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Investigation on Energy Use in Passive Design House at High Altitude Climate in Malang City, Indonesia

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Abstract

Indonesia is a tropical climate, hence building controlling air ventilation and humid condition have been a challenge to meet residents' convenience. It is often energy usage that is majorly used to control indoor air climate circulation. The passive design has recently received increasing attention as an option to reduce energy consumption and abate carbon footprint by taking advantage of local climatic conditions of building features. This pilot study seeks to identify the relationships between real energy consumption data and building design data. A dwelling house located in Malang, Indonesia was selected as a sample building for the study which introduces a method to use real energy consumption data to calculate the extra energy use related to tropical indoor thermal conditions. The 24 h observation result was validated through interviews with residents, before analyzing with criteria of ideal climate conditions from the literature study. This study also presents relationships between the increase in mean daily energy consumption data and trends of humidity building design data. In conclusion, this present study establishes the starting point for exploring all features affecting the tropical climate benefits of passive design for building energy efficiency.

Keywords : Tropical, Energy, Building, Passive Design, Footprint.

1. Introduction

In the modern era, the energy-efficient building goal is effective thermal condition with considerations of comfort for the building occupants (Aghniaey and Lawrence, 2018). Over the past few years, some developing countries have had significant proportion of energy utilization due to the spread of heating, ventilating, and air conditioning (HVAC) installations for a better lifestyle (Guo, X., Wu, and Ao, Y, 2022). Therefore, that condition will increase energy consumption and the possibility of Green House Gas emissions (GHG) in the world in the upcoming days.

Several studies have been done on the thermal comfort of a people where the result is influenced by knowledge, behavioral, and psychological adaptation (Chaiyapinunt and Khamporn, 2020; Ghahramani et al; Sansaniwal et al., 2019). The finding states that individual users are more concerned with greater comfort, reducing operating and maintenance costs than effective control of ventilation, architectural flexibility, or energy efficient. Moreover, (Kuczyński and Staszczuk, 2020) based on the experiment it was found that an individual thermal comfort is set to 25°C regardless of energy consumptions. This condition becomes challenging to intercede airflow without decreasing the supply of air temperature with energy-saving, particularly in tropical climate conditions.

Over the past decade in tropical countries, passive cooling design were applied in vernacular houses to circulate prevailing winds and to Adjust the shading of a window (Saadatjoo et al, 2020). As it provides thermal comfort and energy savings for occupants. However, in Indonesia the rapid population growth leads to high housing demands. Unfortunately the most of the new building designs' do not consider local climate conditions and energy conservation (Uddin et al, 2021). These have resulted in overall poor thermal performance of new buildings and the need for mechanical ventilation and air conditioning that lead to high rate of energy consumption. Therefore, its avoidance or inappropriate applications in house designs is an important issue that needs addressing.

This study is particularly interested in passive design buildings which is constructed to achieve comfortable interior climate with the lowest energy consumption in the particular climatic location (Ascione et al, 2019). A proper practice of passive-design involves various aspects of natural energy flows, building orientation, building materials and landscaping (Guerrero et al, 2020). This study focuses on indonesia's vernacular design, especially passive cooling. Passive cooling in Indonesia has become scarce because of the insertion of modern appliances. This is also affected by the climate condition of most regions in Indonesia. But there are also regions with ideal thermal condition. High altitude regions is found to have a cooler thermal condition rather than regions on the coastal area (Ordóñez et al., 2021). From this climate condition there has been adaptations of the site context to the house design so that the comfort condition can be kept within the interior. (Givoni, 1992; Vuille, 2011; Samodra, Irvansyah and Erwindi, 2018)

This research is set on investigating the thermal condition of a local dwelling in Malang, Indonesia. Based on the data found, this research can categorize the condition of this object based on the standards given by the literature study. (Ridwan, 2011)

1.1 Ideal Climate Condition for Human Living

According to SNI 03-6572-2001 (Standar Nasional Indonesia, 2001), the thermal comfort standard for the comfortable-warm category is 25.8 °C – 27.1 °C, while the relative air humidity for tropical climates is around 40%-50%. For rooms that have a dense capacity such as meeting rooms, the recommended relative humidity is between 55% - 60%. Meanwhile, the speed of air falling over the head should not be greater than 0.25 m/s and preferably less than 0.15 m/s to maintain comfortable conditions.

