International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 13 Issue 1 ǁ January 2025 ǁ PP. 105-114

Principles of Bioclimatic Architecture in the Tropics Case Study: Mesiniaga Tower

Muhammad Rizky Abubakar[1], Akbar[2], Puteri Fitriaty[3]
[1]*Master of Architecture Student, Tadulako University, Palu, Indonesia*
[2]*Master of Architecture Student, Tadulako University, Palu, Indonesia*
[3]*Department of Engineering, Tadulako University, Palu, Indonesia*

Abstract

Bioclimatic architecture has become a primary focus as a solution for sustainable and environmentally friendly design. This approach adapts to local climates by utilizing natural elements such as sunlight, wind, and vegetation to achieve thermal comfort and energy efficiency. This study analyzes the application of bioclimatic principles in tropical regions through a case study of Menara Mesiniaga, designed by Ken Yeang, which is relevant for addressing tropical climate challenges such as high temperatures and humidity, as well as its potential for creating energy-efficient buildings. Using literature reviews and case study analysis, the research identifies design elements such as natural ventilation, daylighting, and vertical vegetation. The findings show that Menara Mesiniaga effectively integrates bioclimatic principles through vertical gardens and adaptive facades, reducing energy consumption and supporting sustainability. The study highlights the potential for adopting similar concepts in Indonesia, although it requires policy support, regulations, and public awareness for successful implementation. This research is expected to provide insights for architects and policymakers in developing more adaptive and sustainable tropical building designs..

Keywords: *Bioclimatic architecture, tropic, ken yeang, menara mesiniaga.*

Date of Submission: 07-01-2025 Date of acceptance: 18-01-2025

I. INTRODUCTION

Bioclimatic architecture is a design approach that aims to create buildings that are in harmony with local climatic conditions. This principle takes advantage of the characteristics of the local environment, such as sun orientation, wind direction, air humidity, and temperature, to produce thermal comfort naturally without relying entirely on modern technology such as air conditioning or artificial heating. This approach is also in line with sustainability principles, as it is able to reduce energy consumption and carbon emissions of buildings. Thus, bioclimatic architecture is not only a design solution, but also a real contribution to environmental conservation [1][2].

In tropical regions, such as Southeast Asia, the application of bioclimatic architecture is very relevant. The tropical climate, which is characterized by hot temperatures, high humidity, and high sunlight intensity throughout the year, demands building designs that are able to overcome these challenges while taking advantage of the advantages of a tropical climate. Climate-non-adaptive designs can significantly increase energy use, especially for air cooling. By applying the principles of bioclimatic architecture, the potential of the tropical environment can be maximized to create natural thermal comfort, while reducing dependence on energy resources [3].

The Mesiniaga Tower, located in Subang Jaya, Malaysia, is one of the best examples of the application of bioclimatic architectural principles in the tropics. Designed by renowned architect Ken Yeang, the building reflects a harmonious integration of modern design and adaptation to the tropical climate. Some of the key features of the Mesiniaga Tower include a vertical garden that serves as natural insulation, cross-ventilation to improve air circulation, as well as the use of local materials to support sustainability. Ken Yeang himself is known as a pioneer in a sustainable approach to tropical architecture, and the Mesiniaga Tower is one of his iconic works that is widely studied by researchers and professionals in the field of architecture [1][3].

The Mesiniaga Tower not only serves as an office building, but also as a model for the application of bioclimatic architectural principles in tropical climates. The design prioritizes the use of passive technology, such as natural ventilation systems and natural lighting, which are able to significantly reduce energy consumption. In addition, the existence of vertical gardens and green roofs not only beautifies the aesthetics of the building, but also increases biodiversity and helps manage the micro-temperature around the building.[2].

Indonesia, as a tropical country located on the equator, faces unique challenges in creating thermally comfortable, energy-efficient, and sustainable buildings. The tropical climate is characterized by air temperatures that tend to be high throughout the year, significant relative humidity, and high intensity of sunlight. This condition often leads to the use of large amounts of energy for air cooling, especially in urban areas, which in turn contributes to increased global energy consumption and carbon footprint.

