners may lack the financial resources to invest in these technologies. As a result, these areas have not seen the same level of temperature reduction and energy savings as more affluent neighborhoods.

2. Tree and Shade Master Plan: This plan aims to increase the tree canopy coverage to 25% by 2030 to provide natural cooling through shade and evapotranspiration (City of Phoenix, 2010).

Effectiveness of this Policy: The expansion of the urban tree canopy has led to localized cooling effects, with surface temperatures under tree canopies being up to 45°F (25°C) cooler than exposed areas (City of Phoenix, 2010). However, the overall tree canopy coverage in Phoenix is still relatively low, at around 12%, and is even lower in low-income areas. These neighborhoods often lack adequate green space, resulting in less cooling and greater exposure to heat-related health risks.

3. Reflective Pavements: Phoenix has piloted the use of reflective pavement coatings that aim to reduce surface temperatures by reflecting more sunlight (Yang et al, 2020).

Effectiveness: Initial studies on the reflective pavement pilot projects in Phoenix showed a surface temperature reduction of about 10°F to 12°F (5.6°C to 6.7°C) on streets where these coatings were applied (Yang et al., 2020). Despite these promising results, the deployment of reflective pavements has been limited, and many low-income neighborhoods have not yet benefited from this technology.

New York City, New York

New York City has implemented the "Cool Neighborhoods NYC" initiative, a UHI mitigation plan that includes:

1. Planting of Trees and Green Spaces: The initiative focuses on expanding the urban tree canopy and increasing green spaces in vulnerable neighborhoods (NYC Mayor's Office, 2017).

Effectiveness of this policy: The expansion of urban green spaces, including the planting of over 1 million trees through the MillionTreesNYC initiative, has had a notable cooling effect, particularly in densely populated areas. Parks and tree-lined streets have recorded surface temperature reductions of up to 10°F (5.6°C), providing much-needed relief during the summer (NYC Parks, 2020). However, the distribution of these green spaces remains uneven, with lower coverage in some of the most heat-vulnerable communities.

2. Cool Roofs NYC Program: Similar to Phoenix, this program incentivizes the installation of cool roofs across the city, with a focus on buildings in heat-vulnerable neighborhoods (NYC Department of Environmental Protection, 2019).

Effectiveness of this initiative: The "Cool Roofs NYC" program has led to the installation of over 10 million square feet of reflective roofing materials across the city. These cool roofs can reduce rooftop temperatures by up to 30°F (16.7°C), significantly lowering indoor cooling energy consumption and providing relief during heatwaves (NYC Department of Environmental Protection, 2019). However, the program has encountered challenges in scaling up in low-income areas, where building owners may lack the resources to participate.

3. Cooling Centers: The city has established a network of cooling centers that provide refuge during heatwaves, particularly targeting low-income and elderly populations (NYC Emergency Management, 2018)

Effectiveness of this initiative: The city has established a network of 500+ cooling centers designed to provide refuge during heatwaves, particularly for vulnerable populations such as the elderly and those with pre-existing health conditions. Despite this, challenges persist in ensuring that these centers are accessible to all who need them. Surveys have indicated that up to 30% of residents in targeted neighborhoods were unaware of the availability of cooling centers, pointing to gaps in outreach and public awareness efforts (NYC Emergency Management, 2018).

Singapore

Singapore's approach to UHI mitigation is integrated into its broader urban planning and environmental policies:

1. Green Building Standards: The Green Mark Scheme requires new buildings to incorporate green roofs, vertical gardens, and energy-efficient systems to reduce urban heat (Building and Construction Authority Singapore, 2020)

Effectiveness of policy: Singapore's extensive implementation of green infrastructure has resulted in a significant reduction in urban temperatures. Studies have shown that green spaces and urban trees can lower ambient temperatures by up to 7°F to 10°F (3.9°C to 5.6°C) in areas with high vegetation density (Ng et al., 2012). These reductions are particularly notable in areas with a high concentration of parks, rooftop gardens, and vertical greenery.

Although the Green Mark certification system promotes energy efficiency and sustainability, the high costs associated with constructing and maintaining Green Mark-certified buildings often result in higher property values and rental costs. "This can lead to affordability issues for low-income residents, potentially pushing them out of these more sustainable, cooler buildings into older, less energy-efficient housing that may not benefit from UHI mitigation measures". (Yuen & Kong, 2018).

2. Urban Greening and Parks: Singapore's extensive urban greening efforts include the development of parks, community gardens, and the planting of roadside trees. The "City in a Garden" vision has led to the creation of interconnected green corridors throughout the city (National Parks Board, 2019).