Based on The American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc (ASHRAE) (Team DesignBuilder, 2019), the recommended a comfortable temperature in winter is 68 F to 74 F and in summer the 72 F to 84 F, with more specific range depends on relative humidity, season, and another factors. Meanwhile, the relative humidity (RH) is recommended to be higher than 30% and lower than 60%.

1.2 Object Environmental Context Description

Malang City is a tropical city located in the province of East Java, Indonesia with two seasons, which are rainy season from October to April and the summer season from April to October. It has the temperature range between 20°C (69°F) and-

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-22°C (72°F). The warmest month with average maximum temperature of 22°C (72°F) is in October while the coldest month with an average maximum temperature of 21°C (69°F) is in August (Lestari and Purnomo, 2021). For the average temperature at certain hours, it has comfortable temperature at 12 am until 8 pm, warm and hot temperatures at 6 pm until 8 am, and returns to comfortable temperatures at 8 am until 12 am (Weather Spark, 2016).

In Malang, it rains throughout the year with the highest average rainfall of 10.8 inches on January, and the lowest average rainfall of 0.4 inches on August. The sun shines throughout the year where the length of the day in Malang does not vary substantially over the year (Alfata, Nugroho and Ekasiwi, 2014). Meanwhile, the annual percentage of humidity in Malang is 77% with the most humid month is February (82.0%) and the least humid month is September (71.0%)(Toftum and Fanger, 1999).

2. Research Method

There are two types of data attained on this investigation paper. the first one is the unmeasured data where the collected information is not in the form of quantity. This form of data consists of information regarding the quality of life, the condition of the user's daily life, and the user's inclination in using the appliances that affects the condition of the house. The second data is based on the quantity within the house such as dimensions, energy consumption, quantity of the appliances used, the usage count of the appliances, the climate conditions such as temperature, humidity and wind speed.

2.1 Direct Interview

The first data acquired is the user's information that can only be attained through discussions from the users themselves. The owner of the house was the main source of these information. The data acquired from this interview consists of the house history, the user's daily habits, the activities done, and the consistency of those activities. Basic information about the object was attained in this interview session.

2.2 Measurement

The measurements done in object are surface-



Figure 1. Anemometer used during the measurement (Source: AZ Instrument Corp)



(a) (b)

Figure 2. Thermo recorder used during the measurement (Source: T&D Corporation; Amazon) (a) T&D ThermoRec, (b) Misol



Figure 3. Watt Meter used during the measurement (Source: Tokopedia)

-temperature measurement, atmospheric temperature measurements in different points of the house, humidity and wind velocity, and energy used by the electronic appliances of the house. The measurements use some tools in order to record the data, which includes Anemometer (figure 1), Thermal Camera, Wattmeter (Figure 3), and Thermal Recorder (Figure 2).

3. Data Analysis and Discussions

This research was conducted during the rainy-

-season in January 2023. This research takes place in a high-velocity tropical climate place which is Ontoseno House. Ontoseno House is located in Ontoseno IV No. 16, Malang City, East Java in a dense urban area. The shape of the house can be seen in Figure 4. This house was originally built 40 years ago in 1982 and has undergone several changes and modifications to fit the owner's needs and preferences. The modification includes adding more area on the second level of the house in 2012. In this house lived three generations of people consisting of two elderlies, three adults, and one teenager. The three generations live different lifestyles.

