Beating the Heat: Policy Recommendations for Kampung Cooling Infrastructure in Surabaya

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List of Abbreviations

KLHK: Ministry of Environment and Forestry
ProKlim: *Program Kampung Iklim* (Climate Kampung Program)
UHI: urban heat island

I. Introduction

Urbanization has driven economic growth and infrastructure development but has also intensified the urban heat island (UHI) effect, where urban areas experience higher temperatures due to impervious surfaces, reduced vegetation, and anthropogenic heat sources (Heaviside et al., 2017; Mirzaei, 2015; Yang et al., 2016). Cities worldwide adopt strategies such as urban greening, reflective materials, and sustainable urban planning. Yet, these initiatives predominantly benefit wealthy classes. In Jakarta, for instance, green open spaces are primarily available in rich neighborhoods, driven by the private sector boosting property values (Ufaira, 2023). The urban heat challenge is further compounded by energy infrastructure decisions, as nations like Japan and China, traditionally proponents of coal-fired power plants, have invested in fossil fuel projects across Indonesia and Southeast Asia, contributing to both local heat generation and broader climate impacts (Henares & Delina, 2022; Delina et al., 2024). As a result, resource-limited communities, such as Surabaya's kampungs, face barriers in addressing the UHI effect.

Surabaya grapples with minimal green spaces, high electricity consumption, and extensive asphalt surfaces, which exacerbate UHI impacts (Kurniati & Nitivattananon, 2016). These challenges are compounded by spatial constraints and limited political will, leaving communities particularly vulnerable to the UHI effect. This paper examines how Surabaya, particularly its local government and kampungs,

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can combat the UHI effect despite such limitations. Conducting in-depth interviews and transect walks for a case study of Kampung Plemahan, we identify community-led, context-specific solutions. We propose a policy development approach to create actionable strategies that not only mitigate heat stress, but also increase adaptive capacity within the community. These findings underscore the importance of integrating urban heat mitigation into Surabaya's policy frameworks to ensure a sustainable, heat-resilient urban future.

This paper is organized into six sections: the second section reviews relevant literature, the third outlines the conceptual framework, the fourth presents the case study, the fifth offers policy recommendations, and the sixth provides the conclusion.

II. Literature Review

Kampungs, characterized by dense populations, informal housing, and resource limitations (Octifanny and Norvyani, 2021), face significant challenges in mitigating the UHI effect. Limited access to green spaces, affordable cooling technologies, and poor ventilation exacerbate heat stress for residents living in overcrowded conditions. This literature review examines both passive and active cooling strategies implemented in comparable urban contexts and evaluates their applicability to Surabaya's kampungs.

In Jakarta's kampungs—such as Krendang, Tanah Tinggi, Galur, and Rawa—outdoor communal spaces have been introduced to enhance urban livability and foster community engagement (Salsabila et al., 2023). While these spaces create opportunities for social interaction, their potential for improving thermal comfort through shading and airflow remains underexamined. In contrast, Dhaka's Korail Basti has implemented reflective roofing materials to reduce indoor temperatures, particularly benefiting factory workers disproportionately affected by heat stress (Sustainable Energy for All, 2021). Although cool roofs present a scalable and low-cost passive cooling solution for dense settlements, challenges related to durability, maintenance, and compatibility with informal housing structures persist.

Green spaces, such as urban parks in dense cities like Hong Kong and Maryland's Franklin Square neighborhood, illustrate the cooling benefits of vegetation through shading, improved air circulation, and temperature regulation (Lo et al., 2022; Anderson & McMinn, 2019). However, the spatial constraints of kampungs limit the feasibility of large parks, necessitating the exploration of micro-scale green interventions. Similarly, in India's Jodhpur's Phalodi Village, a net-zero cooling station showcases how enhanced air circulation and shading can provide sustainable thermal comfort without relying on energy-intensive technologies (Limaye, 2024). While promising, the design's reliance on specific architectural configurations raises concerns about its adaptability to densely packed kampungs.

Beyond passive strategies, active cooling solutions are also being explored for resource-limited urban areas. Shared cooling stations, equipped with fans, shaded rest areas, and water access, have proven effective in providing emergency relief to individuals experiencing heat stress (Limaye, 2024). These active interventions, combined with tailored passive strategies, offer valuable insights for addressing the UHI effect in compact and informal urban settlements like Surabaya's kampungs.

