



UNIVERSITI
TEKNOLOGI
MARA

PROCEEDING FOR INTERNATIONAL COLLOQUIUM ON NEXTGEN CONSTRUCTION

2025

*Future-Ready Construction and Facility Management:
Driving Research and Innovation for a Smart Built Environment*

**PROCEEDING FOR
INTERNATIONAL COLLOQUIUM ON
NEXTGEN CONSTRUCTION
2025**

Organiser:

Universitas Pamulang (UNPAM)

Co-organiser:

Department of Built Environment Studies and Technology,
Faculty of Built Environment,
UiTM Perak Branch

Faculty of Built Environment, UiTM Sarawak Branch

Colloquium Date:

6 May 2025

Unit Penerbitan UiTM Perak, 2025

All rights reserved. No part of this publication may be reproduced, copied, stored in any retrieval system, or transmitted in any form or by any means; electronic, mechanical, photocopying, recording, or otherwise; without permission on writing from the director of Unit Penerbitan UiTM Perak, Universiti Teknologi MARA, Perak Branch, 32610 Seri Iskandar Perak, Malaysia.

Perpustakaan Negara Malaysia

Cataloging in Publication Data

No e- ISBN: 978-967-2776-60-4

Cover Design : Nur'Ain Ismail

Typesetting : Nur'Ain Ismail

ENHANCING RESIDENTIAL SUSTAINABILITY: THE IMPACT OF GREEN ROOFS ON TEMPERATURE, HUMIDITY, AND CARBON DIOXIDE EMISSIONS

Siti Nur Aishah Mohd Noor^{1*}, and Chin Zan Ren²

¹ Department of Built Environment Studies and Technology, Faculty of Built Environment,
Universiti Teknologi MARA, Perak Branch, Malaysia

² Zhao Yang Geotechnic Pte Ltd, Gua Musang, Kelantan

Corresponding Author: sitinuraishahmn@uitm.edu.my

Abstract

The growing impacts of global warming, such as rising global temperatures, melting icebergs, and worsening climate conditions, have highlighted the need for sustainable solutions. Human activities like open burning and excessive fossil fuel consumption significantly contribute to these environmental challenges. While green roofs have become an integral part of sustainable architecture in Europe, their adoption in Malaysia remains limited. This study explores the potential benefits of implementing green roofs in Malaysian residential buildings to mitigate the effects of global warming. The primary objective of this research was to compare the performance of green roofs with conventional roofs in terms of temperature regulation, humidity control, and carbon dioxide (CO₂) emission reduction. To achieve this, data were collected using indoor air quality meters from two 3D model houses: one equipped with a green roof and the other with a conventional roof. Measurements were taken from morning to evening over a full day. Key findings revealed that residential buildings with green roofs experience lower indoor temperatures, reduced humidity levels, and decreased CO₂ emissions compared to their counterparts with conventional roofs. These results underline the potential of green roof applicants to improve indoor air quality and enhance thermal comfort for residential occupants in Malaysia. The study highlights the importance of integrating green roofs into urban planning and sustainable building practices to address environmental challenges and promote healthier living environments.

Keywords: Green roof, Sustainable building, Global warming mitigation, Indoor air quality, thermal comfort

1. INTRODUCTION

Global warming, caused by greenhouse gases including carbon dioxide (CO₂), nitrogen dioxide (NO₂), and water vapor, has resulted in increased global temperatures, impacting thermal comfort and intensifying climate change. Green roofs have emerged as environmentally sustainable alternatives. Vegetation-covered roofs, originating over 3000 years ago with turf roofs in Norway and Iceland, were modernized in the 1960s through various research initiatives. Green roofs provide various advantages, such as decreasing energy consumption in buildings, reducing carbon emissions through photosynthesis, alleviating urban heat, and facilitating stormwater management. Nonetheless, the elevated construction and maintenance expenses, attributed to intricate multi-layered designs and structural necessities, present challenges. Green roofs present considerable potential as sustainable building solutions for addressing global warming and improving urban living conditions.