The elderly male (aged 84) daily activities are mostly spent inside doing household chores.-



Figure 4. Facade of the object

-Meanwhile, the elderly female (aged 76) spends most of her time inside the house sitting while watching television because of the difficulty of walking. The nuclear family that also lives in this house consists of a father (aged 51), mother (aged 49), son (aged 18), and daughter (aged 12) who spend most of their time working outside the house, especially the father, mother, and son. While the daughter is a middle school student who spends her time mostly inside. All in all indoor activities are mainly done by the two elderlies. Figure 5 and 6 shows the layout of the house shows some places where most of the occupants' daily activities take place.



(a) (b)

Figure 5. Condition of the most used area (a) Dining Area & (b) Living Area



Figure 6. High activity area

3.1 Atmospheric Condition of the Object and Its Environment

The data collected for the temperature is done with 9 devices. The Misol Thermal recorder and the T-Thermal recorder. The placement of the Misol device is mostly for the outdoor condition, as seen on figure 5. The devices are given the code Ma, Mb, Mc. As seen on the figure 6, the indoor area is constantly used for daily activities the T-thermal recorder is placed and the code used for this device is T1-6. All of The Thermal recorders are placed in the same height of 150cm above the ground, this is decided based on the position of the human heart when standing. Every measurement device started on 16.00 in the afternoon and ended at the same time on the next day.

The Anemo meter is placed on areas with the highest probability of wind current, as seen on-

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Figure 7. Misol Temperature Recorder Placement on the (a) 1st floor & (b) 2nd floor

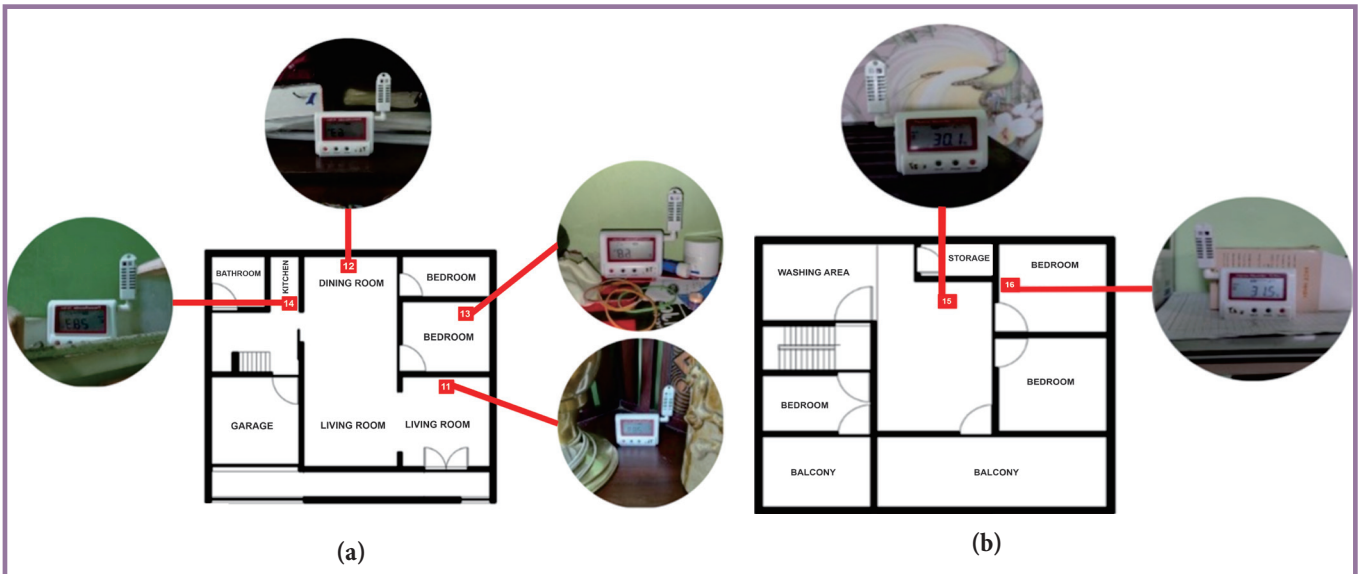


Figure 8. Thermal Recorder 1st Floor (a) 1st floor & (b) 2nd floor

-figure 7. With the code AM, AM-1 is placed on the outer living area where there is a door, giving probability of wind entering the house. AM-2 is placed on the outer bedroom. Both are placed on the first floor because activity is majorly done on the first floor. For the measurement of climate condition, the thermal recorder and anemo meter are used and placed on several places of the object with considerable conditions varying from outdoors to indoors and placed in areas with high user activity.

