A STUDY ON USER PERCEPTIONS WITH ENVIRONMENTAL AND ECONOMIC BENEFITS OF BIO-SOLAR ROOFTOPS IN DHAKA

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ABSTRACT

Dhaka faces critical environmental challenges, specifically the intensification of the Urban Heat Island (UHI) effect and escalating energy demands. Bio-solar rooftops present a dual-purpose solution by mitigating thermal gain while generating renewable energy. This research investigates the feasibility of implementing these systems in Dhaka by evaluating public perception and environmental performance. The methodology employs a mixed-methods approach, utilizing a case study by University of Technology Sydney (UTS) of two public residential adjacent buildings at Barangaroo, Sydney, Australia to analyze operational benefits alongside a survey of 74 diverse participants in Dhaka to assess adoption barriers.

The case study evidence confirms the effectiveness of these systems in reducing ambient temperatures and lowering building energy consumption. However, survey results indicate a gap between interest and implementation in Dhaka; while 58.1% of respondents expressed a willingness to install solar-powered green rooftops, high initial costs and maintenance requirements remain primary deterrents. Additionally, limited rooftop space, insufficient public awareness, and a lack of financial incentives were identified as significant obstacles to large-scale adoption.

The study concludes that while Bio-Solar rooftops offer a sustainable pathway for Dhaka's urban future, widespread implementation is contingent upon addressing financial and regulatory barriers. To unlock their full potential, it is essential to establish robust policy frameworks, provide targeted financial incentives, and enhance public awareness to facilitate the transition toward sustainable urban solutions.

Keywords: *Urban heat island, bio-solar rooftops, energy efficiency, sustainability, policy support.*

1. INTRODUCTION

Scientists have identified the urban heat island (UHI) effect as an established environmental problem which affects Dhaka alongside other major cities throughout the world (Salamanca et al., 2016). The conversion of natural land into concrete and asphalt surfaces produces heat retention that worsens the UHI effect and raises energy needs for cooling (Wang et al., 2016). Rooftop environmental interventions with green roofs and solar panels demonstrate powerful effectiveness in reducing heat absorption while producing renewable energy according to Knut et al. (2023).

Green roofs lower surface temperatures up to 10°C and ambient air temperatures down to 4.2°C which leads to reduced energy costs and enhanced indoor comfort (Li et al., 2014). Rooftop solar panels operate alongside green roofs by producing electricity which decreases fossil fuel usage and minimizes carbon pollution (Cai et al., 2019). The combination between solar panels and green roofs known as biosolar roofs has proven to boost system performance through vegetation cooling which increases solar panel efficiency by 4.5% (Knut et al., 2023). A dual implementation strategy shows promise as an urban sustainable solution which enables combined reduction of energy consumption and UHI impact and greenhouse gas production.

According to The Renewable Energy Policy 2025, the Government of Bangladesh has established a strategic framework to accelerate the transition from conventional power generation to a decarbonized, sustainable energy system. This policy officially repeals the 2008 Renewable Energy Policy and takes immediate effect to support national goals such as the "Integrated Energy and Power Master Plan (IEPMP)" and the "Delta Plan 2100". (Government of the People's Republic of Bangladesh, 2025, p.6328)

The primary objectives of this updated policy are to ensure energy security, reduce government subsidies by lowering electricity tariffs, and foster local manufacturing of renewable energy equipment. Sustainable and Renewable Energy Development Authority (SREDA) remains the nodal agency for promoting sustainable energy.

The policy introduces mandatory Renewable Purchase Obligations (RPO) and Renewable Energy Certificates (REC) for power utilities and large consumers to ensure a minimum percentage of electricity comes from renewable sources. Project developers and equipment manufacturers are fully exempt from corporate income tax for 10 years if commissioned between July 2025 and June 2030. (Government of the People's Republic of Bangladesh, 2025, p.6342)

Dhaka's adoption of solar-powered green rooftops remains limited because of the high initial costs, absence of financial incentives, and regulatory barriers that prevent widespread implementation (Dehwah et al., 2020). Bio-solar roofs remain underutilized because initial costs remain high and there are no financial incentives while policy support is minimal. The lack of public understanding about solar-powered green rooftops prevents their implementation from moving forward (Dehwah et al., 2020). The adoption of bio-solar rooftops will succeed through improved user perception understanding to achieve large-scale implementation.