According to, bioclimatic architecture emphasizes the relationship between building design and environmental elements such as wind, sunlight, and humidity. This strategy can be in the form of optimal building orientation, building materials that have good thermal properties, and vegetation integration to provide a natural cooling effect. In the tropics, this approach has great potential to address climate challenges without sacrificing the thermal comfort of building occupants [4].

Yeang's bioclimatic principles utilize natural ventilation systems, vertical vegetation, and facades designed to control temperature and lighting, so that buildings can 'breathe' and adapt to daily and seasonal climate changes. Vertical vegetation serves not only as shade but also as a carbon sink and balancer for the micro-ecosystem around the building. In the tropics, where the intensity of sunlight is high and humidity is increased, the application of this vertical vegetation helps to reduce the effects of heat and support the thermal balance of the building. The concept also supports Yeang's 'green skyscraper' design approach, which prioritizes sustainability aspects in the design of eco-friendly high-rise buildings.[5][6][7]

[8] It shows that the application of bioclimatic architectural principles in tropical climates is able to significantly improve the thermal comfort of residents and reduce energy consumption. For example, buildings designed with effective natural ventilation and a roof capable of reflecting heat can reduce indoor temperatures by 3–5°C without the use of air conditioning. In addition, it reveals that the use of eco-friendly local materials not only reduces construction costs but also helps create a more balanced thermal environment, especially in the tropics.[9]

Although numerous studies have underlined the benefits of bioclimatic architecture, its implementation still faces various challenges, including a lack of a deep understanding of the most effective design strategies for tropical conditions, technical limitations in measuring thermal comfort, and constraints in integrating ecological design into modern architectural contexts.

With the increasing urgency to create sustainable buildings that are energy-efficient and environmentally friendly, it is important to understand how bioclimatic approaches can be optimally applied in architectural design. This study aims to explore and analyze the application of bioclimatic architectural principles to the Mesiniaga Tower. This analysis includes the identification of design elements that conform to bioclimatic principles, the evaluation of the effectiveness of these elements in creating thermal comfort and energy efficiency, as well as the potential application of similar concepts in other tropical regions, particularly in Indonesia. With this study, it is hoped that it can provide a deeper understanding of the importance of bioclimatic architecture in creating environmentally friendly sustainable buildings.

II. LITERATURE REVIEW

2.1 Bioclimatic Architecture

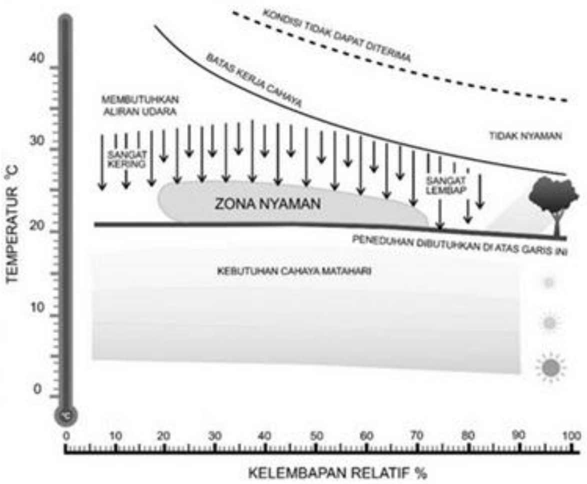
The term Bioclimatic Architecture is used to describe efforts to protect the environment and natural resources through adaptation to local climatic conditions. The main principle is the integration of passive systems that utilize natural resources to create natural conditioning in buildings. The ultimate goal of this approach is to create an indoor climate that is able to provide thermal comfort for residents with minimal energy consumption.

Bioclimatic design refers to a building design approach that is based on local climate data and the use of surrounding natural resources. Elements such as sunlight, wind, air, vegetation, and soil are integrated into the design to reduce overall energy use, while creating a comfortable and pleasant living space. Therefore, understanding the characteristics and types of climate data is the main basis in designing bioclimatic buildings.[10]

Bioclimatic buildings are a form of sustainable development inspired by traditional architecture, with a focus on creating natural comforts optimally. Bioclimatic design refers to an architectural design approach that utilizes solar energy and other related environmental resources, to provide thermal environmental satisfaction for humans inside and outside the building. The origins of bioclimatic design in architecture can be traced to the design principles applied in vernacular buildings that evolved over time, reflecting the environmental, cultural, technological, and historical contexts of a particular location.[11][12][13]

Bioclimatic architecture is the concept, approach, and process of designing buildings that adapt to the natural environmental conditions and the local climate to meet the needs of comfort and energy efficiency. This bioclimatic design tool was first developed by the 1950s, known as bioclimatic graphs.[14]

Bioclimatic graphs are used to show different thermal comfort zones in relation to air temperature and humidity, average temperature of radiation, solar radiation, wind speed, and evaporative cooling. In Figure 1, it can be seen that the comfort zone is in the middle of the diagram, while the temperature above the comfort zone and wind speed are needed to restore comfort related to air humidity.



