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RAFLESIA (Indonesian Solar Reflective House) as a Sustainable Solution for Uninhabitable Housing in Cirebon Regency

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ABSTRACT

The Urban Heat Island (UHI) effect in cities results from the reflection of solar radiation from roof and wall coverings, primarily in the form of short-wave radiation. Roof and wall materials experience the longest exposure to solar radiation on a building. Heat generated at the surface of these elements is transferred into the interior spaces. To reduce heat gain, materials with low albedo—often dark surfaces—and high solar reflectivity are needed. Indonesia's geographical conditions, partly coastal, contribute to significant heat loads experienced by most of the population. This issue is further exacerbated by the fact that approximately 26.42 million low-income people have limited access to cooling systems, making them vulnerable to heat stress. One efficient solution is the Indonesian Solar Reflective House (RAFLESIA), which utilizes metal cladding for roofs and walls that provide a high solar reflective layer. This study aims to evaluate how RAFLESIA improves thermal comfort by lowering indoor temperatures and to assess the effectiveness and efficiency of new materials for sustainable improvements in uninhabitable housing. The methods employed include participatory observation, interviews, and literature reviews. The RAFLESIA building design is tailored to the needs and existing conditions of the houses. As a result, the program addresses the issue of uninhabitable housing and reduces indoor temperatures by an average of 3°C, as well as electricity consumption by up to 20%.

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1. INTRODUCTION

Cirebon Regency is one of the areas in West Java located in the lowlands, with an altitude ranging from 0 to 10 meters above sea level. Several parts of the region are coastal, experiencing average air temperatures between 24°C and 35°C. This hot and humid climate contributes to significant heat loads on buildings. Low-income residents are particularly vulnerable due to limited access to cooling systems. Moreover, many houses in the MBR (low-income) community are damaged or uninhabitable, further diminishing comfort and safety. The number of uninhabitable houses in Cirebon Regency remains high and is a cause for concern. According to community-submitted data via village administrations, there are 18,370 uninhabitable houses in the regency. Addressing this issue requires repair funding not only from the local government but also from provincial and central governments. Dinas Perumahan dan Permukiman Jawa Barat (the West Java housing and settlement service) has set a target of repairing 120 uninhabitable houses in 2024 (Aulia, 2024). In previous repair efforts, aspects such as structural reliability, lighting, ventilation, air circulation, and sanitation were often considered, but thermal comfort was largely overlooked. Given Indonesia's geographic position near the equator, with many coastal and lowland areas, thermal comfort should be a key consideration—especially in light of increasing global warming. This is particularly pressing in urban areas, where solar radiation reflected from roofs and building walls exacerbates heat. When solar radiation strikes a roof, three phenomena occur: absorption, reflectance, and thermal emissivity. Absorption involves materials retaining heat; reflectance refers to surfaces that reflect part of the sun's energy; and thermal emissivity is the process by which roofs release some of the absorbed heat back into the atmosphere (Paramita, 2022).

Albedo is the fraction of solar radiation reflected by a surface. Dark surfaces, such as asphalt pavements and roofs, have low albedo and contribute more to the Urban Heat Island (UHI) effect compared to brighter surfaces. High-albedo surfaces can be achieved through the use of light-colored roofing materials (Paramita, 2022). One option provided by the Rumah Reflektif Surya Indonesia, abbreviated RAFLESIA (Indonesian solar reflective house) is the use of metal cladding for roofing and walls, coated with a high solar-reflective layer. This house represents an innovation in material development and contributes to the effectiveness and efficiency of construction in terms of both cost and time (Ramadhan et al., 2022).

Based on this background, the purpose of this study is to evaluate the extent to which RAFLESIA can contribute to improving thermal comfort for its occupants, and to assess the effectiveness and efficiency of high solar-reflective metal cladding materials in the renovation of uninhabitable houses in Cirebon Regency.

