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# STUDY OF THERMAL COMFORT IN CAFES IN BANDUNG

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**ABSTRACT**

*The purpose of this study was to determine the study of thermal comfort in cafes in Bandung. Indonesia is a country with a tropical climate because its geographical position is on the equator. According to data from the Meteorology, Climatology and Geophysics Agency, the average humidity and temperature in 2020 is 27.30C. The method used to analyze the object of this study is a quantitative method with the formula of Thermal Equilibrium, quantitative research is defined as research based on empirical experience that collects data in the form of numbers that can be calculated and in numerical form. This research was conducted with a quantitative approach by performing calculations using the heat balance method to determine the heat in the 3 study objects and what factors most influence the cooling load in the 3 study objects. Human comfort at Noah's Barn Coffeenery, Amber Field Coffee cannot be separated from the thermal comfort factor. Based on the calculation of the thermal balance in the three cafes, more than 50% of the heat in the room comes from interior heat sources, especially electronic equipment and lighting and humans are the biggest heat contributor in the cafe dining area. Each cafe has a different heat source, therefore, each room has a different solution. The heat in Naoh's Barn Coffeenery is 25.2412504 kW*

**KEYWORDS** *Study; thermal comfort; humidity and temperature*



## INTRODUCTION

Indonesia is a country with a tropical climate because its geographical position is on the equator (Tjasyono, 2007). According to data from the Meteorology, Climatology and Geophysics Agency (BMKG, 2021), the average humidity and temperature in 2020 is 27.3 $^{0}$C. Bandung is the capital city of West Java province whose city center is at 732 meters above sea level and has humidity high (> 50%) between 59.69-76.42%.

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**Figure 1**
**Indonesia at the Equator**
Source: Kompas.com

According to research conducted by (Himayah & Ridwana, 2021), stated that the land surface temperature (*LST)* from 1990-2018 based on Landsat 5 and Landsat 8 satellite imagery stated that the temperature increase from 1990 to 2018. In 1990, the North Bandung area was dominated by -areas where the soil surface temperature is below 20 $^{o}$C. However, there are still some areas with a surface temperature of around 24 $^{o}$C - 29 $^{o}$C which are marked with yellow and orange colors on the map. However, in 2000, the soil surface temperature in North Bandung was dominated by areas where the soil surface temperature was above 27 $^{o}$C, especially in the plains in the southern part of North Bandung. While in that year, the northern part which is still covered by vegetation has a soil surface temperature between 15-23 $^{o}$ C.

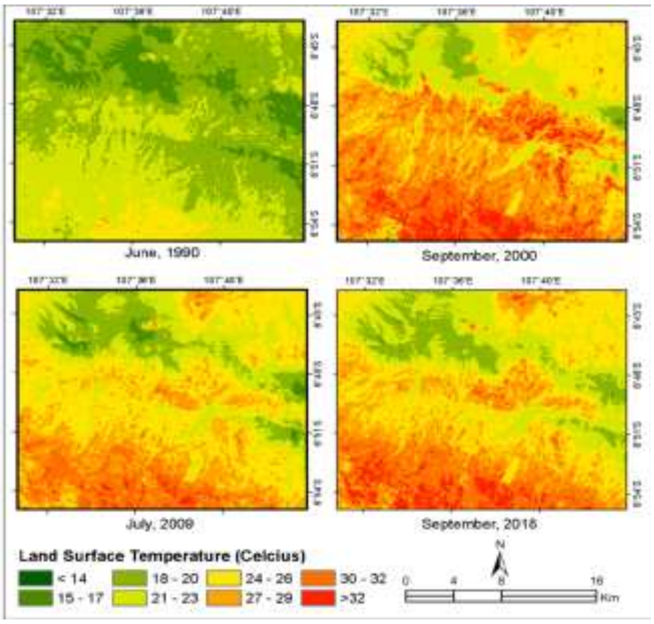



**Figure 2**
**Landsat 5 Imagery and Landsat 8 Imagery North Bandung**
Source: (Himayah & Ridwana, 2021)

The increase in ground surface temperature can be seen in 2018 where more areas have soil surface temperatures above 32 $^o$ C which are marked in red, especially in urban areas. This temperature increase is not only in residential and urban areas but also in mountainous areas. The soil surface temperature in mountainous areas is around 15-17 $^o$ C, while in 2018, the ground surface temperature was 18-20 $^o$ C. This study reinforces the fact that the average temperature in Bandung also increases from year to year.