The research examines bio-solar rooftop feasibility in Dhaka through survey-based user perception analysis and evaluation of the case study. The research aims to:

- Assess how much the public knows about and wants to use solar-powered green rooftops.
- Researchers must determine which financial barriers and structural problems and policy restrictions stand in the way of adoption.

This research analyzes the values derived from surveys together with real-world examples to deliver an all-inclusive understanding of Dhaka's bio-solar rooftop prospects.

2. LITERATURE REVIEW

2.1 Urban Heat Island (UHI) Effect and Mitigation

Urban areas develop higher temperatures than rural areas because man-made materials like concrete and asphalt absorb and store solar energy according to Lee et al. (2014). The phenomenon produces elevated energy requirements combined with heightened air contamination and health dangers that mainly affect densely populated metropolises such as Dhaka which encounters greater heat stress and increased cooling needs due to the UHI effect (Phelan et al., 2015). The proposed UHI mitigation strategies of green roofs, cool roofs and solar-powered green rooftops show promise for decreasing both ambient temperatures and energy usage according to Sharma et al. (2016) and Mohajerani et al. (2017). The combined strategies operate through their ability to decrease surface temperatures while blocking heat absorption and supplying renewable energy sources to fight UHI effects (Akbari and Kolokotsa, 2016; Li et al., 2014).

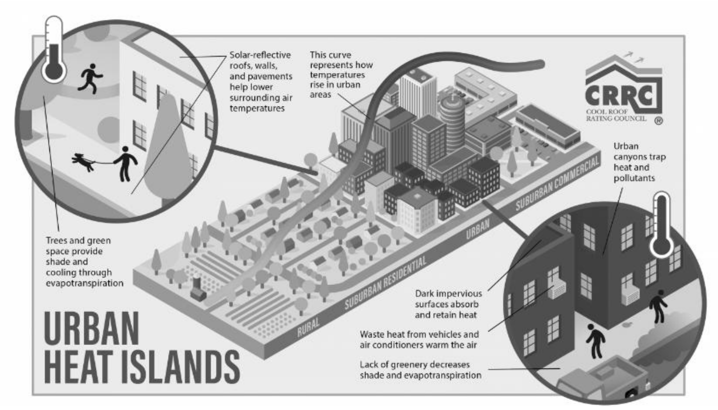

Figure 1. This illustration describes the factors that contribute to urban heat islands (UHI), as well as factors that help mitigate UHI. Urban heat islands occur when the temperature in urban environments is higher than surrounding areas. High surface temperatures lead to elevated air temperatures, especially at night. Heat islands increase heat-related discomfort, illness, and death. They also cause greater air conditioner use, which increases energy costs and air pollution. Urban heat has a disproportionate impact on disadvantaged communities (HSU et al., 2021; Hoffman et al., 2020; and Wilson, 2020). Image credit: Cool Roof Rating Council.

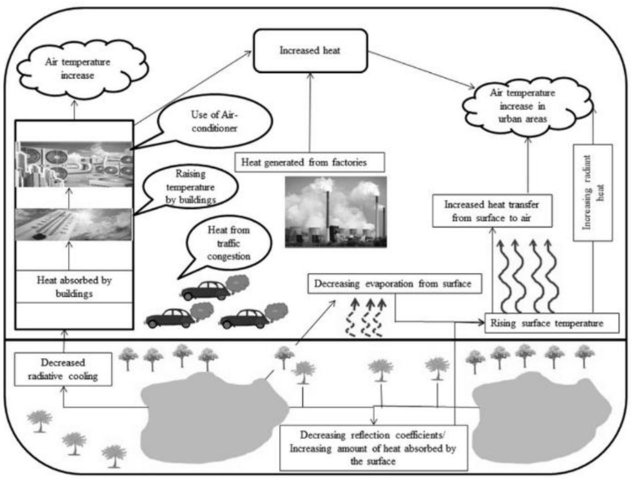

Figure 2. The causes of the Urban Heat Island effect. Source: (Anjum et al., 2019)