1.1 Literature Review

1.1.1 Urban Heat Island and Sustainable Materials

One of the main contributors to urban environmental problems and declining environmental quality is the Urban Heat Island (UHI) effect (Yang et.al., 2015). The UHI phenomenon places the world at a crossroads, as surface temperatures continue to rise due to increasing urbanization and development. There is a causal relationship between the UHI effect and the occurrence of natural disasters (Irfeey, 2023). The morphology of urban buildings creates distinct microclimates, and building density contributes significantly to urban heat gain, particularly in land areas, open spaces, walls, and roofs. Other studies have shown that heat transfer in building walls lasts longer than on ground surfaces, making building surface materials critical in determining heat gain and loss. The larger the surface area, the more heat is trapped, thereby increasing the average radiation temperature. Extreme heat events due to climate change have become more frequent in

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recent years. The effects of this heat are particularly challenging for economically disadvantaged communities, as they have limited access to cooling systems such as air conditioners or air coolers. These systems also consume relatively high amounts of electrical energy. The need for adaptation and mitigation related to the impact of Urban Heat Islands (UHI) is urgent, and one possible solution is the use of reflective materials in building construction (Yang et.al.,2015). Materials are a critical factor, as their use directly influences the urban heat balance (Santamouris & Yun, 2020). According to Irfeey (2023), sustainable materials contribute to reducing urban heat, particularly through the use of reflective materials on sidewalks, coatings with bright or fluorescent paint, and energy-efficient equipment, all of which are considered environmentally friendly. Roofing materials with reflective coatings—commonly referred to as cool roofs—absorb only a small amount of solar energy and can significantly lower indoor temperatures (Akbari & Kolokotsa, 2016). The use of cool roofs can reduce energy consumption and help ease the financial burden, especially electricity costs for cooling systems such as ACs or air coolers. Cool roofs also play a vital role in reducing urban heat islands, improving indoor thermal comfort, and conserving energy (Tian et.al.,2023) (Febrina et.al.,2024).

1.1.2 Healthy, Livable and Sustainable Housing

The basic principle of sustainable development requires a balance between economic growth, environmental protection, and social justice. *Sustainable Development Goal* (SDG) 11 emphasizes inclusive, safe, resilient, and sustainable cities and human settlements. Various obstacles hinder the implementation of environmentally friendly infrastructure, including the lack of supportive government policies (e.g., legislation), inadequate economic assessments, limited technological advancement, and the reluctance of affected parties to become involved (Irfeey, 2023). Another major challenge is the community's inability to fulfill the need for decent housing. In fact, according to the 1945 Constitution (UUD 1945), impoverished families have the right to adequate housing. The government is therefore responsible for providing decent homes, which has led to the emergence of uninhabitable house rehabilitation programs in various regions across Indonesia. The Rutilahu program plays a role in promoting a culture of mutual cooperation among communities, as reflected in increased self-reliance (Haniah & Bakhri, 2022). The rehabilitation of uninhabitable houses must meet the components or criteria of a healthy home, such as a strong and stable foundation, waterproof or moisture-resistant flooring, doors and windows that allow natural light to enter, and protection from water, wind, heat, and dust—while also ensuring privacy for occupants. A healthy house should also incorporate aspects of sustainability, including the use of environmentally friendly materials and energy-efficient design (Karimuna et.al.,2024).

2. RESEARCH METHODS

The methods used in this study include participatory observation, interviews, and a literature review. Data obtained from the field are then analyzed, followed by the design of a solar reflective building tailored to the needs and conditions of uninhabitable houses selected as case studies. The implementation steps begin with identifying uninhabitable houses to be used as case studies—specifically, those listed by the Dinas Perumahan dan Permukiman Jawa Barat (West Java housing and settlement service) with the lowest levels of self-reliance. This is followed by data validation or field surveys, which involve confirming the data obtained from the Housing and Settlement Service and verifying its accuracy based on established criteria through measurements, interviews, and discussions with relevant stakeholders. Once

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the analysis and design are completed according to the identified needs, the construction process is carried out and the building is handed over.