According to data from the Meteorology, Climatology and Geophysics Agency (BMKG, 2021), the average temperature in 2020 is 27.3 $^o$C in Indonesia. In Bandung itself, the maximum temperature during the day is 28-30 $^o$ C, while according to the 1993 SNI, the optimal comfortable temperature is 22.8 °C - 25.8 °C and the comfortable warm temperature is 25.8 °C - 27.1 °C, so that at the peak of the day the temperature in Bandung does not meet the standard of thermal comfort so that many public buildings use air conditioning to maintain the comfort of room users.

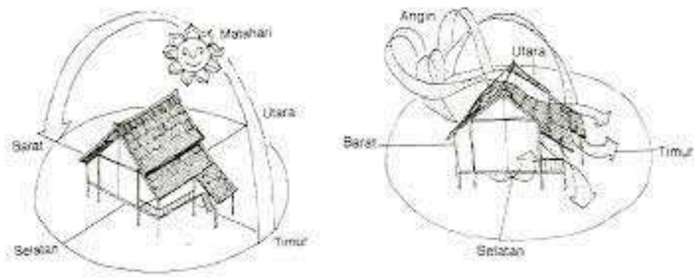



**Figure 3**
**Building Orientation**
Source: N. Senthilkumar

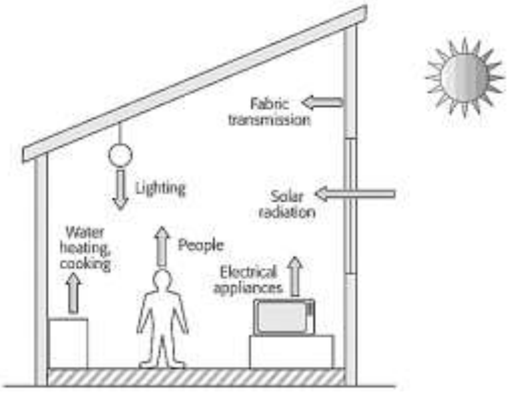



**Figure 4**
**Heat Sources in Buildings**
Source: Architectural Journal

The heat inside the building caused by the sun's heat giving off heat, etc. penetrate through glass, outdoor temperature, walls, presence of electronic equipment. This study aims to determine the factors such as building orientation, glass area to wall ratio (*Window-to-Wall Ratio, WWR)* that most influence the building's cooling load and suggest architectural changes that can be made to reduce the building's cooling load. Cooling load is the amount of heat energy that needs to be removed from the room (cooling) to maintain an acceptable indoor temperature for the occupants of the room to achieve thermal balance. Thermal balance occurs when the sum of all the different types of heat flow in and out of the building is zero so the main formula for this method is $Qm = Qi + Qs + Qc + Qv$.

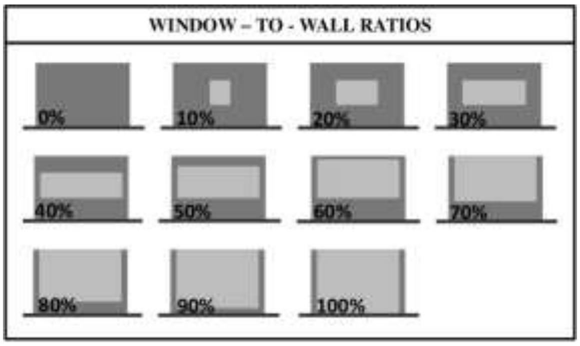



**Figure 5**
**Glass Area to Wall Ratio ( *Window-to-Wall Ratio, WWR)***
Source: Himayah (2019)

**Table 1**
**Heat Production Rate in Human Body**

| Activity | Rate of heat production | |
|---|---|---|
| | (W) | ($W/m^2$) |
| Sleeping | 60 | 35 |
| Resting | 80 | 45 |
| Sitting, Normal office work | 100 | 55 |
| Typing | 150 | 85 |
| Slow walking (3 km/h) | 200 | 110 |
| Fast walking (6 km/h) | 250 | 140 |
| Hard work (filing, cutting, digging etc.) | More than 300 | More than 170 |