2.2 Bio-solar Roofs and UHI Mitigation

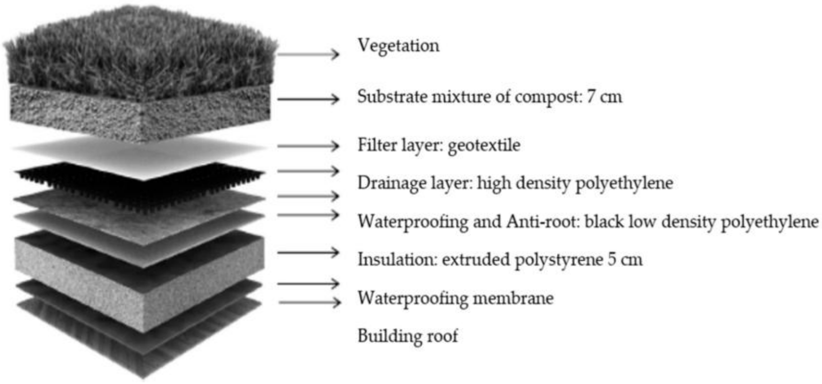

Figure 3. Composition and layers of green roofs. Source: (Azkorra-Larrinaga et al., 2023)

Bio-solar roofs continue to gain prominence as a modern UHI mitigation approach because they unite solar panels with green roofs. According to Masson et al. (2014) and Pyrgou and Yang (2017) solar panels installed on green roofs provide environmental cooling by creating shade while lowering building heat retention and producing renewable energy. The cooling effects from green roofs' vegetation layer increase when solar panels are integrated because evapotranspiration and solar energy generation work together. Experimental data demonstrates that solar-powered green roofs create 2-4°C temperature decreases on rooftops during daylight peak times (Akbari and Kolokotsa, 2016). Solar panels generate cooling effects between 0.5-0.6 K throughout daytime hours and simultaneously deliver energy savings according to Sharma et al. (2016). Biosolar roofs implement a dual purpose of solar power generation with cooling effects to achieve outstanding performance in UHI reduction and energy efficiency according to Li et al. (2014) and Masson et al. (2014).

2.3 Energy Savings and Electricity Demand Reduction

Bio-solar roofs; Green roofs and solar photovoltaic (PV) systems work together to provide significant benefits for building sustainability and energy efficiency. According to studies, this combination improves both systems' performance by providing cooling and shading effects (M Hui and C Chan, 2011). Green roofs serve as thermal insulation, decreasing indoor air temperatures by as much as 11.85% in hot climates (Abdalazeem et al., 2024). This leads to decreased energy consumption for air conditioning and heating (Zheng and Weng, 2020). Additionally, the cooling effect of green roofs improves PV panel efficiency, increasing electricity output by up to 8.3% compared to standalone systems (Abdalazeem et al., 2024; M Hui and C Chan, 2011). The effectiveness of green roofs depends on factors such as soil type, depth, irrigation, and vegetation (Abdalazeem et al., 2024; Zheng and Weng, 2020). Overall, the integration of green roofs and PV systems can significantly reduce cooling energy requirements and CO2 emissions in buildings (Abdalazeem et al., 2024).

Figure 4. Green roof mounted with rooftop solar photovoltaic(PV) systems. Source: (Zheng and Weng, 2020)

2.4 Fuel Loss Reduction and Environmental Benefits

Green roofs possess considerable potential for mitigating carbon dioxide emissions in urban environments via both direct and indirect methods. Direct carbon sequestration occurs via vegetation and soil media capturing atmospheric CO2 (Shafique et al., 2020). Indirectly, green roofs reduce building energy consumption, leading to decreased fossil fuel use and associated emissions (Tan et al., 2023). A study in Dhaka found that rooftop solar photovoltaic systems could generate 9,454 GWh of electricity annually, potentially reducing CO2 emissions by 4.3 MtCO2e/year (Nayeema Rashid and Kabir, 2024). Research on an intensive green roof system demonstrated that indirect CO2 reductions through energy savings far outweighed direct reductions, with a total annual reduction of 4355.6 g $CO_2 \cdot m^{-2}$ (Cai et al., 2019). Factors influencing green roof performance include vegetation type, substrate properties, building environment, and maintenance (Tan et al., 2023).These findings support the implementation of green roofs as an effective climate change mitigation strategy in urban areas.