2. LITERATURE REVIEW

Global warming refers to the increase in the Earth's surface temperature over time,

primarily caused by the accumulation of greenhouse gases due to human activities. During the 20th century, the Earth's average temperature rose by approximately 0.6°C (1.1°F) (Smith, 2000). Major contributors to global warming include the combustion of fossil fuels and large-scale deforestation, which release significant amounts of greenhouse gases into the atmosphere. While these gases play a crucial role in maintaining the earth's temperature at livable levels, their excessive presence has adverse effects. Key greenhouse gases include water vapor (H₂O), carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and fluorinated gases such as sulfur hexafluoride (SF₆) (Center for Climate and Energy Solutions, 2021). These gases trap solar radiation and retain heat, hereby contributing to rising global temperatures and climate instability.

Carbon dioxide (CO₂) is a naturally occurring gas that composed of one carbon atom and two oxygen atoms bonded covalently. It is colorless, odorless, and found in trace amounts in the Earth's atmosphere. CO₂ is the primary greenhouse gas responsible for the global warming effect, accounting for the majority of emissions resulting from human activities. These activities include open burning, fossil fuel combustion, industrial processes, agricultural practices, and fertilizer use (Brown, 2013). The increasing concentration of CO₂ intensifies the greenhouse effect, thereby accelerating global temperature rise and associated environmental challenges.

Humidity refers to the amount of water vapor present in the air, which is another significant greenhouse gas contributing to global warming. High levels of humidity can affect human thermal comfort, as water's high heat capacity requires more energy for evaporation (Williams et al., 2010). Elevated humidity levels exacerbate the feeling of warmth, particularly in tropical climates, and impact overall thermal comfort for individuals.

A green roof also referred to as a vegetative roof, comprises a roof surface covered entirely or partially with vegetation. The system typically consists of multiple layers, including a top vegetation layer, a soil medium, a filter fabric, a drainage layer, a waterproof membrane, and a roof deck (Miller & Green, 2017). Modern green roof technology gained recognition in the 1960s, with German researcher Reinhard Bornkamm emphasizing its environmental benefits. In 1961, the Geno Haus projects applied Bornkamm's concepts, popularizing green roofs in urban architecture (Smith et al., 1965). Today, green roofs are valued for their role in reducing building energy consumption, mitigating urban heat, and managing stormwater.

Indoor Air Quality (IAQ) meters are vital tools for assessing and monitoring the air quality within buildings. These devices are commonly used for green building assessments, allowing for efficient detection of potential IAQ issues. IAQ meters contribute to balancing energy efficiency with occupant health, comfort, and productivity. By providing real-time, accurate measurements, they enable proactive responses to indoor air complaints and prevent potential problems from escalating (Johnson, 2019).

3. METHODOLOGY

3.1 Research Design

This research utilizes an experimental design to assess the thermal performance, carbon dioxide emissions, and humidity levels of green roofs in comparison to conventional roofs, within a controlled setting. The study utilized two house models: one featuring a green roof and the other a conventional roof. Data were collected with an indoor air quality (IAQ) meter under controlled conditions to assess temperature, humidity, and CO₂ emissions from 10.00 am to 4.00 pm.

3.2 Raw Materials and Setup

The house models were constructed using concrete to better represent real residential buildings. Galvanized iron was utilized for the roof deck, as it is commonly used in Malaysian construction. The materials required for the green roof included:

- a) **Waterproof Membrane:** A plastic waterproof membrane to prevent water penetration to the roof deck.
- b) **Drainage Layer:** An anti-slip mat with an S-shaped hollow plastic mesh to enhance water drainage.
- c) **Filter Layer:** Stainless steel wire cloth screen to separate soil from water and prevent soil runoff.
- d) **Soil Layer:** Soil collected from agricultural or farm areas.
- e) **Vegetation Layer:** Green grass, selected due to its shallow root system, minimizing structural impacts on the roof.

The conventional roof comprised a standard wooden roof deck without additional layers.