Source: (Kumar, Aggarwal, Sharma, & Pathania, 2012)

Thermal comfort is related to human activities in a room. Thermal comfort discussed in this study is thermal comfort in a closed air-conditioned dining room with a volume of 40 m-192$m^3$ or non-air-conditioned but ventilated with a volume of 48$m^3$. The following are some definitions of thermal comfort from several experts:

This thermal discomfort can cause people to feel uncomfortable in public spaces and leave that public space. Thermal discomfort not only affects the visitors but also affects the work productivity of workers (Mandey & Kindangen, 2017)

- The state of mind of a person who expresses his satisfaction with his thermal environment (Szokolay & Koenigsberger, 1973)
- Conditions where humans feel comfortable with the temperature and climate of their environment.

- *Thermal comfort* is a condition of the human mind that shows satisfaction with the thermal environment (Nugroho, Visser, & Kuipers, 2011).
- Thermal comfort is a state of human thought that shows satisfaction with the thermal environment (Nugroho et al., 2011).
- Convenience in relation to the building can be defined as a condition that can provide a sense of comfort and pleasure for its occupants. (Karyono, Abdullah, Cotgrave, & Bras, 2020)
- Thermal comfort is a state related to nature that can affect humans and can be controlled by architecture (Snyder, 1989)
- Thermal comfort is a condition that expresses satisfaction with the surrounding thermal environment. (Fanger & Smyth, 1972)
- Thermal comfort is a comfortable air condition in which a person can maintain a normal balance between heat production and *heat loss* , at normal body temperature without sweating. (Yaglou et al., 1950)

From these examples or experts, it can be concluded that thermal comfort is a sense of comfort with the temperature and climate around it.

According to SNI 1993, the optimal comfortable temperature is 22.8 °C – 25.8°C. To ensure thermal comfort in cafes for the middle of the day, cafes in Bandung mostly use HVAC to ensure optimal thermal comfort. According to research from (Katili, Boukhanouf, & Wilson, 2015), states that buildings are one of the largest energy consumers in many countries and in the Southeast Asia region accounts for about 30% of primary energy demand. Air conditioning accounts for 56% of the total energy consumption in buildings located in the tropics. This also applies in Bandung, especially in cafes located in Bandung during the pandemic which started from the initial detection of the COVID-19 virus on March 2, 2020 in Depok, West Java until the president decided to implement Large-Scale Social Restrictions (PSBB) with the issuance of Government Regulation Number 21 of 2020 concerning Large-Scale Social Restrictions in the Context of Accelerating the Handling of Covid-19 issued on March 31, 2020 by the State Secretariat and announced by the president (Khusaini, Remi, Fahmi, & Purnagunawan, 2020)


**Figure 6**
**Glass Area to Wall Ratio (*Window-to-Wall Ratio, WWR)***
Source: Himayah (2019)

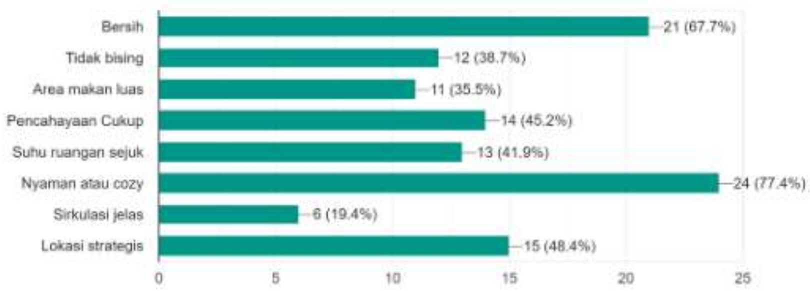
According to this regulation, only 8 essential sectors are allowed to operate during the PSBB (Luoma et al., 2020). One of the 8 sectors that may operate is a business sector operating in the beverage, food and food sector (Arnani & Wedhaswary, 2021). However, at that time, visitors were not allowed to eat on the premises, but only brought the food home.