However, adapting these strategies to Surabaya requires accounting for its unique urban realities. Spatial constraints limit the feasibility of large parks or expansive cooling infrastructure, necessitating micro-scale interventions like rooftop gardens, pocket parks, and shaded communal spaces. Informal housing structures in kampungs require flexible, low-cost solutions such as cool roofs and modular cooling stations that align with their irregular layouts. Governance limitations, including weak political will and limited resources, further complicate implementation, emphasizing the need for collaborative approaches involving local communities, NGOs, and public-private partnerships. Affordability remains a key barrier, requiring innovative funding mechanisms to ensure accessibility and sustainability.

Despite advancements in cooling solutions, significant gaps remain. There is limited research on micro-scale, low-cost interventions specifically tailored to informal settlements like kampungs. Few studies explore the governance, community leadership, and participatory approaches necessary for successful implementation. Moreover, the integration of hybrid cooling approaches, combining passive and active strategies, has received little attention in the context of informal housing. Addressing these gaps would allow for more holistic, context-specific solutions to the UHI effect in Surabaya's kampungs.

III. Framework of the Study

To address the research challenge of how Surabaya's kampung communities achieve thermal justice, we identified government intervention as a crucial factor in supporting the urban poor. This research employs a qualitative approach focused on local government policy development. According to Henstra (2015), policy serves as a tool to guide individual and organizational behavior in climate change adaptation efforts. Government policy ultimately facilitates collaboration among various stakeholders in climate-focused programs.

The Surabaya government has implemented the Program Kampung Iklim (ProKlim) or the Climate Kampung Program, hosted by the Ministry of Environment and Forestry (KLHK). ProKlim recognizes community commitment to climate change adaptation and mitigation efforts at the neighborhood level. Derived from the National Program for Participatory-Based Climate Change Management, it encourages collaboration among stakeholders—government, businesses, academics, and communities—on local mitigation and adaptation initiatives, particularly in kampungs. In Surabaya, this program takes the form of a kampung competition, with assessment criteria based on adaptation, mitigation, and community support and sustainability, as outlined in KLHK Regulation No. P.84/MENLHK-SETJEN/KUN.1/11 of 2016.

As shown in **Figure 1**, three steps are involved in deriving policy recommendations. First, we reviewed the ProKlim assessment criteria by gathering feedback from government entities, academic institutions, and community members. Next, we analyzed the criteria, proposing either the addition of new elements or the enhancement of existing ones. Finally, we applied the criteria to kampungs, formulating policy recommendations tailored to the needs of Surabaya's communities in combating urban heat. Kampung Plemahan serves as our case study.

Figure 1. Conceptual Framework

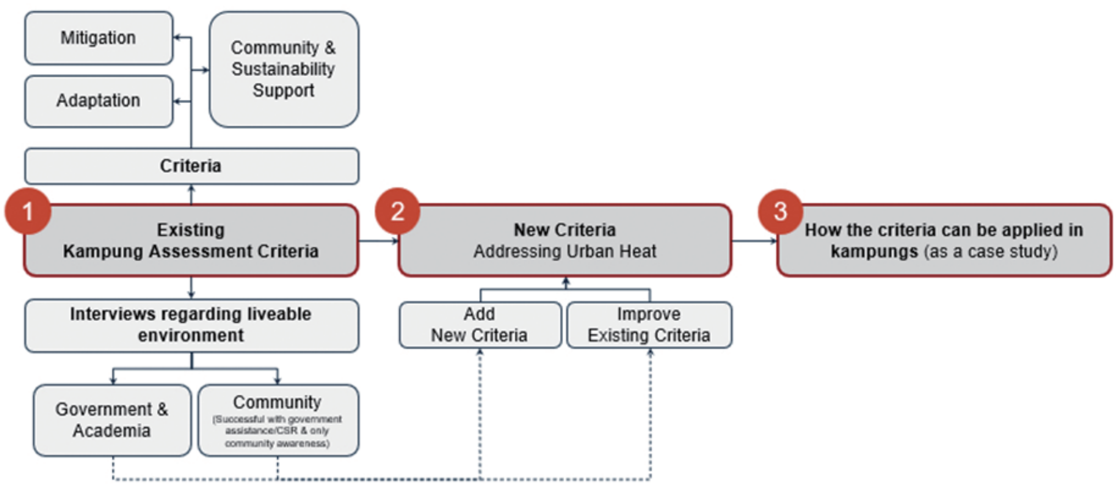


Figure 1 illustrates the iterative nature of this process, emphasizing stakeholdercollaboration and alignment with local climate adaptation priorities.

Source: the authors.