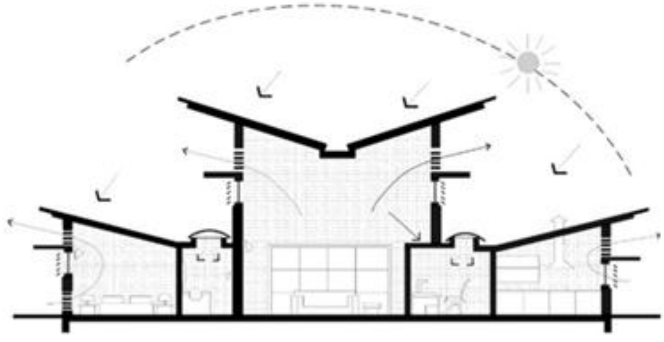
Picture 1. Diagram Bioclimate [14].

2.2 Bioclimatic Architecture Criteria

The development of bioclimatic architecture is currently an important approach in design for architects and developers, as it offers various advantages such as reduced building energy requirements, comfort, reduced costs, as well as positive impact on the environment. The success of bioclimatic design is highly dependent on the application of basic principles adapted to user behavior. Some important criteria for bioclimatic design include proper design, use of renewable energy, sustainable use of materials, accurate implementation during construction, user contribution in building operations, adequate maintenance, and building lifecycle considerations.

Key features of bioclimatic design include:

a. Protect buildings from overheating by utilizing appropriate shading techniques and the use of vegetation.
b. Provides optimal thermal protection on the exterior of the building.
c. Dissipates heat from inside the building through passive cooling systems and natural ventilation.
d. It creates a harmonious relationship between the outdoor and indoor environment of the building, so it is convenient and pleasant for users.
e. Using solar energy as part of a building's passive conditioning system.
f. Utilizing sunlight for natural lighting.[10]



Picture 2. Examples of Bioclimatic Residences [15].

2.3 Bioclimatic Tall Building Design by Ken Yeang

According to Ken Yeang, a bioclimatic skyscraper is a tall building designed with a form configuration in mind that uses energy-saving technology according to the local climate and meteorological data of the site's location. The result is a tall building that is environmentally friendly, efficient in the use of energy during the construction and operational process, and has good aesthetic quality.

Bioclimatic architecture focuses on the design of tall buildings that reduce energy requirements to create thermal comfort in them. In fact, this approach encourages buildings to generate their own energy, for example by utilizing solar panels on rooftops and facades to generate electricity, or using rain harvesting systems to water plants and support water use, such as in urinal flushing.

2.3.1 Building Orientation

Table 1. The orientation of the building is adapted to the conditions of each climate [16].

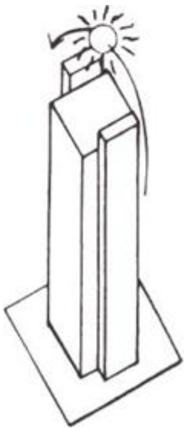
Zone	The main orientation of the building	Directional emphasis
Tropical	On the 5° north axis from the east	North – south
Dry	On the 25° north axis from the east	South – east
Keep	On the 18° north axis from the east	South – southeast
Cold	On the south-facing axis	Facing south

2.3.2 Core

The setting of the main mass can be an important consideration in bioclimatic design, especially related to the position of the building in obtaining shade to avoid overheating or storing heat based on its shape.

For tropical zones, the placement of the core is recommended on the east and west sides of the building. This helps to provide shade that protects the building from exposure to sunlight at low angles throughout the year. The position of the core service in a building, especially high-rise buildings, is very important. Apart from being part of the structure, the core also affects the thermal condition of the building and the scenery it offers. The placement of the core also determines which areas are used as openings and which serve as exterior walls. Based on the location, there are three types of core placement: side core, end core, and central core.