For the measurement of energy consumption, the Wattmeter was connected to the appliances that was based on the interview, frequently used daily by the users of this object, which are television--and refrigerator. The figures above shows the conditions of the measurement equipments and the measuring condition.The Thermal measurement-

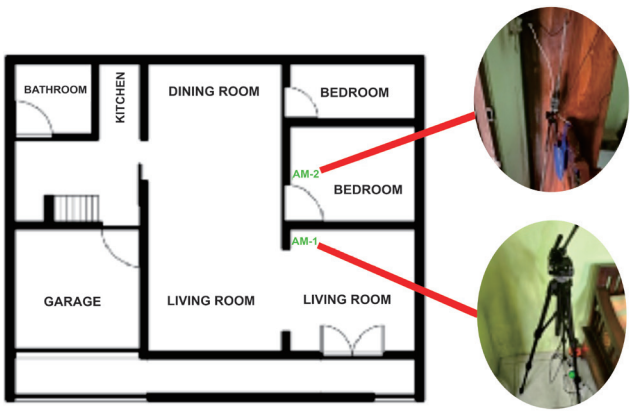


Figure 9. Anemometer Placement

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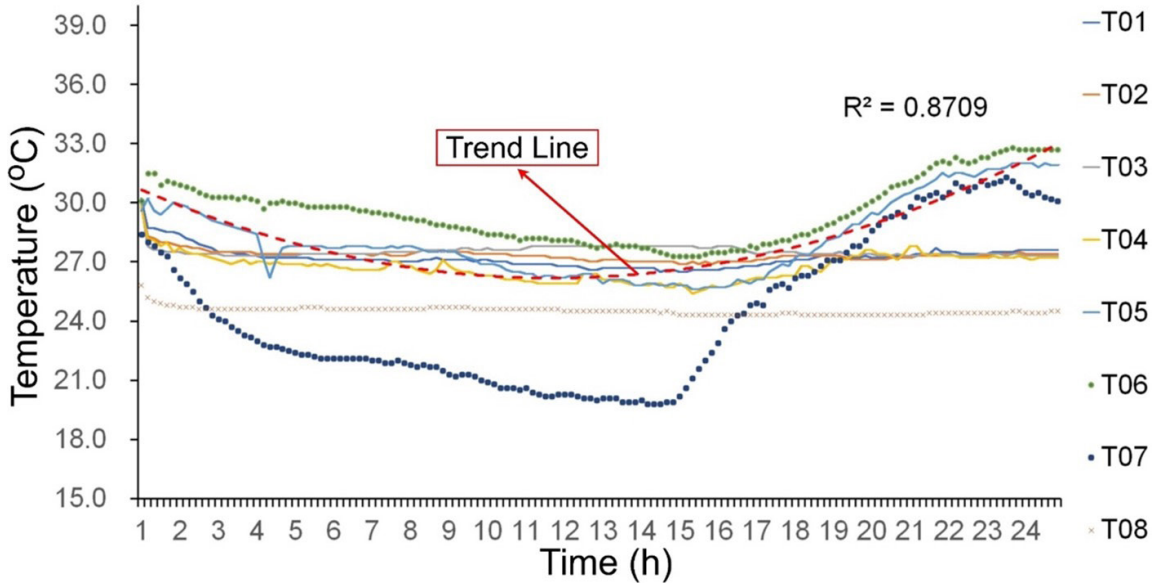