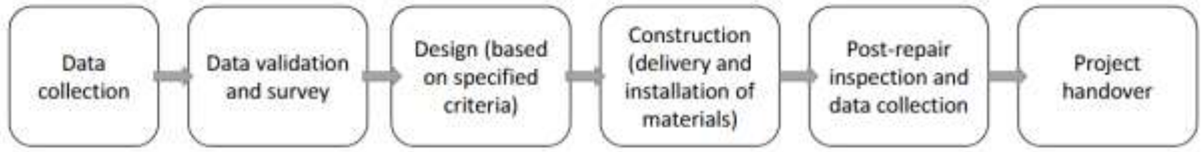

Figure 1. Implementation Phase
(Source: Author, 2024)

3. RESULT AND DISSCUSSION

3.1 Discussion

This program is implemented in two locations: Jagastaru Village (Mrs. Kasminah's house) and Kesenden Village (Mr. Subakir's house). Both locations are situated in lowland areas near the coast and are categorized as densely populated. Based on a survey of the existing conditions at both Mrs. Kasminah’s and Mr. Subakir’s houses, it is evident that these houses are classified as uninhabitable, as shown in Figures 2 and 3 below:

Figure 2. Existing Condition of Mrs. Kasminah's House in Jagastaru Village, Cirebon Regency
(Source: Author’s Documentation, 2024)

Based on the survey results, the existing condition of Mrs. Kasminah's house is concerning due to frequent leaks in the clay tile roof, its elongated shape with minimal ventilation and openings, and the damaged, damp condition of the wall materials.

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Figure 3. Existing Condition of Mr. Subakir's House in Kesenden Village, Cirebon Regency (Source: Author’s Documentation, 2024)

Unlike Mrs. Kasminah's house, the existing condition of Mr. Subakir's house in the Kesenden sub-district includes deteriorated wooden walls, a leaking roof, and a weakened structural frame. These issues render the house vulnerable to collapse and unsafe for habitation. Additionally, the hot and humid environmental conditions further reduce thermal comfort inside the dwelling. Therefore, repairs are necessary to enhance the residents' quality of life.

Based on data and surveys from both locations, a design plan was developed to accommodate the occupants' needs and improve their comfort. The proposed repairs include replacing wall materials with metal cladding on several sides, as illustrated in the image below.

Figure 4. Mrs. Kasminah's House Design Improvement (Source: Analysis, 2024)

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The RAFLESIA building design implemented in Mrs. Kasminah's house utilizes solar-reflective metal cladding on the roof and part of the walls—specifically at the rear of the building—to reduce indoor temperatures and enhance occupant comfort. The repair process began with partial reconstruction of the brick wall and the installation of a lightweight steel roof frame, supported by community self-help efforts and assistance from the West Java Housing and Settlement Service. This was followed by the installation of solar-reflective metal cladding on the walls and roof, with additional support provided by UPI.

The metal cladding material, used for the roof covering and part of the walls, was prepared in advance and cut according to the design specifications. The metal cladding was then painted and labeled to facilitate easy assembly in accordance with the field guidebook, as shown in Figure 5 below and Figure 6, which illustrates the construction process.

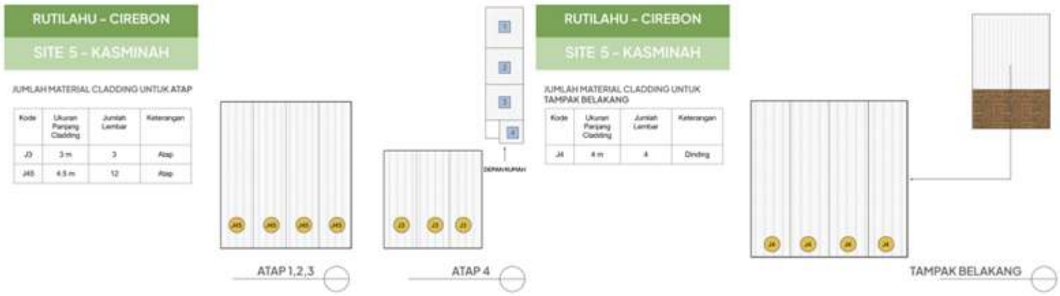

Figure 5. Metal Cladding Guide Book for Mrs. Kasminah's House
(Source: Analysis, 2024)