In the tropics, the use of double cores on the east and west sides is highly recommended because the cores serve as buffer zones that insulate heat, protecting indoor spaces from high temperatures. This approach has been proven to be able to reduce the need for air conditioning, by concentrating openings on the north and south sides. A similar strategy can also be applied to temperate regions.



Picture 3. The core is on the east-west side [16].

2.3.3 Area Service

Areas such as elevator lobbies, stairs, and toilets should be well ventilated and directly connected to the outside air and the view. The placement of these elements around the edges of the building can help save energy, as it does not require mechanical ventilation. In addition, natural lighting can reduce the need for artificial lighting. The addition of a mechanical chimney can also be considered for safety purposes, such as fire hazard mitigation. By placing service zones on the exterior of the building, the area can take advantage of direct sunlight for natural lighting and have access to the outside scenery, which is difficult to achieve with a central core layout.

Picture 4. The location of the service zone on the exterior of the building allows for the optimization of lighting and natural ventilation [16].

2.3.4 Site Orientation

The orientation of the building to the movement of the sun is very important, but it is still necessary to consider the shape and geometry of the site. If the geometry of the tread is not aligned with the movement of the sun, then design adjustments such as 'corner shading adjustment' can be made. This is so that the opening of the building still faces north and south, especially in the tropics. However, exceptions can be made if there are other considerations, such as to optimize the scenery.

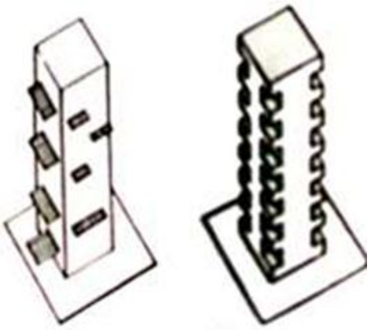
Picture 5. corner shading adjustment [16].

2.3.5 Façade

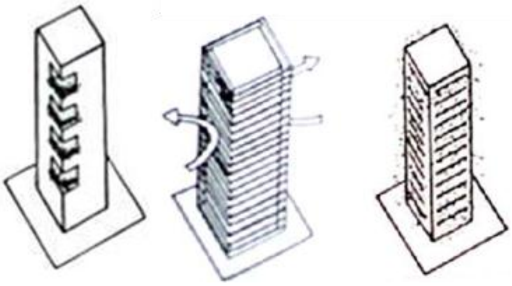
A sufficiently deep opening can give a shadow effect to walls exposed to heat. In addition to serving as a shield from the sun, elements such as a small balcony or skycourt also have additional benefits. The placement of balconies, for example, can provide access for air conditioning on every floor, especially on the sun-exposed sides of the building.

The use of good thermal insulation on the building skin can help reduce heat transfer into the space. One way is to create a second layer of skin on the building, which is positioned above or in front of the main wall, with an air chamber in between as an insulator. In addition, the use of a spray water system is also effective in reducing heat on the skin of the building. The spraying of water on the hot wall triggers an evaporation process that creates a cooling effect on the area.

In temperate climates, panels such as solar windows or solar collector walls can be installed on the exterior of the building. These panels are designed to capture and utilize the sun's thermal energy as an additional energy source.



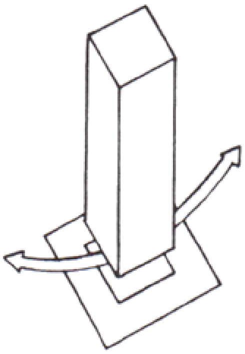
Picture 6. The façade design of the building integrates the use of canopies and balconies [16].



Picture 7. The application of vegetation on balconies and heat-retaining walls in the tropics, as well as the use of water spray walls on the surface of buildings are designed to reduce heat on the building skin [16].

2.3.6 Ground floor

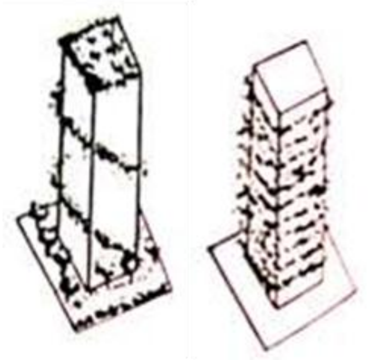
In the tropics, it is recommended to use openings that point outward to ensure optimal air circulation. This opening also functions as an air inlet to support the air chimney effect (stack effect).