Figure 10. Graph of the thermal condition based on the measurement

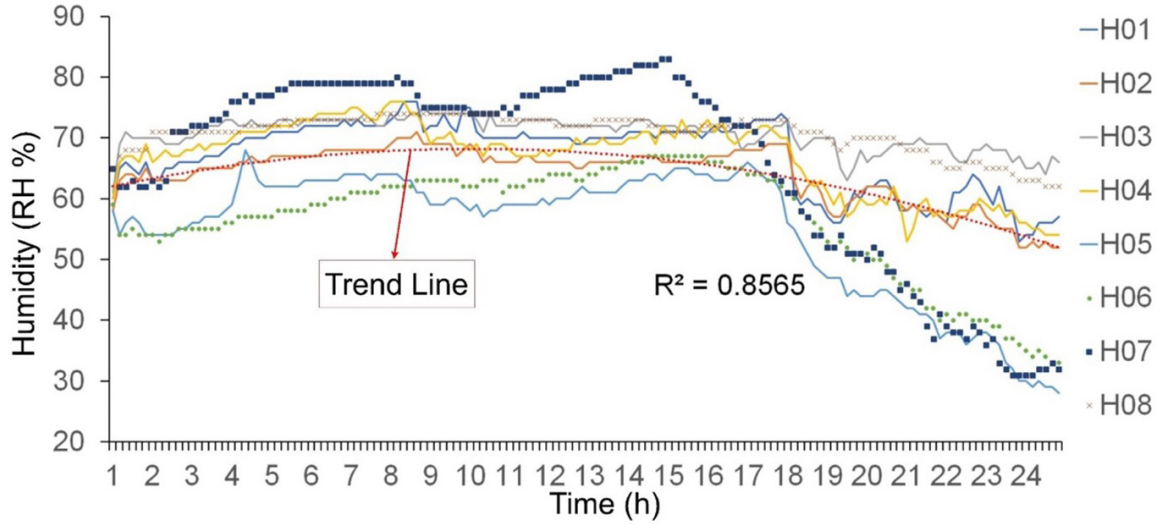


Figure 11. Graph of the humidity condition based on the measurement

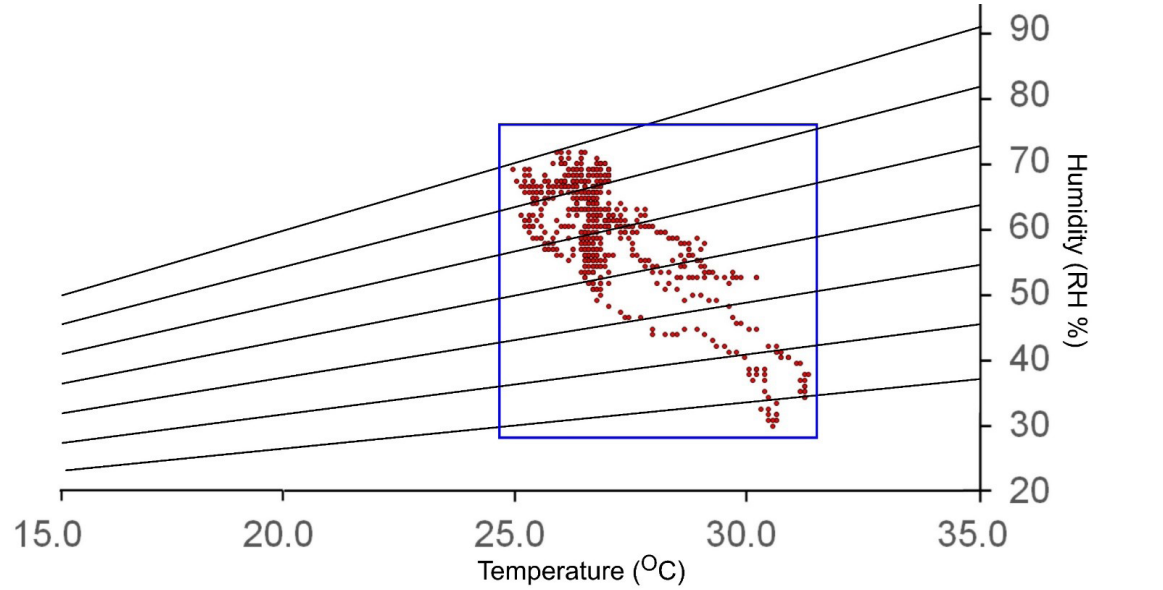


Figure 12. Correlation graph between indoor temperature and humidity

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-result can be seen on the graph of figure 10. The thermal condition of the outdoor devices indicates the dynamic natural atmospheric condition of the environment around the object by the line of T7 and T8. The indoor condition of the first floor is graphed on line T1-T4 and the second floor on line T5 and T6. From the graph there is a drastic fluctuation on the outdoor area of the object where at noon, the thermal condition is extremely high to the point of 31,2˚C and when it enters the nighttime, the temperature completely drops low to 19,5˚C, the fluctuation also happens on the indoor area of the second floor (T5-6). Contrary to that condition the indoor first floor condition is quite stable on the point of 24,8˚C 27,5˚C.

The humidity condition is also affected by the placement of the devices. As seen on figure 11, The outdoor and second floor devices shows the dynamic fluctuation of humidity. But there is a drop starting on morning. The highest humid percentage can be seen around 3.00 – 6.00 in the morning on 82% and drops to 28% on the noon. The first-floor indoor area is stable for the whole day on 51% to 72%.

The figure 12 shows the correlation of the Temperature and the Humidity where the higher the temperature, the lower the humidity becomes, and so is the opposite, the higher the humidity, the lower the temperature is.

3.2 Energy usage for housing appliance

This household uses several daily appliances that run every day for twenty-four hours and also appliances that run every day but for a long time. The appliances that run for twenty-four hours are the refrigerator and Wi-Fi. These two appliances use very different power consumption as the refrigerator consumes 514 watts and the Wi-Fi consumes 12 watts. Another appliance that runs mostly during the day is the television which consumes 55 watts for 15 hours and another appliance that consumes a high power is the washing machine which runs 2 hours on average per day.

The Ontoseno House uses 1300 VA power consumption from PLN. The power consumption in the table shows that this household does not consume a lot of energy as the occupants still rely on passive conditioning to find comfort. They do not use high-power consumption appliances such as air conditioners or water heaters. The water-