2.5 Policy Implications and Challenges in Dhaka

There are many social, economic, and environmental advantages to green roofs, especially in cities like Dhaka, Bangladesh. However, a number of challenges stand in the way of their widespread adoption. These consist of inadequate public awareness, a lack of government support, and high installation and maintenance costs (Hossain et al., 2019). Adoption remains limited despite favorable climatic conditions because of miscommunication, personal resistance, and knowledge gaps (Hossain et al., 2019; Huq et al., 2019). Globally, a variety of incentive policies, including financial subsidies, tax incentives, and legal constraints, have been used to get past these obstacles (Liberalesso et al., 2020). Public-private partnerships present a vital solution to help the transition toward sustainable urban infrastructure according to (Akash et al., 2018 ; Hossain et al., 2021).

2.6 Research Gap

While there is a growing consensus on the environmental benefits of bio-solar rooftops, a significant research gap exists in reconciling the high levels of public interest with the complex socio-economic barriers to adoption in Dhaka. Current studies frequently emphasize the technical performance of solar-green systems but lack an integrated analysis of how to transform Dhaka's rooftops into "multifunctional areas" that satisfy both aesthetic social needs and technical energy efficiency. Specifically, there is a lack of empirical evidence on how to navigate the "occasional rooftop usage" for social gatherings; a vital cultural practice, while implementing engineered solar and vegetation layers. Furthermore, although the Renewable Energy Policy 2025 outlines ambitious national targets (20% renewable energy by 2030), there remains a knowledge disparity in how localized financial incentives, such as those from the Sustainable Energy Development Fund (SEDF), can be applied to mitigate the specific high maintenance and installation costs that current residents identify as primary deterrents.

3. METHODOLOGY

This study explores the feasibility and benefits of bio-solar rooftops in mitigating urban heat island (UHI) effects, reducing energy consumption, and enhancing environmental sustainability in Dhaka, Bangladesh. It examines public perception, barriers to adoption, and policy challenges while comparing the effectiveness of biosolar roofs against conventional rooftop solutions.

3.1 Case Study

A case-study approach is designed to evaluate the feasibility and advantages of bio-solar rooftops on mitigative parameters such as urban heat island (UHI) effects, energy consumption, and environmental sustainability advantages in Dhaka, Bangladesh. This research draws upon the case Study of two public residential adjacent buildings at Barangaroo, Sydney, Australia that considers the impact of solar-integrated green roofs in an urban context. It was chosen because it presents real-world evidence of biosolar technology application, demonstrating energy efficiency and urban-cooling benefits.

3.2 Data Collection

The study uses qualitative method to assess public perceptions of bio-solar rooftops of public residential buildings.

3.2.1 Questionnaire Survey

Using Google Forms, a structured survey was made available to a wide range of responders from different age groups and occupations. The survey explored willingness to install, cost concerns, maintenance challenges, public awareness, and energy savings. With 74 responds, the study offers an extensive overview of public opinion regarding the implementation of these systems in Dhaka. Among respondents, 38 (18-30 years) formed the largest group, followed by 22 (31-50 years), 8 (below 18 years) and 6 (above 50 years).