Picture 8. Open to sky ground floor [16].

2.3.7 Vegetation and Landscape

The use of vegetation in buildings not only provides ecological and aesthetic benefits, but also helps to lower the air temperature before entering the building. In tall buildings, vegetation can be placed vertically on the façade and inner court area. Plants have the ability to absorb carbon dioxide and produce oxygen, which is very beneficial for the inhabitants of the building and the surrounding environment. In addition, plants also release water vapor which helps to cool the indoor temperature.



Picture 9. Position of vegetation on the bark of the building [16].

2.3.8 Building Structure

The building mass can be used to store heat. The walls of the building are able to release heat at night while still keeping the room temperature cool during the day. In temperate regions, the building mass functions to absorb heat during the day and warm the room at night.

Therefore, based on the principle of bioclimatic design, the building should be designed to be integrated with the surrounding environment. As an approach in ecological architecture, bioclimatic design focuses on the use of climate to reduce energy consumption. Ken Yeang, an architect known for his application of bioclimatic design, emphasized the importance of achieving thermal comfort by utilizing natural energy sources. With this approach, architecture not only avoids negative impacts on the environment, but also utilizes natural elements to support human activities within buildings.

Picture 10. Building structures as heat insulators of sunlight [16].

III. RESEARCH METHODS

This study uses a literature review method with a case study approach to analyze the principles of bioclimatic architecture in Ken Yeang's work in the tropics. This approach was chosen because case studies allow researchers to examine in depth the principles of bioclimatic architecture in specific buildings, including the design, the bioclimatic elements used, and their impact on the environment and the thermal comfort of buildings in tropical climates.

IV. RESULT AND DISCUSSION

4.1 Mesiniaga Tower

Ken Yeang implemented various design elements that integrated the building with the local tropical climate. In the Mesiniaga Tower (Figure 11), Yeang uses "sky gardens" on each floor, which works to improve natural ventilation while reducing heat trapped in the building. These gardens create a natural cooling effect that reduces reliance on artificial cooling, as well as increases thermal comfort for residents. Ken Yeang's bioclimatic design concept emphasizes the use of natural potential on every side of the building. The building is designed to adapt to tropical climates, which have intense sun exposure and high rainfall. During the rainy season, roof gardens are designed to drain water from the roof to the balcony before returning to the catchment area. In summer, roof gardens function to reduce heat radiation from the ground surface below and the surrounding environment.[1], [17]

Picture 11. The Mesiniaga's Tower in Malaysia [3].

Main Ideas and Concepts of Mesiniaga Tower:

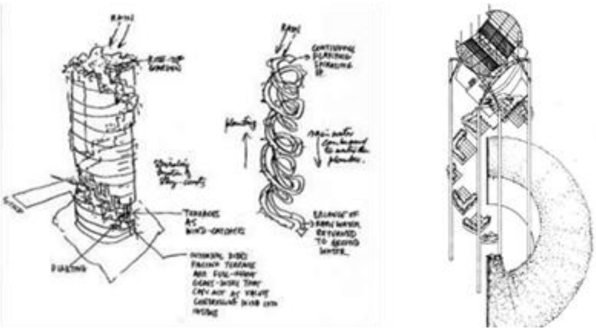
- A sky park that serves as a small "village".
- A vertical landscape that rotates like a spiral.
- Sunken and shaded windows on the east and west sides.
- Glass curtain walls on the north and south sides.
- The single service core is located on the hot side, which is the east.

Toilets, stairs and elevator lobby are naturally ventilated and get sunlight. A spiral balcony on the exterior wall with a full sliding door to the office space inside.

Building Description: The building has 15 floors and is circular in shape. Ken Yeang designed the tower with three main elements:

1. An inclined landscape base that connects the ground with the verticality of the building.
2. The body of the building rotates in a circle with a landscape sky garden, providing visual freshness for office workers while maintaining the continuity of the space that connects the land with the building.
3. The upper floor is equipped with a swimming pool and gym.