3.3 Construction of House Models

1. **Formwork Creation:** Plywood was measured (300 mm), cut, and assembled into a square formwork, which was placed on a plywood base. Wire mesh was cut to match the formwork dimensions to reinforce the concrete.
2. **Concrete Preparation:** Cement, sand, and water were mixed in specific proportions and poured into the formwork. After curing, the formwork was removed to reveal hardened concrete plates, which were joined with superglue to form the house model.
3. **Roof Construction:** Galvanized iron sheets (400 mm) were measured, marked, and cut for use as the roof deck. For the green roof, a plywood container was constructed to hold the layers of the material in the following sequence: galvanized iron deck, plywood base (insulator), waterproof membrane, drainage layer, filter layer, soil layer, and vegetation layer (green grass).

3.4 Experiment Procedure

- a) **Setup of IAQ Meter:** The indoor air quality meter was calibrated and prepared for data collection

b) **Data Collection**

The house model with the green roof was placed at the testing location. Measurements for temperature, humidity, and CO₂ emission were recorded every 20 seconds for accuracy.

The green roof was then replaced with the conventional roof, and measurements were taken after a one-minute interval to minimize error.

Outdoor conditions were also measured using the IAQ meter.

c) **Repetition:** Data collection was conducted three times per hour to obtain average results for each roof type over the six-hour testing period (10.00 am to 4.00 pm)



Figure 1: Green Roof with 3D Concrete House Model

3.5 Data Analysis

The collected data were analyzed to compare the performance of green roofs and conventional roofs. Statistical tools were employed to calculate the average temperature, humidity levels, and CO₂ emissions for each roof type, highlighting significant differences.

4. FINDING AND DISCUSSION

4.1 Temperature Analysis

The findings revealed that the temperature inside the house model with a conventional roof was significantly higher compared to the green roof. This is due to the thermal properties of the conventional roof materials, which is metal. Metal is highly heat-absorbent, causing the interior temperature to rise. In contrast, the green roof functions as a cooling roof, where the vegetation layer traps sunlight and carbon dioxide for photosynthesis, releasing oxygen and subsequently reducing the temperature. These results align with previous studies that highlight the role of green roofs in minimizing heat gain and enhancing thermal comfort (Miller & Green, 2017).

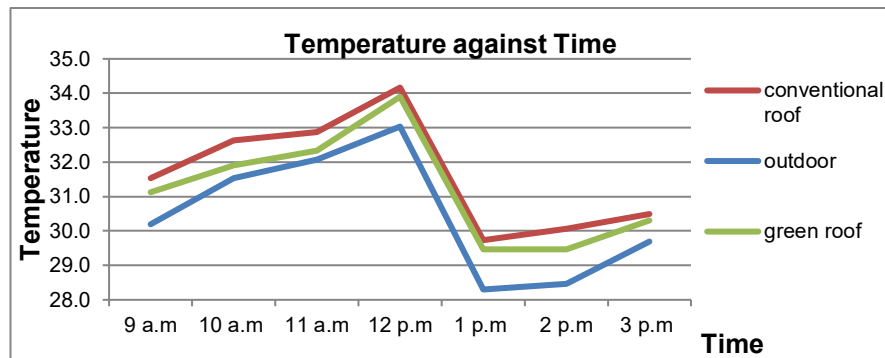


Figure 2: Temperature against Time

4.2 Carbon Dioxide Emissions

Carbon dioxide (CO₂) emissions were found to be highest in outdoor conditions compared to both roof types, except at 2.00 pm. This is likely due to outdoor environments being directly exposed to CO₂ emissions from human activities such as transportation and industrial processes. However, during the experiment, the house model acted as a barrier, reducing CO₂ exposure indoors. At 2.00 p.m., CO₂ levels for the green and conventional roofs temporarily exceeded outdoor levels due to the presence of wind dispersing CO₂ outdoors. The green roof displayed slightly lower CO₂ emissions than the conventional roof, as green plants absorbed CO₂ during photosynthesis. These findings corroborate studies emphasizing the role of green roofs in improving air quality (Jones et.al, 2015).