4. RESULTS ANALYSIS

4.1 Questionnaire Survey

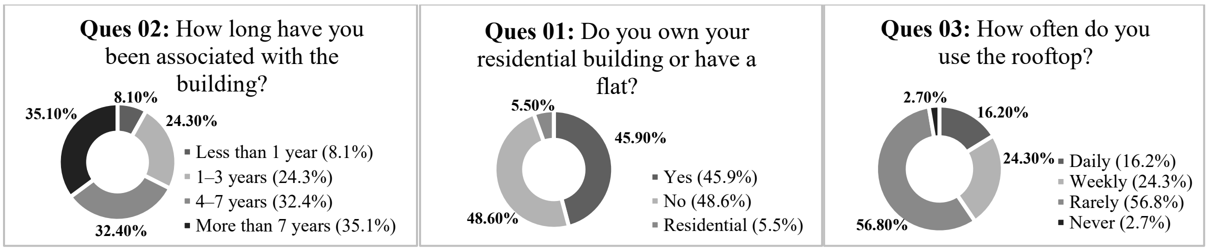

Figure 5: Graph and chart showing questionnaire result

- Ownership (Ques 01): 45.9% of respondents own their homes, while 48.6% do not, indicating that many are renters, which may affect their willingness to invest in long-term solutions like solar-powered green rooftops.
- Duration of Residence (Ques 02): A majority, 35.1%, have lived in their current building for 7+ years, suggesting that long-term residents may be more likely to invest in such improvements.
- Rooftop Usage (Ques 03): 56.8% use their rooftops rarely, with only 16.2% using them daily. This low frequency of use could make it harder to encourage adoption of rooftop-based technologies like bio-solar rooftops.

The findings imply that respondents' opinions on homeownership and rooftop usage are not entirely consistent. The fact that many have lived there for a long time may be an incentive to think about making investments in bio-solar rooftops. The high proportion of renters and the occasional usage of rooftops, however, suggest that there may be difficulties in promoting widespread adoption. Education regarding the long-term advantages and environmental effects of these systems is certainly required particularly for people who do not already consider their rooftop to be an active part of their living area.

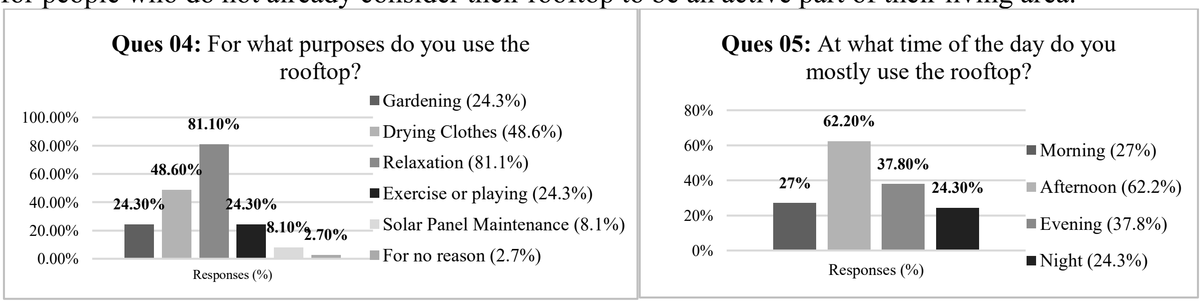

Figure 6: Graph and chart showing questionnaire result

- Purpose of Rooftop Usage (Ques 04): 81.1% of respondents use their rooftop for relaxation, making it the most common activity. 48.6% use it for drying clothes, and 24.3% for gardening A small percentage, 8.1%, use the rooftop for solar panel maintenance, while 2.7% have no specific reason for using it.
- Time of Day for Rooftop Usage (Ques 05): 62.2% of respondents use the rooftop in the afternoon, while 37.8% use it in the evening. A small 27%, use it in the morning and 24.3% use it at night.

In contrast to sustainability-focused uses like gardening or solar panel maintenance, rooftops are primarily used for practical daily tasks or recreational uses, as seen by the majority of respondents using them for relaxation (81.1%) and drying clothing (48.6%). The afternoon (62.2%) is when rooftop usage is at its highest, which aligns with daylight hours and is therefore the best time of day for bio-solar rooftops to produce energy efficiently. Even while rooftops aren't often used for energy generation currently, there is a lot of opportunity to market them as multifunctional spaces that can meet environmental and personal demands, which would encourage a wider adoption of sustainable practices.

