Energy Conservation Techniques in Tropical Climate - A Comprehensive Review and Adaptation of the Lamin House for Nusantara

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Energy Conservation Techniques in Tropical Climate - A Comprehensive Review and Adaptation of the Lamin House for Nusantara

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Abstract: Nusantara is the future capital of Indonesia, located on the east coast of Borneo in East Kalimantan province. As of July 2022, Nusantara construction began, with the first phase of clearing land and installing roads. As a matter of fact, Indonesia's main problem is its high energy consumption. Over one-third of the country's energy consumption is consumed by buildings. Therefore, energy-saving strategies will be essential to making the cities more sustainable, especially in Nusantara. Since Nusantara was planned to be a model sustainable city that could serve as an example for other Indonesian cities. An analysis of tropical-climate residential building design is presented in this paper. A strategy for energy-efficient buildings is outlined based on literature analysis and results from a case study in tropical cities. An energy simulation analysis shows that middle-rise residential houses adapted from Lamin houses will likely consume less electricity (8%) than typical apartment buildings. The simple adaptation of a traditional local building, Lamin house, to a modern mid-rise residential building suggested an open plan with a long and narrow floor plan, overhang over the window, and cross ventilation through window openings.

Keywords: Nusantara; future city; sustainable building; energy efficiency; Lamin house

1. Introduction

Nusantara is the future capital of Indonesia, located on the east coast of Borneo in East Kalimantan province (Fig. 1). As of July 2022, Nusantara construction began, with the first phase of clearing land and installing roads[1,2]. As a matter of fact, Indonesia's main problem is its high energy consumption[3]. In order to increase the energy efficiency of a building, it must take a holistic approach, taking into account its design, the materials from which it is made, its location, its condition, and its use[4-8]. Therefore, energy-saving strategies will be essential for a sustainable Nusantara. Since Nusantara was planned as a sustainable city that could serve as a model for other Indonesian cities, energy-saving strategies will be crucial[1]. The simplest and easiest way to design energy-saving modern buildings is by learning from traditional houses. Traditional houses were built on trial and error, and of course, they adapted to their local conditions[6,9,10,11,12].

Fig. 1: Nusantara is located in the centre of Indonesia.

This paper examines the design of a residential building suitable for the tropical climate of Nusantara. An energy-efficient building strategy has been developed based on a literature analysis of several traditional houses in Indonesia, especially a deep analysis of a traditional house in East Kalimantan called Lou (*Rumah Panjang Lamin*). As part of this research, local climate adaptation strategies were also discussed with the help of climate consultants. As a final step, Nusantara residential buildings were analyzed using simulation software. This analysis provided insight into effective strategies for reducing energy consumption in Nusantara residential buildings.

2. Methodology

To reduce energy consumption through traditional houses, the study focuses on designing residential houses based on a climate study of East Kalimantan. A flow chart showing the entire methodology is shown in Fig. 2. Literature searches are conducted using journals, proceedings, and other relevant sources. The literature covers the following: (1) the culture of the Lamin house; (2) passive cooling and the envelope design of traditional Indonesian houses and Lamin house; (3) the theory of shape and geometry of energy-saving possibilities from traditional Indonesian houses and Lamin house. An application of the theory would be made to modern residential houses (middle-rise buildings). The weather data analysis from the climate consultant simulation tools[13]. It's a graphic-based computer program that simulates the best strategies to reduce energy consumption in East Kalimantan according to EPW local climate data. A comparison energy simulation analysis was conducted using the software eQuest[14] to validate the effectiveness of the design. To understand the performance of a building, building simulation was commonly used[5,15,16]. The modern Lamin house was compared to a typical middle-rise residential house in Indonesia.