Effectiveness of policy:

The increase in green coverage has also led to better air quality in the city. Vegetation in urban areas helps to filter pollutants and reduce particulate matter, leading to a 10% to 15% improvement in air quality in districts with extensive greenery compared to less vegetated areas (National Environment Agency Singapore, 2020). However, the enhancement of urban environments through UHI mitigation strategies can lead to gentrification, where rising property values and living costs force out lower-income residents. As these areas become more desirable due to improved livability, there is a risk that the original, low-income residents may be displaced by wealthier newcomers, exacerbating social inequality.

3. Water Features: The incorporation of water features in urban design, such as ponds, fountains, and rivers, helps to cool the environment through evaporative cooling (Urban Redevelopment Authority, 2021).

Effectiveness of policy: Incorporating water features into the urban landscape, such as the Marina Bay Sands and Bishan-Ang Mo Kio Park, has also contributed to cooling effects, with localized temperature reductions of 2°F to 4°F (1.1°C to 2.2°C) in surrounding areas. These water bodies help to dissipate heat and increase humidity, creating a cooler microclimate (Public Utilities Board Singapore, 2018).

5.b) Policy gaps and challenges

Similarities: All three cities emphasize the importance of green infrastructure and cool roofs as key strategies for mitigating UHI. These efforts have led to measurable reductions in urban temperatures and improvements in public health outcomes.
Differences:

1. Implementation Scale and Focus: Singapore's approach is more integrated and systemic, with UHI mitigation strategies woven into the fabric of urban planning and environmental policy. In contrast, Phoenix and New York City have implemented more targeted interventions, often with varying success in low-income neighborhoods.

2. Equity and Accessibility: While New York City has made efforts to prioritize vulnerable communities, challenges remain in ensuring equitable access to UHI mitigation benefits. Phoenix's policies have shown limited impact in low-income areas, highlighting a need for more inclusive approaches.

5.d) Proposed Improvements for Cities world-wide

To enhance the effectiveness and equity of Urban Heat Island (UHI) mitigation strategies globally, cities must adopt more integrated, inclusive, and sustainable approaches. The following proposed improvements aim to address the challenges identified in existing policies, particularly focusing on equitable resource distribution and long-term resilience.

1. **Urban Planning Integration:**

Cities should follow Singapore's model of integrating UHI mitigation into all aspects of urban planning, ensuring that green infrastructure, building codes, and cooling strategies are not treated as isolated interventions but as essential components of a broader urban resilience framework. Creating and implementing an urban plan that included UHI mitigation strategies, such as green roofs, urban tree canopies, and reflective pavements, ensuring these are prioritized in all new developments and urban renewals.

2. **Equitable Resource Distribution**

Prioritizing low-income and vulnerable communities by ensuring resources are distributed equitable across all neighborhoods, especially during peak summer months. By introducing targeted subsidies and funding mechanisms to support the retrofitting of buildings in low-income areas with heat-resilient features. Additionally, implementing heat-resilient building codes universally, with financial assistance for compliance in disadvantaged communities.

3. **Community Engagement**

By developing community health programs that address both immediate health-related risks and long-term health impacts of UHIE. These can include mobile health units, public awareness campaigns, and partnerships with local health organizations to ensure broad and equitable access

4. **Long-Term Monitoring and Adaptation**

Singapore utilized advanced monitoring systems which combine environmental sensors, remote sensors, and urban climate modeling to assess the ongoing effectiveness of UHI mitigation policies. In order to ensure the longevity of these policies, it is important to establish continuous monitoring and evaluations frameworks that track the impact of UHI mitigation strategies on temperature reduction, public health, and equity. These frameworks should allow for adaptive management, where policies are regularly updated based on real-time data and community feedback.

5. **Spark Global Collaboration**

Cities around the world should collaborate to share successful UHI mitigation strategies, data, and research findings. Organizations such as the United Nations and World Health Organization can facilitate these exchanges. Although cities around the word must account for their own geographical terrain, by partnering globally cities are encouraged to participate in global initiatives like the C40 Cities Climate Leadership Group, where they can collaborate on common challenges and solutions.

Conclusion

In conclusion, the Urban Heat Island (UHI) effect poses significant challenges for cities worldwide, exacerbating environmental, health, and social disparities, particularly among low-income and marginalized communities. Cities like Phoenix, New York City, and Singapore have implemented various UHI mitigation strategies, including green infrastructure, cool roofs, and enhanced urban planning, with varying degrees of success. While these efforts have reduced urban temperatures and improved public health, challenges remain in ensuring equitable distribution of benefits and addressing the specific needs of vulnerable populations. To bridge these gaps, cities must adopt more integrated and inclusive approaches, such as targeted investments, community engagement, and continuous monitoring. By leveraging global best practices and prioritizing equity in resource distribution, urban planners can create more resilient and livable cities, ultimately aligning with the goals of sustainable urban development. Future research and policy efforts should focus on long-term efficacy, economic analysis, and the mitigation of unintended consequences like gentrification, ensuring that all communities benefit from these vital interventions.

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