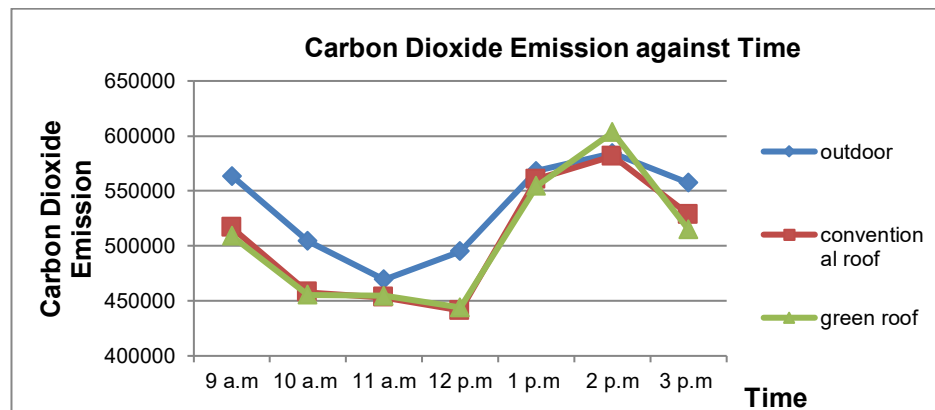


Figure 3: Carbon Dioxide Emission against Time

4.3 Humidity Analysis

The humidity levels inside the house model with a conventional roof were consistently higher than those with a green roof and outdoor conditions. This can be attributed to the inability of conventional roofs to regulate humidity levels. Conversely, the green roof reduced indoor humidity due to the moisture absorption properties of vegetation. During a rain event at noon., humidity levels in both roof types increased sharply, exceeding outdoor humidity levels. This occurred because rainwater became trapped

within the house models, delaying evaporation. However, the green roof exhibited lower humidity levels than the conventional roof, as its vegetation absorbed water vapor from the air. This observation aligns with research indicating that green roofs effectively manage indoor humidity and enhance occupant comfort (Tseng,2022).

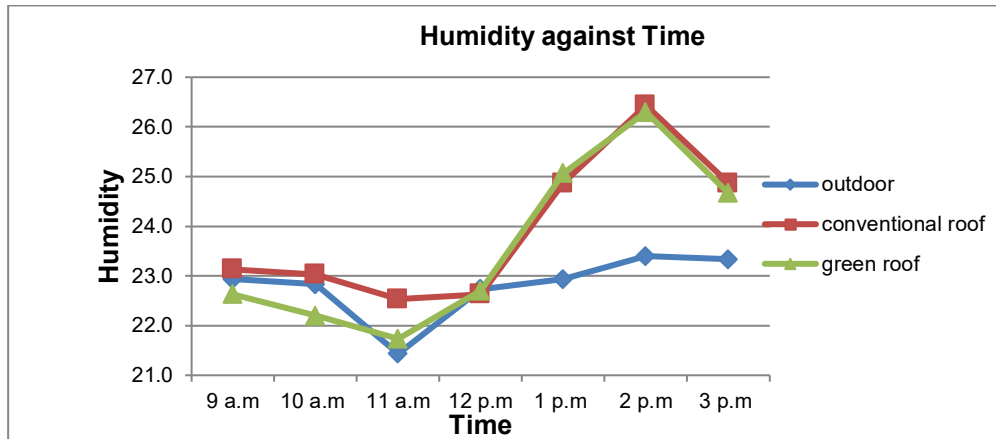


Figure 4: Humidity against Time

4.4 Interpretations and Implications

The results underscore the effectiveness of green roofs in mitigating urban heat, reducing CO₂ emissions, and controlling indoor humidity. These findings reinforce the potential of green roofs as a sustainable building solution to combat the effects of global warming, improve indoor air quality, and enhance thermal comfort. By incorporating green roofs into urban planning and residential construction, policymakers and architects can address critical environmental challenges while promoting energy-efficient and eco-friendly living environments.