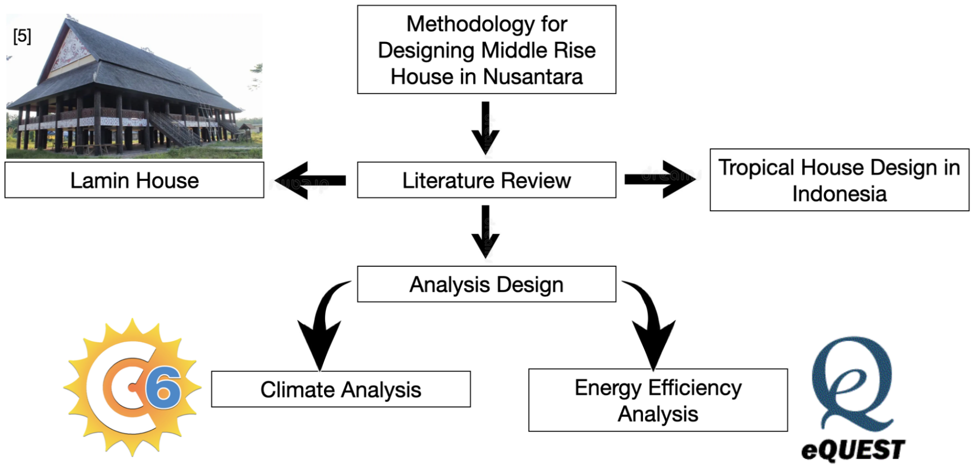


Fig. 2: The design method for a middle-rise house in Nusantara, Indonesia.

3. Literature review

3.1 Lamin house

The island of Kalimantan, also known as Borneo, is the third largest island in the world. In particular, the Kalimantan region of Indonesia consists of five provinces: South Kalimantan, Kalimantan Central Kalimantan, East Kalimantan, West Kalimantan and North Kalimantan[17]. There are many different types of traditional houses among the tribes in East Kalimantan. In this paper, the author specifically discusses one of those houses, the Lamin house, since most of the future Indonesian capital will be located there, Nusantara. The Dayak ethnic group uses the Lamin house as a centre of life and social activities, founded on the values of togetherness and a place to live[18]. The architectural form is influenced by geography, climate, and culture (Fig. 3). It was used for family development, traditional ceremonies, and gathering[19].

Fig. 3: The Latin House located in East Kalimantan[20].

3.2 A house's shape and materials

Typically, Lamin houses are found in the Dayak tribe on Borneo's Island[21]. The Lamin house has a stage-like shape with a height of three meters at the bottom. The Lamin house can measure 25 meters wide by 200 meters long[21]. Traditionally, the Lamin house consists of three components:

1. **Roof**. A gable roof with shingles covers this house[19]. The Lamin roof is shaped like a saddle and has a steep roof slope.
2. **Walls**. The Lamin house ranges from 100-200 meters in length to 20-25 meters in width, depending on the homeowner's needs. The shape symbolizes the

culture of the Dayak, who adhere to a multi-family system. This house is made of ironwood[19]. Lamin house has many openings, such as windows without covers, located in a part of the gathering room.

3. **Legs.** A stage shape is used in Lamin's house to defend against threats and disturbances from outside, such as animal and enemy attacks (from other tribes). In general, the legs of the lamia house are used by the Dayaks as places to raise animals. To reach the main room of the building, a ladder built from scraped or chipped logs is used. This ladder is easily stored and pulled up. Under the lamia house, the leg or column is not covered by a wall so air can circulate freely.

3.3 Space organization

In general, Lamin houses have rectangular layouts. A Lamin house has two longitudinal sections on each side of the interior room[21]. An open room on the front side of the Lamin is used to receive guests, to perform traditional ceremonies, and gather family members[18]. In the back of the building, there is a spacious room that can accommodate five families each.Specifically, Lamin has four rooms: Pagen, Dalem Amin, Tilong and Atang (Fig. 4). These rooms have the following functions:

1. A Pagen is a part of Lamin's house located at the front of the house. The page serves as an area for family leaders to socialize and to make decisions regarding the leadership of the Dayak Kenyah tribe.It is for adult males only.
2. Dalem Amin is located in the centre of Lamin, which is completely closed. Dalem Amin serves as a gathering place for the entire family living in Lamin's traditional house.
3. Tilong serves as a sleeping area for girls and older men.
4. Atang is an open space at the back of the Lamin house that serves as a space for storing water and cooking.