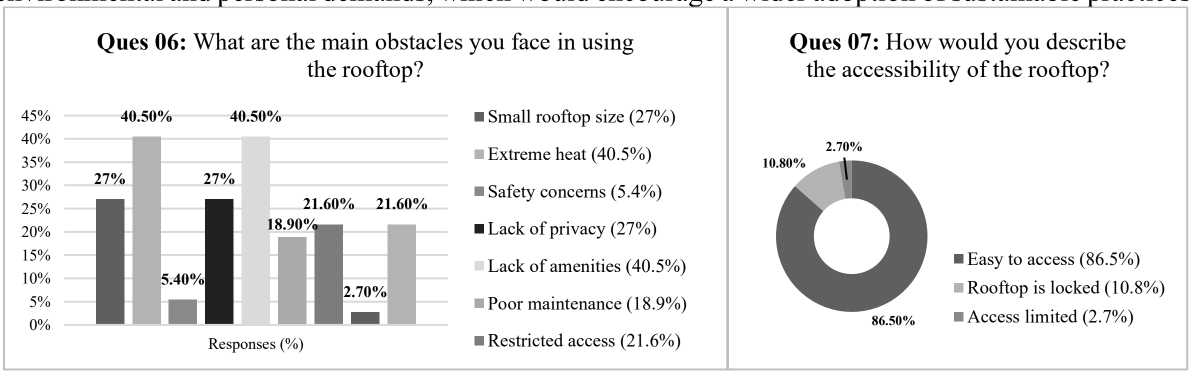

Figure 7: Graph and chart showing questionnaire result

- Obstacles in Using the Rooftop (Ques 06): The key obstacles are extreme heat (40.5%) and lack of amenities (40.5%). Other concerns include small rooftop size (27%), poor maintenance (18.9%), and restricted access (21.6%). 21.6% of respondents reported having no problems.
- Rooftop Accessibility (Ques 07): 86.5% find the rooftop easy to access, while 10.8% say it's locked, and 2.7% report limited access.

According to the data, the lack of amenities and intense heat are the main barriers to using rooftops. The adoption of bio-solar rooftops may be hampered by these obstacles since they might need extra care to make sure that both residents and maintenance staff can use the rooftops comfortably. Most respondents (86.5%) found the rooftops reasonably accessible in spite of these difficulties is encouraging for the possible installation of bio-solar rooftops. To promote more use and investment in sustainable rooftop solutions, it will be necessary to solve problems including heat, a lack of facilities, and restricted access.

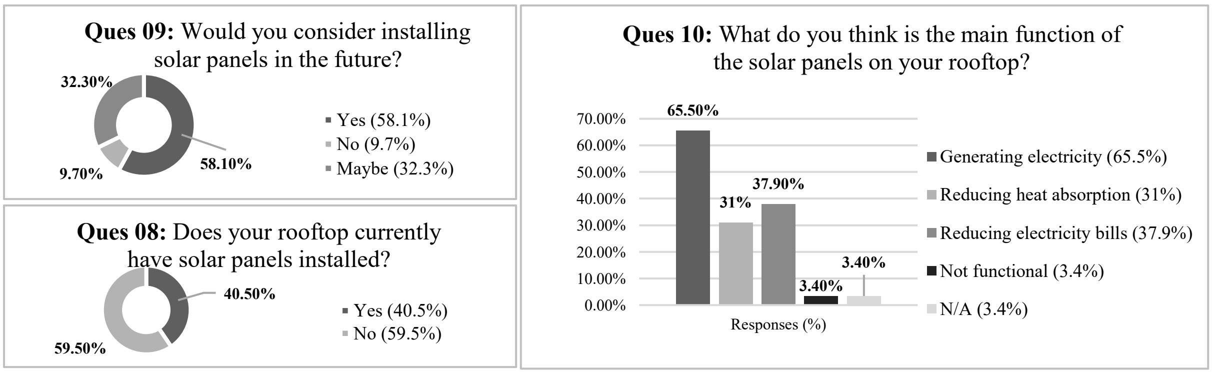

Figure 8: Graph and chart showing questionnaire result

- Current Solar Panel Installation (Ques 08): 40.5% have solar panels installed, while 59.5% do not.
- Interest in Installing Solar Panels (Ques 09): 58.1% would consider installing solar panels, 32.3% are uncertain, and 9.7% would not.
- Perceived Function of Solar Panels (Ques 10): The primary function of solar panels is perceived as generating electricity (65.5%). 37.9% believe the main function is reducing electricity bills, while 31% think they help in reducing heat absorption. A small percentage, 3.4%, find their panels non-functional, and 3.4% have no opinion.