Along with the easing of the rules regarding PSBB, on June 12, 2020, the Bandung City Government allowed *dine-in* with the issuance of Bandung Mayor Regulation number 34 of 2020 concerning the fourth amendment to Bandung Mayor Regulation no. 21 of 2020 concerning the Implementation of Restrictions Large-Scale Social Services in the Context of Accelerating the handling of Corona Virus Disease 2019 (COVID-19) in the City of Bandung (Hadiningtyas, 2021). However, along with the entry of the Delta variant in Indonesia.


**Figure 7**
**COVID-19 Delta**
Source: (Himayah & Ridwana, 2021)

However, about a year later, on June 30, 2021, the Governor of West Java announced that the Delta variant had entered Bandung City and daily COVID-19 cases had increased to the Delta variant (Sudrajat, Indrianti, Supriatin, Hayati, & Lindayani, 2021). Until July 1, 2019, Indonesia officially announced Emergency PPKM whose regulations were directly regulated by the central government (Bustomi & Avianto, 2021) whose provisions were finally relaxed, so that visitors could dine in cafes with 50% capacity on August 23, 2021. Due to easy access To conduct a site survey and monitor the number of visitors, the cafe was chosen to be the object of this research study during a pandemic.

Cafes are one of the most popular public places for young people. The cafe is a popular place for young people to visit, as evidenced by a survey conducted by Faisal in 2019, where 67% of respondents chose cafes as their favorite hangout. In the study, 93% of cafe visitors were born between 1990-2000 and 85% of visitors were university students. 67% of visitors visit the cafe 1-2 times per week. 3 selected cafes from different areas such as North Bandung, downtown, and suburbs.




**Graph 1**
**Convenience Factor**
Source: Haristanti (2011)

According to a survey conducted by (Haristianti, Raja, & Putri, 2021), the convenience factor is the biggest factor for people to visit a cafe. While the second most common factor, why people visit cafes is the design of the cafe. In this survey, the highest standards of comfort were coziness ( 77.4%), cleanliness (67.7%), strategic location (48.4%), lighting (45.2%), and room temperature (41.9%). This is shown by Graph 1. To ensure *coziness* and stable room temperature, many cafes in Bandung use active ventilation. According to (Katili et al., 2015), 50% of energy is used for active cooling systems and this percentage increases during peak times of 80%. Therefore, one way to reduce energy use in buildings is to reduce the cooling load of the building.

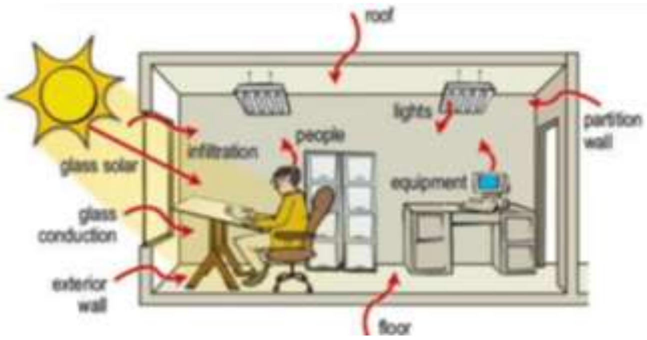
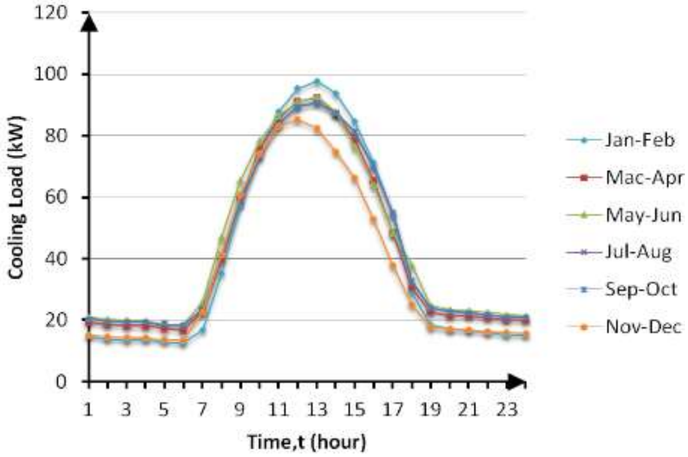