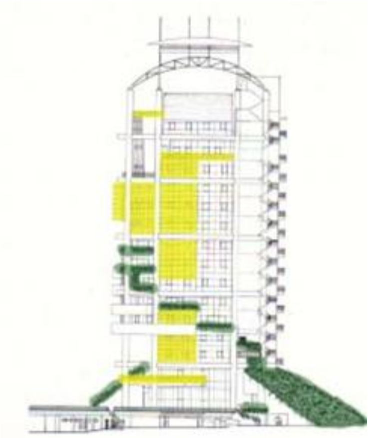
Since the building is located in a tropical climate with high rainfall and solar heat, the vegetation is laid in a spiral from the roof to the ground floor. During the rainy season, water flows from the roof to the balcony and back to the catchment area, and in summer, the roof garden serves to reduce the sun's heat radiation from the space below it and the surrounding environment.



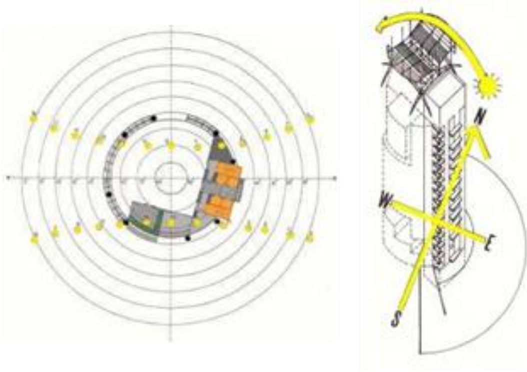
Picture 12. Placement of Vegetation and Sky Garden on the Tower [18][3].

The placement of spiraling stepped sky courts on each floor, as well as the design of vertical spiral vegetation on the balcony, serves to reduce the entry of direct sunlight heat into the room. Some of the heat is absorbed and filtered by the vegetation, while the airflow that passes through the balcony helps create cooler air.

Ken Yeang proposed the idea of maximizing the potential of the tread by adding a greenery ramp that stretches from the ground floor to the roof. This ramp functions to reduce wind turbulence around the bottom of the building, while directing the flow of air to the balcony, so that the wind can flow evenly around the building. The terrace of the building is equipped with glass sliding doors covered with window film to maintain thermal comfort in the room. In addition, this green ramp also helps reduce the impression of the height of the building that is too towering.



Picture 13. Sunscreen (yellow) / Garden Spaces (green) [18].



Picture 14. Sunpath Diagram [18].

4.2 Consideration of Factors in the Tropical Climate

Tropical climate factors, such as high temperatures, humidity, sunlight intensity, and wind patterns, are key considerations in Yeang's bioclimatic design. The Mesiniaga Tower uses an open façade and cross-ventilation to maximize airflow and help lower indoor temperatures naturally. Yeang added an adaptive shade system that controls the intensity of sunlight entering the building, creating natural lighting without causing overheating. This climate-adaptive design helps to reduce energy consumption while maintaining high thermal comfort.[19][20]

4.3 Adaptation Potential in Indonesia

The results of this study highlight the great potential for Indonesia to adopt bioclimatic concepts such as those applied by Yeang. With similar tropical climatic conditions, adaptation of bioclimatic principles can help create a cooler and more sustainable urban environment. However, to achieve this success, commitment from the government and the private sector is needed to support the implementation of bioclimatic architecture through adequate incentives, regulations, and training programs.[20]

V. CONCLUSION

This research shows that Ken Yeang has successfully applied the principles of bioclimatic architecture in the design of his buildings in the tropics by utilizing vertical vegetation, natural lighting, and natural ventilation. Tropical climate factors, such as temperature and sunlight intensity, are key considerations in building design to create natural thermal comfort and reduce energy consumption. Despite the challenges in implementing bioclimatic architecture, its long-term benefits for environmental sustainability demonstrate the relevance of this concept in the face of climate change.

Suggestions that can be given are to expand field data-based research to measure the effectiveness of bioclimatic principles and adapt them to small-scale buildings to make them more inclusive. Innovations in environmentally friendly materials and technologies need to be developed to support energy efficiency. In addition, it is important to increase public and professional awareness through education, as well as encourage government regulations and incentives that support the implementation of bioclimatic architectures. Cross-disciplinary collaboration and long-term research are also needed to ensure its impact on environmental sustainability.