40.5% of those surveyed already have solar panels installed on their roofs, 59.5% do not. Though 58.1% said they would be interested in installing them in the future. This demonstrates a strong desire to use solar technology, which raises the possibility of wider adoption with the suitable incentives. According to 65.5% of respondents, the primary purpose of solar panels is to generate electricity, which is consistent with the main advantage of bio-solar rooftops. But cost savings (37.9%) and a decrease in heat absorption (31%) are also regarded as useful features, suggesting that financial and environmental advantages are important inspiration for further use.

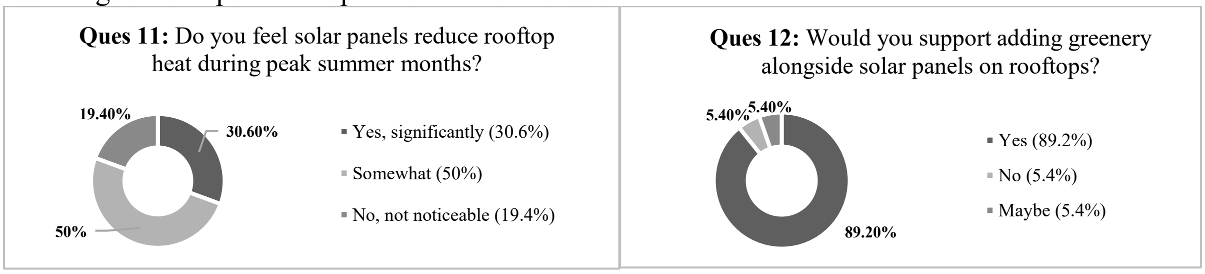

Figure 9: Graph and chart showing questionnaire result

- Perceived Impact on Rooftop Heat (Ques 11): 30.6% feel that solar panels significantly reduce rooftop heat during peak summer months. 50% believe they somewhat reduce heat, while 19.4% think they do not have a noticeable effect.
- Adding Greenery with Solar Panels (Ques 12): 89.2% would support adding greenery alongside solar panels on rooftops. 5.4% would not, and another 5.4% are uncertain.

Most respondents (80.6%) think that solar panels contribute to a considerable or moderate reduction in rooftop heat. This demonstrates how widely acknowledged their cooling advantages are. Additionally, 89.2% of respondents strongly favor the addition of greenery alongside solar panels, indicating a significant desire to combine energy production and environmental advantages like cooling. This indicates that a sizable portion of the public is open to accepting solar-powered green rooftops as a practical, multifunctional alternative.

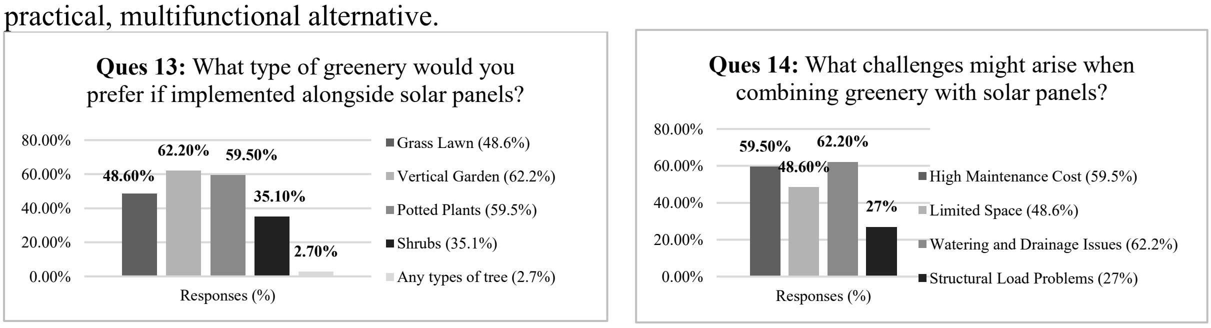

Figure 10: Graph and chart showing questionnaire result

- Preferred Type of Greenery (Ques 13): 62.2% prefer vertical gardens alongside solar panels. 59.5% favor potted plants, and 48.6% prefer grass lawns. 35.1% would choose shrubs, while only 2.7% would prefer any types of tree.
- Challenges of Combining Greenery (Ques 14): The biggest concern is high maintenance cost (59.5%). 62.2% also noted watering and drainage issues, while 48.6% mentioned limited space. 27% are concerned about structural load problems.