Figure 6. Mrs. Kasminah's House Repair
(Sumber: Author's Documentation, 2024)

Figure 7. Mr. Subakir's House Design Improvement
(Source: Analysis, 2024)

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The metal cladding material, used as roofing and partial wall covering, was prepared in advance and cut according to the design specifications. It was then painted and labeled to facilitate easy assembly, following the field guidebook, as illustrated in Figures 8 and 9, which show the construction process.

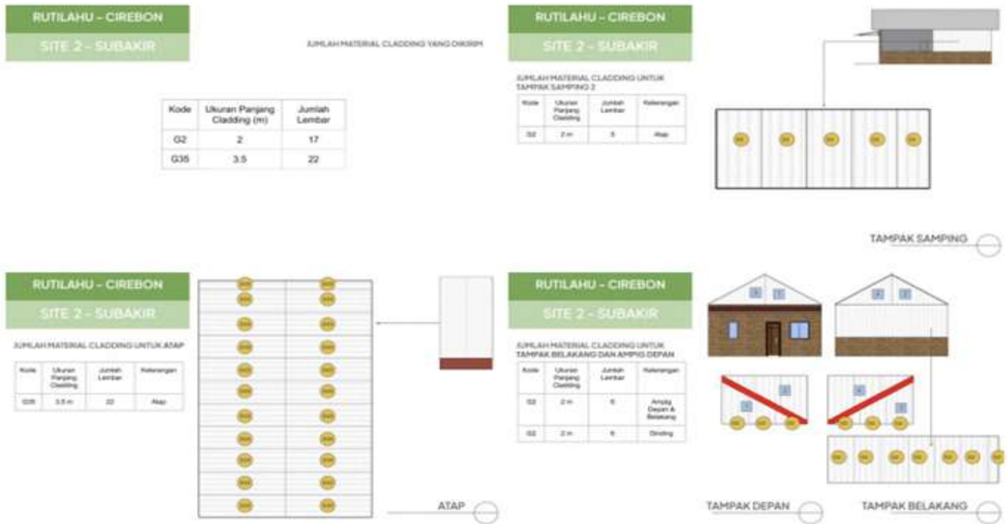

Figure 8. Metal Cladding Guide Book for Mr. Subakir's House
(Source: Analysis, 2024)

Figure 9. Mr. Subakir's House Repair
(Source: Analysis, 2024)