5. CONCLUSION

This study highlights the advantages of green roofs in reducing indoor temperature, lowering carbon dioxide (CO₂) emissions, and managing humidity compared to conventional roofs. Green roofs act as cooling systems, improving indoor comfort and air quality by utilizing vegetation to absorb CO₂ and release oxygen. The results also show that green roofs perform better under sunlight, making them an effective sustainable solution. However, the study faced limitations, such as the short experiment duration and external weather influences. Future research should extend the study period, use real residential buildings, and focus on urban areas to better understand the benefits of green roofs. This study emphasized the importance of green roofs in promoting sustainable architecture and addressing environmental like global warming.

6. ACKNOWLEDGEMENT

The authors acknowledge the contributions of AI tools and platforms: OpenAI's ChatGPT for grammar and clarity, Quill Bot for paraphrasing, Research Rabbit for literature organization, Google Scholar for sourcing articles, and Mendeley for citation management. Their support has greatly enhanced this work.

7. REFERENCES

- Ana, P., Filipe, P. Ana, and P. Filipe, (2014) "Green roofs - construction and functional requirements for four buildings on the IST campus Morvarid Mobasheri," no. October.
- Center for Climate and Energy Solutions, 2021, Sixth Assessment Report, Intergovernmental on Climate Change.
- Freije, A. M., Hussain, T. , and Salman, E. A. (2017) "Global warming awareness among the University of Bahrain science students," *Journal of the Association of Arab Universities for Basic and Applied Sciences*, vol. 22, pp. 9–16.
- Graywolf, (2014) "IAQ air quality meter," *Advanced Environmental Instrumentation*, pp. 1–4.
- Messaoud, H., and Cherifa, A.,(2017) "Influence of humidity and temperature on the deterioration of the building stones," *Facilities*, vol. 35, no. 11/12, pp. 590–600
- Mohammed Ahmed, R., and Halil Alibaba, A.Z. (2016) "An Evaluation of Green Roofing in Buildings," *International Journal of Scientific and Research Publications*, vol. 6, no. 1, pp. 366–2250
- Nottingham, "Decruz, Aloysius (2016) Development and integration of a green roof model within whole building energy simulation. PhD thesis, University of Nottingham.
- Perivoliotis, D., Arvanitis, I., Tzavali, A., Papakostas, V., Kappou, S., Andreacos, G., Fotiadi, A., Paravantis, J.A., Souliotis, M., and Mihalakakou, G. (2023) Sustainability Urban Environment through Green Roofs: A Literature Review with Case Studies, *Sustainability*, 15(22), MDPI
- Pi, E. A., (2013) "Final Report Air movement as an energy-efficient means toward occupant comfort," no. November.
- Schlesinger, E. S. B., William, H., (2012) *An Analysis of Global Change*, Three.
- Tan, T., Kong, F., Yin, H., Cook, L.M., Middel, A. & Yang, S., (2023) Carbon dioxide reduction from green roofs: A comprehensive review of processes, factors, and quantitative methods. *Renewable and Sustainable Energy Reviews*, Volume 182.
- Tangang, F.T., Juneng, L., Salimun, E., Sei, K.M., Le, L. J and Muhamad, H., "Climate change and variability over Malaysia: Gaps in science and research information," *Sains Malaysiana*, vol. 41, no. 11, pp. 1355–1366, 2012.
- Tseng, K. H., Chung, M. Y., Chen, L.H. and Chou, L.A.,(2022) A Study of Green Roof and Impact on the temperature of Buildings using Integrated IoT System
- Thurston, M., and Eckelman, M.J.,(2011) "Assessing greenhouse gas emissions from university purchases," *International Journal of Sustainability in Higher Education*, vol. 12, no. 3, pp. 225–235



UNIVERSITI
TEKNOLOGI
MARA

PROCEEDING FOR INTERNATIONAL COLLOQUIUM ON NEXTGEN CONSTRUCTION 2025

*Future-Ready Construction and Facility Management:
Driving Research and Innovation for a Smart Built Environment*

eISBN 978-967-2776-60-4