Interest in compact greenery solutions can be seen from respondents' strong preference for potted plants (59.5%) and vertical gardens (62.2%) when paired with solar panels. Although less common, grass lawns (48.6%) are also in demand. The feasibility of combining plants with solar panels may be limited by the primary constraints, which include high maintenance costs (59.5%) and watering/drainage problems (62.2%). These issues show that in order to guarantee the sustainability and viability of bio-solar rooftops, economical solutions and appropriate water management systems are required.

4.2 Case Study Analysis

Figure 11: Rooftop view looking south, showing plantings around and underneath solar panels. Source: (Alameddine et al., 2021)

The case Study examined the effects of a bio-solar rooftop and a traditional rooftop on temperature regulation, biodiversity, and solar panel efficiency. According to the study, solar panel temperatures can drop by up to 9.63°C and roof surface temperatures can drop by 6.93°C when green roofs are installed. Depending on the month, this cooling effect enhanced solar panel efficiency and power output by 21–107%.

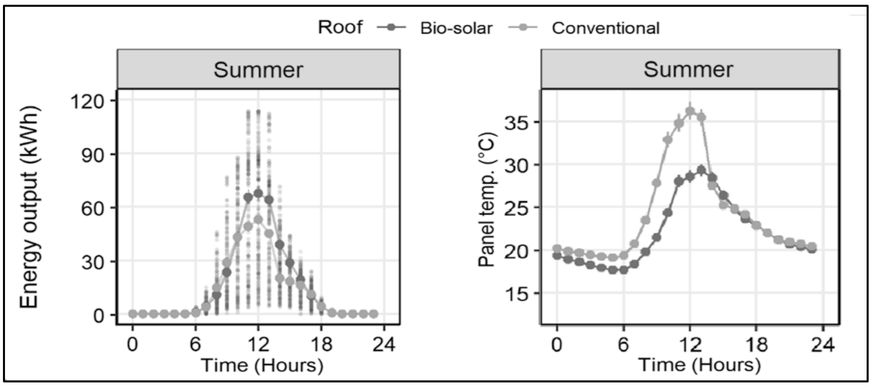

Figure 12: Energy output (left) and surface temperatures (right) of solar panels on a bio-solar green roof and on a conventional roof. Source: (Alameddine et al., 2021)

The bio-solar roof had significantly more biodiversity than the conventional roof, supporting twice as many snails and slugs, seven times as many arthropods, and four times as many bird species. Additionally, the green roof enhanced building insulation and decreased rainwater runoff, which resulted in energy savings. The study demonstrates that bio-solar roofs have two advantages: they increase solar energy production while also encouraging biodiversity and urban cooling. These results highlight how crucial it is to combine renewable energy sources and green infrastructure for sustainable urban growth.

5. CONCLUSIONS

The results of the poll and the case study demonstrate how popular bio-solar rooftops are in Dhaka and how their advantages are becoming more widely acknowledged. The potential of such systems to save energy and the environment was clearly recognized by the respondents. Support for combining solar panels with vegetation was overwhelmingly positive, indicating a desire for multifunctional rooftop areas that provide both aesthetic appeal and energy efficiency. However, for these systems to be widely used in the urban setting of Dhaka, a few issues such high maintenance costs, space constraints, and occasional rooftop usage must be resolved. Important findings include:

- Bio-solar rooftops have generated a lot of interest, particularly among long-term residents.
- Energy conservation, heat reduction, and environmental impact are the three primary perceived advantages of these systems.
- The biggest obstacles to adoption are space limitations and the high expenses of setup and maintenance.

8. DECLARATION

The authors state that artificial intelligence (AI) tools were exclusively used for language refining, grammar correction and clarifying clarity when preparing the manuscripts. The research design, data collection, analysis, interpretation, and scholarly content were entirely developed by the authors. All AI assisted outputs were critically reviewed to ensure accuracy, originality and meeting academic standards. No AI tools were used in the fundamental research and decision-making processes. The integrity and authenticity of this manuscript is the sole responsibility of the authors.

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