Figure 13. The Electricity meter condition during the measurement

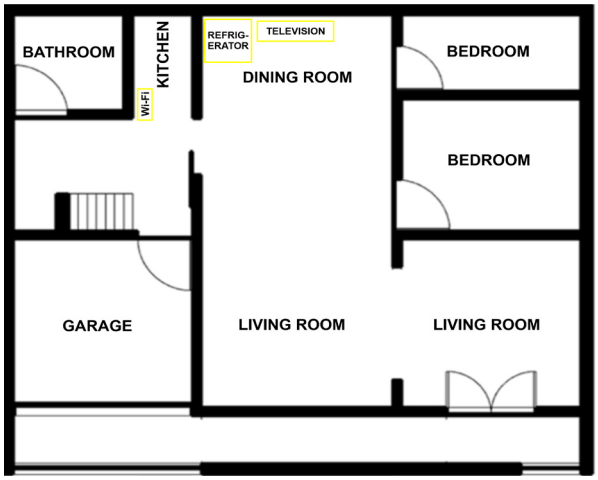


Figure 14. Placement of the Appliances on the 1st Floor

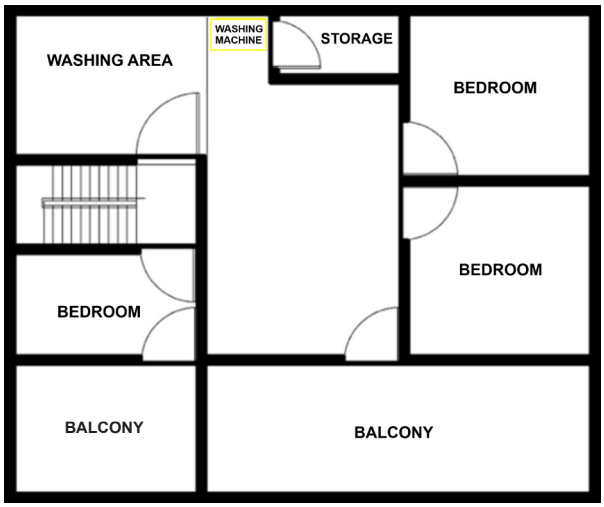


Figure 15. Placement of the Appliances on the 2nd Floor

Table 1. Length of Use for the Electrical Appliance

Qty	Appliance	Power Consumption (W)	Daily Usage Hours (hr)
1	Refrigerator	514 W	24
1	Television	55 W	15
1	Wi-fi	12 W	24
1	Washing Machine	450	2

Table 2. Table of Activity in a Day by The Users

Time	Owner	Wife	Son	Daughter-in-law	Grandson	Granddaughter
00:00	Sleeping	watching TV	working	sleeping	came from work	sleeping
01:00		sleeping			sleeping	
02:00						
03:00						
04:00	wake up					
05:00	praying	wake up				
06:00	cooking and eating breakfast	eating breakfast	sleeping	cooking		eating breakfast
07:00	doing household chores	watching TV		taking a bath		going to school
08:00				going to work		school
09:00				working		
10:00						
11:00			eating		eating	
12:00			taking a bath		taking a bath	
13:00	eating	sleeping	sleeping		going to work	
14:00	praying				working	eating lunch
15:00						playing
16:00	doing household chores		going to work			
17:00			working			
18:00						taking a Bath
19:00	eating	eating				studying
20:00	watching TV	watching TV				
21:00						
22:00	sleeping					sleeping
23:00				sleeping		
24:00						

-used in the object also has a high water pressure, making no need this object's user to use any water pump for the water to flow.

The Ontoseno house occupants has a pattern of living each day and has been recorded through direct interview with the users. Table 2 shows the activities and by this data, this research has attained a pattern of living in which the usage of energy consuming appliance can be traced. This data also-becomes a form of behavioural study and has been an instrument to understand the users behaviours on the daily. It shows that the most energy used within the house is done by the owner and wife, that is because most of their activity is done within the house and not much outside. The younger users whose daily activities are partially or mostly done outside with school and work consume less energy than the owner and wife.

4. Conclusion

Based on this Paper, it is found that:

- From the data acquired and the literature study, there is an ideal temperature area, that is the indoor first floor. If compared to the SNI (the Indonesia National Standard) where the standard comfort temperature that is on 25.8 °C – 27.1 °C and the humidity on 55% - 60%, the first floor indoor area fulfilled the criteria of stable temperature and on the ideal thermal condition of 24,8˚C – 27,5˚C and the humidity of 51% with the highest till 72%.
- The ideal condition might be caused by the insulation made by the addition of the second floor. By adding the second floor, the first floor is completely covered from direct sunlight from above.
- This condition also proves the effectiveness of space as insulation in tropical houses by forming massive roofs and spaces on the upper or top level of the house.
- The condition where the sides and back of the house are concealed by the neighboring houses might also be the causing factor of the stable condition on the first floor, making the sides unaffected by sunlight heat
- The comfortable thermal condition affects the usage of appliance within the object. The use of passive cooling condition on daily basis makes the users have no tendency in using any electrical cooling appliance, thus minimaliz the energy consumption for atmospheric alterations.

Author Contribution

Data Curation, AES, RTH, NBK, TH, DN; investigation, AES, NBK, FEA; methodology AES, RTH, DN; supervision AES and DN; visualization NBK, TH, DN; writing AES, NBK, FEA. All authors have read and agreed on the published version of the manuscript.

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