**Figure 8**
**Thermal Cooling Load Components**
Source: broughtoneap.co.uk




**Graphics 2**
**Cooling Load against time**
Source: Haslinda Mohamed Kamar (2015)

In order to reduce the cooling load of the building, the cooling load must first be known. The thermal balance method is one way to determine the cooling load in a room. By using the thermal balance method, it can be seen that the heat in a room is expressed in Watts (W) (Satwiko, 2008). In this method, the factors that affect the cooling load are window area, *solar glass gain factor* , wall area, wall material, indoor and outdoor temperature difference, and ventilation speed. This study seeks to determine what factors most influence the load that most affect the cooling load of cafes in the city of Bandung. The factors that want to be reviewed are window-to-wall ratio (WWR), location, orientation, location, outdoor and indoor temperature, glass material, wall material, building orientation, and outdoor temperature.

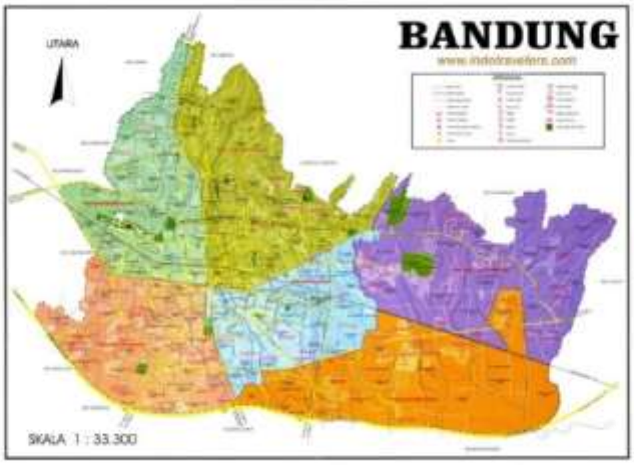



**Figure 9**
**District in Bandung**
Source: Haristanti (2011)

For this reason, 3 cafes with different locations in Bandung were chosen, namely in North Bandung which has a cooler climate, in the middle of Bandung City which is dominated by trade areas, and in the southern part of Bandung City which is in a lower plain. In addition, these three cafes have different orientations. Amber Field Cafe faces North, Noah's Barn Cafe faces West and Mr. The Roastman Experience faces West. (Temporary conclusion) Differences in window-to-wall ratio (WWR) and building orientation are the two most influential factors in increasing the cooling load caused by radiation and solar heat conduction through windows and walls.

## RESEARCH METHOD

This type of research uses quantitative research methods with the Thermal Balance Formula (Satwiko, 2008) the research method is a tool to calculate the cooling load of buildings in the room. The result is the calculation of the cooling load of this building will be expressed in units of Watt (W). Quantitative research, according to (Sugiyono, 2017) is a method used to examine certain populations or samples, analyze quantitative data to test hypotheses. According to (Sujarweni, 2014) stated that research using statistical procedures or with quantification. This research begins with the search for 30 cafes in Bandung which are candidates for research objects which are then narrowed down to 3 study objects located in the center of Bandung City, North Bandung and West Bandung City, each of which has a wall-to-window ratio (WWR), different orientations and elevations. After the research object is determined, it is continued with observations on the research object to measure the variables needed for the calculation of the heat balance. In addition to observations and measurements, interviews were also conducted with the owner with the baristas and workers at the cafe to meet the completeness of the data.