IV. Case Study

Kampung Plemahan, located in the heart of Surabaya adjacent to Tunjungan Plaza, the largest shopping mall in East Java, participated in a kampung competition organized by the Surabaya government.

Figure 2 highlights the juxtaposition of traditional community life and modern urban development. The rapid expansion of Tunjungan Plaza poses a significant threat to the kampung, as much of Plemahan I has already been acquired for parking and future high-rise construction, and Plemahan II is partially purchased. The architectural landscape of Kampung Plemahan is marked by densely packed, low-rise structures that reflect the residents' cultural practices and needs (Gunawan, 2015).

Despite these pressures, a field survey of Plemahan II reveals an exceptionally vibrant and well-maintained environment, with lush greenery, organized pathways, and a strong community commitment to cleanliness and sustainability. Residents have transformed narrow alleyways into verdant spaces with potted plants and communal areas, demonstrating resilience in maintaining a serene, eco-friendly neighborhood amidst encroaching commercialization. While development pressures continue to grow, Kampung Plemahan remains a testament to the coexistence of urban and traditional life, highlighting the importance of preserving such cultural and environmental enclaves in rapidly expanding cities. Community engagement in Kampung Plemahan is strong, with residents actively participating in cultural and social activities (Jaya & Srinarwati, 2022).

Figure 2. Aerial map and ground photos of Kampung Plemahan

This figure provides a visual comparison of the kampung's layout (left) alongside photographs (right) that capture its vibrant community and unique architectural features.

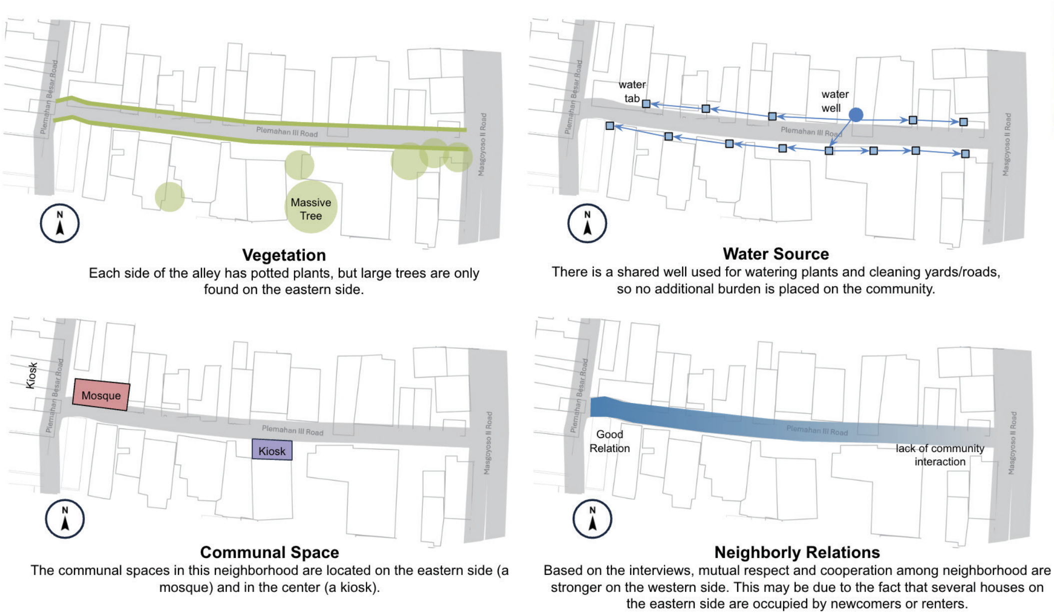
Source: Google Maps (left) and the authors (right).

Figure 3 provides a detailed overview of Kampung Plemahan's spatial and social dynamics, focusing on vegetation, water sources, communal spaces, and neighborhood relations. Vegetation is well-maintained, with potted plants lining the alleyways, contributing to the kampung's green, tidy atmosphere. Large trees, however, are mostly concentrated on the eastern side, including a notable "massive tree," which reflects the community's efforts to preserve greenery in this dense urban environment. Water sources play a critical role in sustaining the kampung's ecological efforts. A centrally located shared water well is used by residents to water plants and clean yards and roads, ensuring sustainability without imposing additional financial or logistical burdens. Studies show that proximity to water is essential for fostering biodiversity and ecosystem health (Petit-Prost et al., 2024).