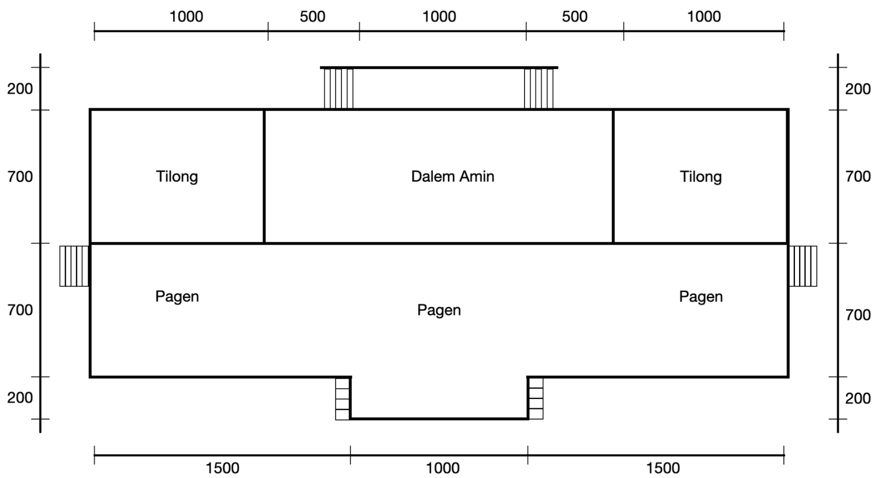


Fig. 4: An overview of the space organization in the Lamin house.

3.4 Lamin House Passive Design

A traditional building has evolved over time to match the local climate and culture of a particular location. It adapted to the environment using low-tech procedures. To understand how Lamin House performs, literature reviews were conducted. However, there was limited data about the Lamin house passive design analysis.

In Lamin's house, the roof serves as an element that dominates the house. The research found that the roof maximized heat transfer, as in the Brusu Dayak tribe living in North Kalimantan[22] and Betang Ensaid Panjang, the traditional Dayak house in Sintang Regency[23]. A research method includes direct surveys and measurements of several points in a traditional house, including measurements of temperature, humidity, and air movement[22,23].

The thermal comfort of Lamin houses varies at different times in different spaces[22,23]. As a result, it can be classified as slightly cool in the morning, warm in the afternoon and evening, and comfortable at night. Since solar radiation can enter directly through the roof gaps, causing air temperature and wind movement to change[22]. Other building components affect heat transfer and air movement as well. including layout, shading, and wood as wall material[23]. This section proves that Lamin house was well adapted to the local climate.

3.5 Adaptive Climate Strategies from Indonesia Traditional Houses

Indonesia has traditional houses on every island. However, since it is a large country with a different climate conditions, such as temperature, humidity, and wind direction, there is a need for a literature review. There are many ways to adapt methods found in traditional Indonesian houses to modern buildings. This section discusses some strategies researchers have used to analyse adaptive methods that can be applied to modern houses. This literature review focuses on methods and strategies for reducing energy consumption in residential buildings, particularly in tropical climates and traditional

Indonesian houses. Moreover, Table 1 provides a literature review summary for adaptive climate measures for traditional Indonesian houses.

Table 1. A summary of Indonesian traditional house adaptation strategies to climate change.

Location	Method	Strategies
Bawean[24]	Ecotect Analysis and Computational Fluid Dynamic (CFD) analysis	● An open plan can increase the wind flow. ● Having a verandah reduces solar glare and radiation since it creates shading.
Mbaru Niang, Flores[25]	Climate Consultant and Computational Fluid Dynamic (CFD) analysis	● Natural cross ventilation can be achieved by designing an open-plan interior. ● Cross-ventilation can be increased by designing high ceilings, window shading, and a verandah. ● To balance daylighting in the South building area, provide enough glazing. ● To minimize heat gain, use plants as one of the building elements. ● Raising the floor will maximize natural ventilation. ● Reduce heat gain by shading west-facing glazing.
Cibinong, Java[26]	Computational Fluid Dynamic (CFD) analysis	● Through heat transfer from the ground to the roof, raised floors contribute to greater thermal comfort. ● Open roof ventilation can significantly influence wind flow inside the house. ● The horizontal fin near the window increases the internal wind velocity.
Gayo, Aceh[27]	Observation, interview and comparison through study literature	● Windows and doors do not expose their interiors directly to a cool external environment. ● A gathering space and kitchen are positioned near the sun (east).
Minahasa, Sumatra[28]	Computational Fluid Dynamic (CFD) analysis	● The height of stilts contributes to better thermal comfort. ● Roof openings produce a greater internal wind velocity than house wall openings. ● Combining a roof with a wall opening almost doubles the internal wind velocity when compared to a roof or wall opening alone. ● A raised floor house's floor opening improves wind velocity.
Java Island[29]	Study literature	● Tropical humid areas have a strong relationship between traditional architecture and the climate. ● Wind direction and solar radiation are strongly correlated with building orientation. ● The design and construction of a building's roof directly influence its temperature.