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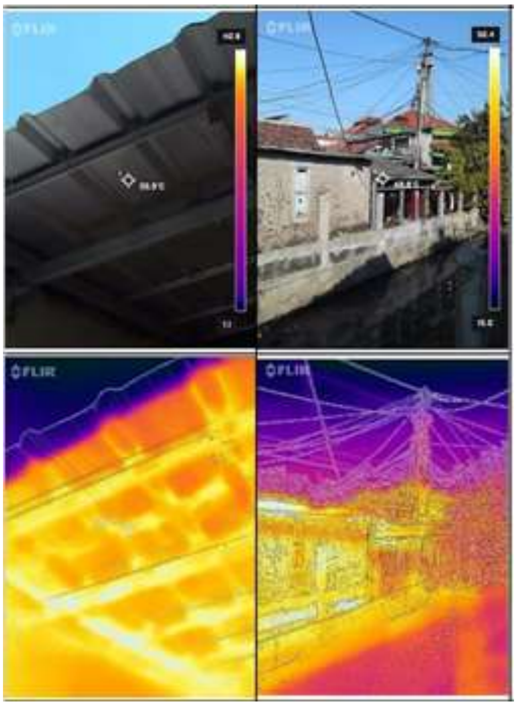
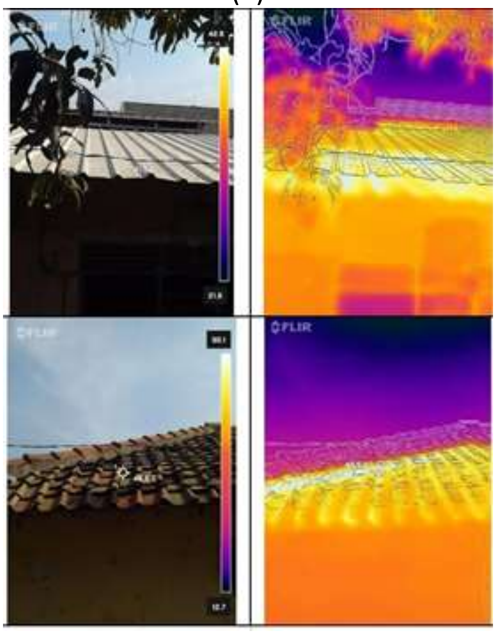
The solar-reflective roof and wall coverings are designed to reduce interior surface temperatures by approximately 20% to 40%. Unlike conventional materials, which reflect less than 50% of solar radiation and primarily operate within the short-wave spectrum (around 700 nm), RAFLESIA reflects over 80% of solar radiation across a broader range of 700–2,500 nm (long-wave). This performance is measured using the Solar Reflectance Index (SRI), which quantifies a material's ability to reflect solar radiation and emit heat, depending on its emissivity. Materials with a high SRI reflect more solar energy and stay cooler, whereas those with a low SRI absorb more heat.



(a)



(b)

Figure 10. Differences in Room Temperature and Neighbors' Temperature in Mrs. Kasminah's House (a), and Mr. Subakir's House (b)
(Source: Analysis, 2024)

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The implementation of RAFLESIA has successfully reduced the average indoor temperature by 3°C, thus significantly increasing the thermal comfort for the occupants. The surface temperature after the implementation of the RAFLESIA house also showed a decrease in temperature. The potential sustainability of this program is:

a. Surface Temperature Reduction: The program has the potential to reduce surface temperatures by 15–20°C, which contributes to mitigating the Urban Heat Island (UHI) effect. This reduction has a positive impact on public health and energy savings.
b. Project Duplication: The success of the RAFLESIA project creates opportunities for replication within the Rutilahu (*Rumah Tinggal Layak Huni* or decent homes) program in future years, extending its benefits to broader communities in need of decent and environmentally friendly housing solutions.
c. Carbon Emission Reduction: The use of alternative materials offers a significant reduction in carbon emissions—up to 30% compared to conventional materials such as bricks and concrete. This makes the program an environmentally friendly solution aligned with national and global carbon reduction targets.
d. Community Participation and Self-Reliance: Collaboration with the Housing and Settlement Service, along with active community involvement through self-supplied funds, materials, and labor, fosters a sense of ownership and long-term sustainability. This participatory approach not only lowers costs but also enhances the program's success through strengthened community support.

Thus, the RAFLESIA program demonstrates a positive and wide-reaching impact, with the potential to serve as a sustainable model for environmentally friendly and inclusive housing solutions.

4. CONCLUSION

The RAFLESIA (Indonesian solar reflective house program) not only provides solutions to address the issue of uninhabitable houses but also contributes to reducing indoor temperatures and improving energy efficiency. The application of the RAFLESIA design has been shown to reduce room temperatures by an average of 3°C and decrease electricity consumption by up to 20%. The program’s potential sustainability includes reducing surface temperatures by 15–20°C. Additionally, RAFLESIA reduces the use of carbon-intensive materials by 30%, offering significant potential for replication within the Rutilahu program in the future. Overall, this program supports efforts to mitigate global warming through environmentally friendly and energy-efficient modular housing designs.

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