REFERENCES

[1] K. Yeang, *The Green Skyscraper: The Basis for Designing Sustainable Intensive Buildings*. Prestel, 1999.

[2] A. GhaffarianHoseini, N. D. Dahlan, U. Berardi, A. GhaffarianHoseini, N. Makaremi, and M. GhaffarianHoseini, “Sustainable energy performances of green buildings: A review of current theories, implementations and challenges,” *Renewable and Sustainable Energy Reviews*, vol. 25, pp. 1–17, Sep. 2013, doi: 10.1016/j.rser.2013.01.010.

[3] D. Douglass and Jaimes, “AD Classics: Menara Mesiniaga / T.R. Hamzah & Yeang Sdn. Bhd.” Accessed: Nov. 21, 2024. [Online]. Available: https://www.archdaily.com/774098/ad-classics-menara-mesiniaga-t-r-hamzah-and-yeang-sdn-bhd

[4] V. Olgyay, *Design With Climate: Bioclimatic Approach to Architectural Regionalism*. Princeton University Press, 1963.

[5] F. Ragette, *Traditional Domestic Architecture of the Arab Region*. Edition Axel Menges, 2003.

[6] K. Yeang, *Ecodesign: A Manual for Ecological Design*. Wiley, 2008.

[7] B. Vale and R. Vale, *Green Architecture: Design for a Sustainable Future*. Thames and Hudson, 1996.

[8] T. H. Karyono, *Arsitektur dan kota tropis dunia ketiga: suatu bahasan tentang Indonesia*. Rajawali Pers, 2013.

[9] J. P. S. Handoko and I. Ikaputra, “Prinsip Desain Arsitektur Bioklimatik Pada Iklim Tropis,” *Langkau Betang: Jurnal Arsitektur*, vol. 6, no. 2, p. 87, Dec. 2019.

[10] K. Matolcsy, Z. Budavári, and E. B. Kuthi, “Guide for bioclimatic design,” *European Union, PIME’S project*, pp. 1–139, 2015.

[11] G. Desogus, L. G. Felice Cannas, and A. Sanna, “Bioclimatic lessons from Mediterranean vernacular architecture: The Sardinian case study,” *Energy Build*, vol. 129, pp. 574–588, Oct. 2016, doi: 10.1016/j.enbuild.2016.07.051.

[12] A. B. Daemei, S. R. Eghbali, and E. M. Khotbehsara, “Bioclimatic design strategies: A guideline to enhance human thermal comfort in Cfa climate zones,” *Journal of Building Engineering*, vol. 25, p. 100758, Sep. 2019, doi: 10.1016/j.jobe.2019.100758.

[13] A. T. Nguyen and S. Reiter, “Bioclimatism in architecture: An evolutionary perspective,” *International Journal of Design & Nature and Ecodynamics*, vol. 12, no. 1, pp. 16–29, Jan. 2017, doi: 10.2495/DNE-V12-N1-16-29.

[14] V. Olgyay, A. Olgyay, D. Lyndon, V. W. Olgyay, J. Reynolds, and K. Yeang, *Design with Climate: Bioclimatic Approach to Architectural Regionalism - New and expanded Edition*, REV-Revised. Princeton University Press, 2015. doi: 10.2307/j.ctvc77kqb.

[15] R. Hyde, *Bioclimatic Housing: Innovative Designs for Warm Climates*. Earthscan, 2008.

[16] K. Yeang, A. Balfour, and I. Richards, *Bioclimatic Skyscrapers*. Ellipsis, 1994.

[17] W. Rees, “Ecological footprint,” in *Companion to environmental studies*, Routledge, 2018, pp. 43–48.

[18] R. Powell, *Rethinking the Skyscraper: The Complete Architecture of Ken Yeang*. Whitney Library of Design, 1999.

[19] N. Baker and K. Steemers, *Daylight design of buildings: a handbook for architects and engineers*. Routledge, 2014.

[20] A. M. Nugroho and W. Iyati, *Arsitektur Bioklimatik: Inovasi Sains Arsitektur Negeri untuk Kenyamanan Termal Alami Bangunan*. Universitas Brawijaya Press, 2021.