According to Table 1, most researches state that opening patterns and house layout can increase wind flow and thus reduce the requirement for cooling systems. Natural ventilation can be maximized in traditional houses through a large number of windows. A verandah in traditional Indonesian houses has tons of thermal and acoustic comfort functions, which can also be applied to the current architectural realm.

Research presented in this study provides insights into the local wisdom values of traditional Indonesian houses and contributes to the design of environmentally adaptive buildings. From the literature reviewed above, some Lamin house and other Indonesian traditional houses can be adapted to modern residential buildings in Nusantara, such as:

1. A long, narrow, open-plan house's design.
2. The house has plenty of openings on both sides.
3. Heat can be reduced by raising the floor.
4. The roof has an overhang and a gable.

4. Result and discussion

4.1 Climate of Nusantara, East Kalimantan

East Kalimantan, which is located between 113° 35'31" "and 119° 12'48" east longitude, and 2° 34'23" north latitude and 2° 44'14" south latitude[14], is the fourth largest province in Indonesia (127,346.92 km²). In general, the climate is tropical with two seasons: rainy season and dry season. The dry season usually occurs from May to October, while the rainy season occurs from November to April[14]. The average temperature and humidity in East Kalimantan are shown in Fig. 5. The highest temperature was 35.8°C in March and December, and the lowest was 23.2°C in January. In May, it has the highest humidity at 84%, while June, September, and March have the lowest humidity at 39%[17]. April has the highest wind speed of 12.86 m/s. The Maximum precipitation during 2020 is 282.50 mm with 26 rain days, where intensity occurred on September[17]. The lowest precipitation reached 91.8 mm in February.

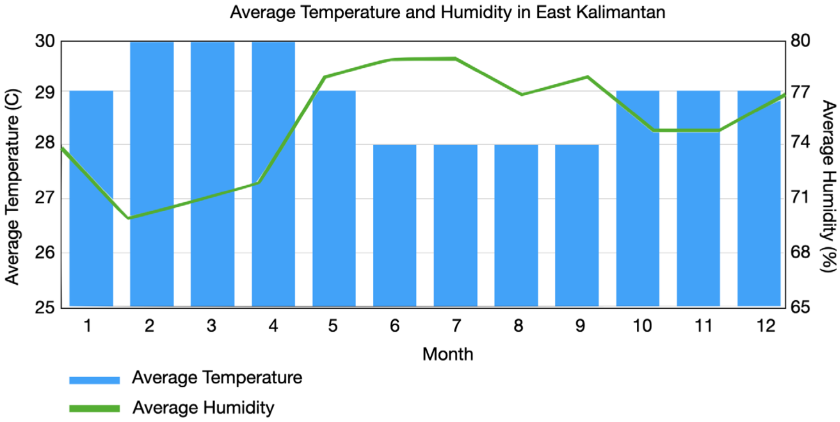


Fig. 5: The average temperature (celsius) and humidity (%) in East Kalimantan.

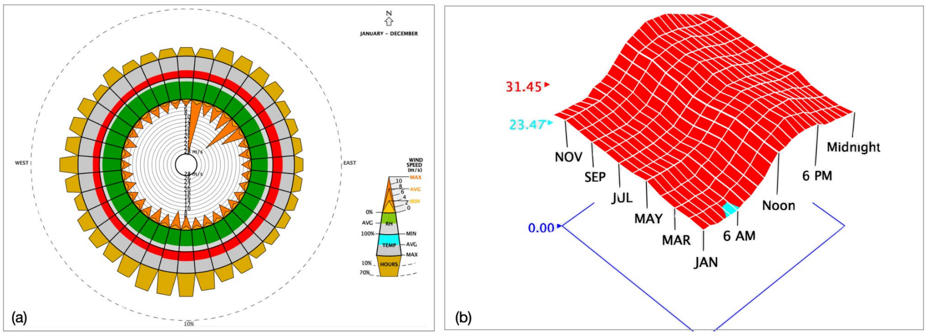


Fig. 6: The climate consultant program shows the local climate in East Kalimantan as follows: (a) wind speed and wind direction, (b) temperature.