Communal spaces are thoughtfully distributed to promote social and cultural interactions. A mosque on the western side serves as a central hub for religious and communal activities, while a kiosk in the middle of the alley acts as a gathering place for daily interactions and small-scale commerce. These spaces help preserve a sense of unity and identity among the residents. Neighborhood relations reveal both cohesion and fragmentation. Mutual respect and cooperation are stronger on the western side, where long-term residents reside, creating a sense of belonging and shared responsibility. On the eastern side, however, weaker community engagement is noted, largely due to the influx of newcomers and renters. Research underscores how engagement in communal spaces fosters well-being and strengthens neighborhood sustainability (Holden, 2018).

Kampung Plemahan represents a well-balanced urban kampung that prioritizes environmental sustainability, shared resources, and strong communal spaces, all contributing to residents' quality of life despite increasing urban pressures. However, challenges remain, particularly the social fragmentation on the eastern side due to the influx of transient residents. Additionally, the uneven distribution of vegetation, with large trees concentrated on one side, highlights opportunities for targeted greening strategies. Addressing these challenges requires policies that promote social integration and equitable environmental initiatives. In the next section, we provide our recommendations.

Figure 3. Spatial Layout of Kampung Plemahan



This figure shows the distribution of key environmental and social features, highlighting communal spaces, vegetation, and neighborhood interactions.
Source: the authors.

V. Recommendations

Our investigation of current climate change policies and findings from in-depth interviews reveal that "urban heat" is notably absent from existing climate policies in Surabaya. Unlike other disasters, such as floods and landslides, which are thoroughly addressed in the ProKlim criteria, factors related to urban heat, including the infrastructure needed to mitigate its effects, are largely neglected. In light of this, we propose integrating cooling solutions into community infrastructure for kampungs in Surabaya to combat the UHI effect.

In Indonesia, the penetration rate of air conditioning is approximately 15% (Daikin Industries data). Due to the high costs associated with both installation and electricity, air conditioning remains out of reach for many households. With rising urban temperatures due to the UHI effect, health impacts and reductions in quality of life are expected to become more pronounced. Therefore, a public mechanism is needed to ensure that residents without the financial means to install air conditioning can still access cool environments and avoid heat-related illnesses. This mechanism must meet the following criteria: cost-effectiveness, low environmental impact, and suitability for use in kampungs.

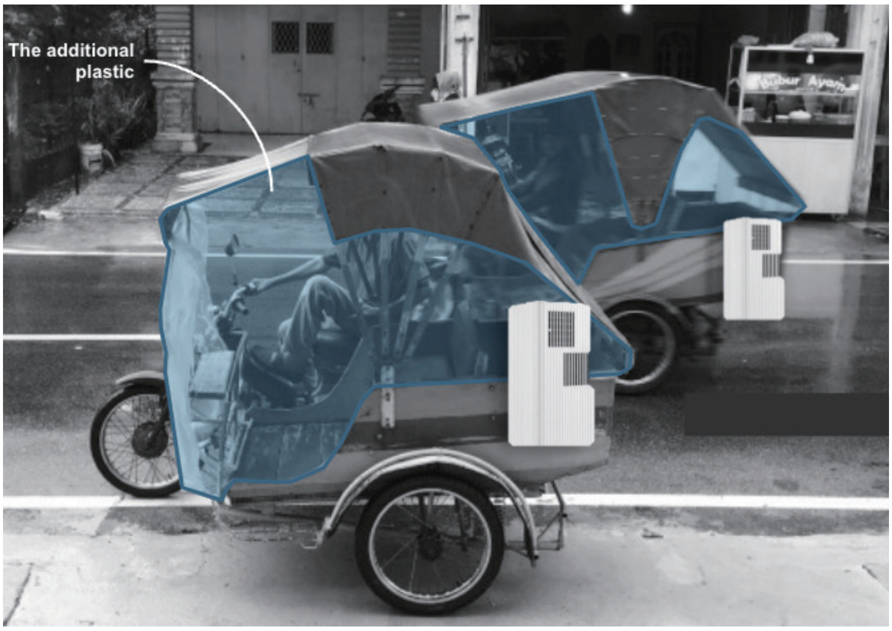
We propose two specific solutions to address urban heat and UHI in kampungs. Our first solution is the **"Cooly Pad" Mobile Cooling Unit**, a mobile cooling unit that can be deployed during heatwaves, offering a portable, air-conditioned space to residents in need of immediate relief. The second solution is a **Net-Zero Cooling Station**, a fixed, community-based space where kampung residents can access air conditioning, offering a sustainable, long-term solution to urban heat within the neighborhood.