The program found that almost all day long, East Kalimantan temperature was quite high (31-45 C) (Fig. 6). The most comfortable weather is only in January at 6 am. This is why the next section will show the final design of the recommended residential building to be located in the future Indonesian capital city, Nusantara.

According to the analysis above, it recommended residential house was designed. Fig. 7 shows Nusantara's final recommendation for residential buildings. This building is a middle-rise residential (5th floor). The first floor was designed to be a parking area, and the second to fourth floors were designed as a residential area. Each floor includes 4 units. The layout of each house includes two bedrooms, one bathroom, one kitchen, and one living room. The design also takes influence from the Lamin house. This also combines with adaptive strategies recommended by climate consultants and literature reviews to reduce energy consumption. These strategies are explained below:

1. The openings on both sides of the house showed good natural ventilation. This can reduce or eliminate the need for air conditioning in hot and humid climates. It also designed shading and orienting the windows to the prevailing winds.
2. A long narrow building floor plan can help maximize cross ventilation in temperate and hot humid climates. Traditional Lamin houses also use this long narrow floor plan.
3. Cross ventilation can be maximized by placing large openings on opposite sides of the building.
4. The interior is designed to be an open plan to facilitate natural cross ventilation. The Lamin house also has an open plan, since the house was used for a variety of purposes.
5. The ceiling heights were high, and tall operable windows were protected by deep overhangs and verandahs.
6. Having a low-pitch roof with a wide overhang.
7. Raising the building above the ground will minimise dampness and maximise natural ventilation. The Lamin house also influenced the design. In addition, the ground floor was used for parking.

8. Window overhangs (designed for this latitude) or operable sunshades (awnings that extend in summer) can allow air conditioning to be reduced or eliminated entirely.

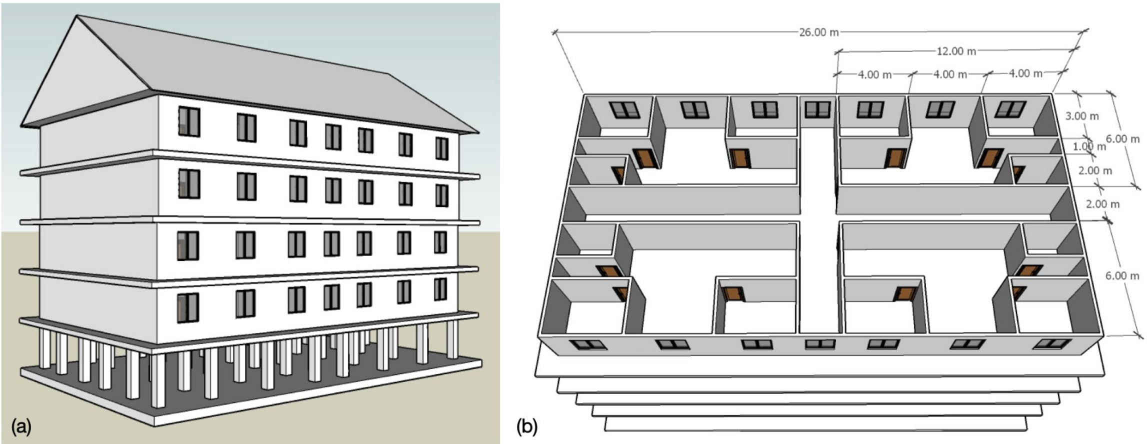
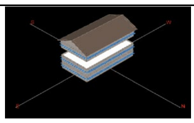
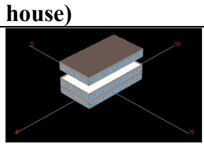


Fig. 7: Adaptive's design of residential building in Nusantara (a) The 3D view; (b) the floor plan.

4.2 Simulation setting

For energy modeling, eQuest[14)] was used. It provides a model similar to the original. A simulation is carried out to understand the performance of a residential house designed based on the traditional Lamin house design. The house was compared with a typical Indonesian middle-rise house. The detailed specifications can be found in Table 2. Energy analysis was performed using the Schematic Design Wizard (SD Wizard). The buildings were both facing south. Models with similar parameter settings and window locations have similar layouts. There is no basement in either building. Both buildings consist of five floors. There were four families on each floor, each with air conditioning. The first floor served as a parking area.

Table 2. The detailed specifications of a designed middle-rise house and a typical residential house in Nusantara.

Location	**House designed using Lamin's roof concept**	**House designed with flat roof (typical middle rise house)**
3D Model		
Roof	Low pitch roof with a wide overhang. Metal frame, using roof tile.	A flat concrete roof without overhang.
External and Internal Wall	Concrete	Concrete
Glass and Window	Single clear 1/8 in, aluminium frame	Single clear 1/8 in, aluminium frame
Window wall ratio (WWR)	10%	10%
Interior ground floor	Ceramic	Ceramic
Ceiling	Gypsum	Gypsum

4.3 Building Efficiency Analysis

The electrical consumption of two different middle rise house designs in Nusantara, Indonesia, was analyzed on an hourly electricity consumption. A monthly energy use overview can be found in Fig. 8. Simulation results showed the consumption of electricity throughout the whole building. This building consisted of 16 families (4 families on each floor). The assumption was that all user behavior and appliances were similar.

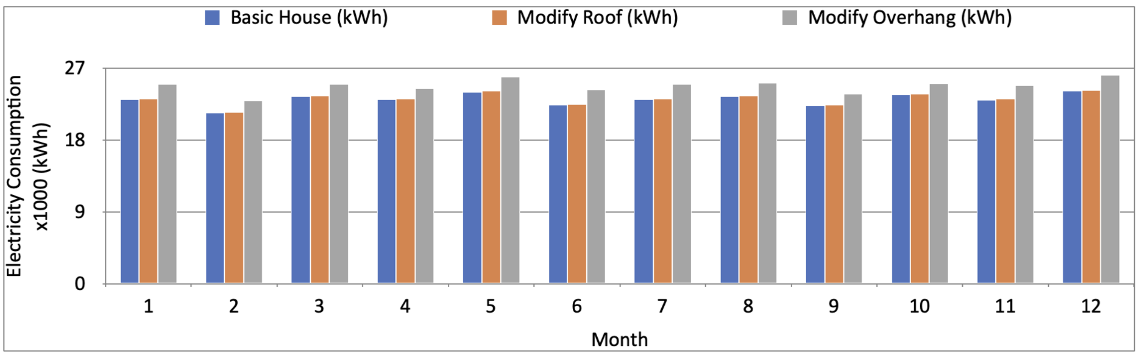


Fig. 8: Electrical consumption (kWh) simulation results of the model houses based on Lamin traditional houses. Compared with typical middle-rise buildings in Indonesia. The overhang has a big impact when compared with the roof shape.

Simulations were performed on two main envelope designs that demonstrate the roof shape and overhang characteristics of a Lamin house. The analysis focused on both variables. A pitched roof reduces electricity consumption by approximately 1% less than a flat roof. Changing the roof type does not appear to reduce the electricity consumption significantly.

A second analysis focused on the overhang, which was 1 m wide and lay over all windows. The design can potentially reduce electricity consumption in January, June, July, and December. There is a minimum of 6% in March, April, September, and October. In addition, the remaining months accounted for approximately 7%. In Nusantara, modifying the overhang reduced electricity consumption more effectively than resigning the roof. In Nusantara, the average radiation levels are quite high. This overhang can reduce the direct sunlight that passes through glass windows.

5. Conclusion

A traditional house in East Kalimantan, the Lamin house, reflects the local culture and is highly adaptable to its surroundings. Moreover, the buildings that were designed specifically for Nusantara should reflect the local culture. This will also become a guideline for other cities in Indonesia. Especially in tropical climates, natural ventilation plays a major role in determining how much energy is consumed by buildings. The design of the building envelope also plays an important role in this. A large amount of data can be created and analyzed with the help of simulation modeling technology. Specifically, this study examines the effectiveness of a middle-rise house designed on the model of Lamin traditional houses. This research focused on roof, window and opening size, space organization, and overhang calculation for the house's design. These studies provide preliminary insight into how to reduce electricity consumption in houses according to local culture.

The roof design appears to have a modest impact on electricity consumption (less than 1%). The overhang, however, contributes significantly to monthly energy savings (6-8%). It is also important to consider how the space is organized and the rise of the floor. It can also increase cross ventilation, as it was adapted from Lamin houses.

In future research, it will be necessary to analyze the energy consumption and effectiveness of roof, opening, space organization, and raising floor in more detail. Based on the literature review (Table 1), Computational Fluid Dynamics (CFD) is one of the most precise methods to analyze airflow. Moreover, future research would like to use CFD as an analysis method.

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