A. "Cooly Pad" Mobile Cooling Unit

The Cooly Pad utilizes vehicles equipped with sidecar baskets, commonly used for transportation in Indonesia (see Figure 4). By covering the sidecar with a plastic canopy and attaching a small air conditioner, the interior remains cool, transforming it into a mobile cooling space that provides relief during heatwaves for individuals with illnesses that reduce heat tolerance, or in cases of imminent heatstroke.

The integration of a Cooly Pad enhances accessibility, providing immediate cooling relief during extreme heat. Users can easily summon the Cooly Pad via phone or an app, and its compact size allows it to navigate the narrow alleys of kampungs. This mobile unit, designed for individual use, is capable of navigating narrow kampung alleys offering vulnerable residents a convenient solution. This system is designed by modifying existing pedicabs, keeping costs low and minimizing environmental impact due to its small-scale cooling and low energy consumption. As a flexible, on-demand cooling solution, it could be implemented as a government service or a business venture to address urban heat challenges.

Figure 4. Concept of the "Cooly Pad"



This illustration depicts the Cooly Pad, a modified pedicab with a sidecar and air conditioner, designed to provide on-demand cooling in kampungs.
Source: the authors.

B. Net-Zero Cooling Station

While the Cooly Pad serves individual users during emergencies, the Net-Zero Cooling Station is designed to accommodate larger groups (see Figures 5 and 6). By upgrading the RT Office, it can serve as a neighborhood cooling hub, offering essential services such as a health center and nursing room, and promoting social inclusion. Information boards and QR codes will link residents to nearby kiosks for food and drinks, improving access to local amenities. This multifunctional station addresses urban heat challenges while promoting community well-being. Central to the design is a green canopy that provides natural shading, reducing sunlight exposure and creating a cooler microclimate, enhancing both comfort and the aesthetic appeal of the kampung. Benches around the canopy encourage social interaction, fostering community engagement and strengthening social bonds.

A key feature of the station is the use of vacant land for a community garden, which not only contributes to urban cooling but also encourages environmental awareness and community participation. By combining passive cooling techniques such as shading and ventilation with active methods like fans and air conditioning, and integrating solar power generation, we can create cost-effective and environmentally sustainable cooling spaces. These facilities should be considered essential infrastructure for public welfare. Retrofitting community centers or mosques into cooling spaces would provide public cooling areas, naturally attracting residents seeking respite from the heat. These spaces could also be equipped with books and computers to serve as learning environments, enhancing educational opportunities while supporting healthy community dynamics.

The Net-Zero Cooling Station provides more than just relief from urban heat; it transforms communal spaces into vibrant, multifunctional hubs. By blending environmental sustainability with community-centric features, it ensures that residents enjoy a better quality of life while preserving the identity of the kampung and strengthening social ties. This model offers a scalable solution that can be replicated in other urban kampungs, making it a significant step toward sustainable urban development.

Figure 5. Conceptual Illustration of the Net-Zero Cooling Station

This figure represents a conceptual design of the Net-Zero Cooling Station, showcasing its core features and integration within the kampung environment.

Source: the authors.

Figure 6. AI-Generated Image of the Cooling Station

This AI-generated image illustrates a proposed design for a Cooling Station, created using DALL-E. While certain elements, such as the outdoor unit on the wall, may appear unconventional, the focus should be on the fundamental concept of the design.

Source: DALL-E.

VI. Conclusion

In conclusion, this paper has explored the urgent need for cooling infrastructure in Surabaya's kampungs, where urban heat exacerbates challenges brought on by rapid urbanization and climate change. The proposed solutions, such as the Cooly Pad and Net-Zero Cooling Station, offer scalable, sustainable ways to provide cooling while enhancing community well-being. These interventions highlight the need for policies that address both immediate cooling needs and long-term urban resilience.

While cooling is a critical concern, it must be understood within the broader context of social issues like education, hygiene, and employment. In Surabaya, where the impacts of global warming and urbanization are intensifying, it is essential to shift the mindset as some of our interviewees have mentioned: "Heat is inevitable, and air conditioning is a luxury." Ensuring equitable access to cooling, particularly in densely populated areas, is necessary for improving the quality of life for vulnerable communities.

Finally, effective cooling infrastructure requires tailored solutions based on local conditions. The mapping of cooling strategies presented in this paper offers a framework for policymakers to select appropriate options based on their cost-effectiveness and social impact. Governments should recognize cooling as a critical urban issue and work with community groups, urban planners, and the private sector to implement these solutions, ensuring Surabaya's kampungs remain resilient and sustainable in the face of growing environmental challenges.

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