This descriptive research and field review was conducted to achieve the objectives of the research. The objectives to be achieved as described in chapter 1 are to find out the amount of cooling load in the 3 cafes that are case studies and to know the level of what factors have the most influence on the cooling load of cafes in Bandung, so ending the research the author can provide suggestions to the cafe owner what changes to the building can be made to reduce the cooling load so that the cafe's operating costs can be reduced.

## RESULTS AND DISCUSSION

### Thermal Balance

During the end of October to December, the rainfall in Bandung City is very high and this causes the air temperature in Bandung City to be lower. Therefore, this research was conducted at the end of September to mid-October 2021, after the preparation of the research proposal. The indoor temperature was measured at 12.00 o'clock . The air change in one hour in this room is 0.35. All lights are assumed to be lit. All material absorption coefficients or commonly known as *U-values* in this experiment were taken from the Building Physics Book by (Satwiko, 2008).

**1 General Data of Noah's Barn Coffeenery**

a. Building Name : Noah's Barn Coffeenery
b. Address : Jl. Garuda No. 39, Dungus Cariang, Kec. Andir, Bandung, West Java, 40184
d. Number of Floors : 1 floor
e. Dining/drinking area : *indoor* and *outdoor*


**Figure 10**
**Noah's Barn Coffeenery**
Source: ottencoffee.co.id

Facade Noah's Barn Coffeenery is a cafe that faces West and has a facade that is dominated by glass. This cafe is in a shopping and school area. Behind the facade there is a large room that is used as an *indoor dining area* and a coffee shop. Behind the dining area there is an empty area that connects the *indoor dining area* with the toilets and the *outdoor dining area.*

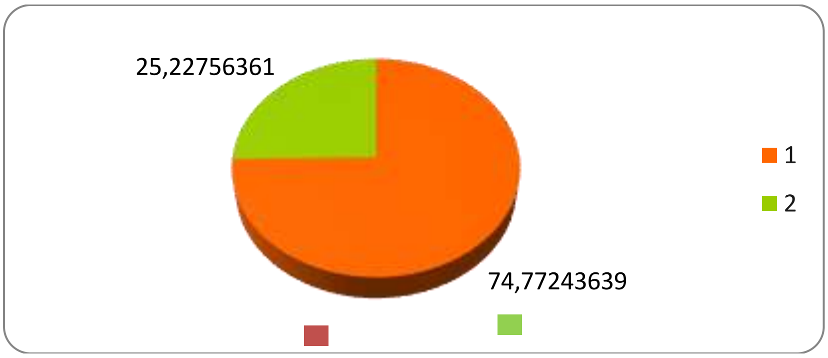
**Figure 11**
***Semi-outdoor***
Source: ottencoffee.co.id

**Figure 12**
**Connecting Room**
Source: ottencoffee.co.id

*outdoor* dining area is provided for smoking diners. The *outdoor* dining area is covered by a PVC canopy and whitewashed brick walls. In 2021, the highest outdoor temperature observed during observations was at 32 $^{0}$ C and the indoor temperature was 26 $^{0}$ C. The average capacity of the *indoor dining area* is 15 people with 2 baristas on duty, bringing a total of 17 people. All spotlights and all other lights are assumed to be on.

**Figure 13**
**The window between Splash Kitchen and Noah's Barn**
Source: Research Documentation

*indoor* dining area only has dead windows between the Noah Barn's cafe and Splash Kitchen and between the dining area to the transition area to the toilets and the *outdoor area*. Apart from that most of the facades are glass walls with aluminum frames painted black . The windows on the facade are exposed directly to sunlight coming from the front of the building. This dining area is filled with electronic equipment for heating *pastries* and making coffee and other beverages. The temperature outside and inside the building is taken based on the temperature at the time of observation. Based on the calculation of the thermal balance the value of Qm is 25.2412504 Watt. The heat coming from the interior is 77.71% while the heat coming from the exterior is 22.29%.




Interior Heat Exterior Heat
**Graphics 3**
**Percentage of Indoor and Outdoor Heat Sources at Noah's Barn**
Source: Research Documentation

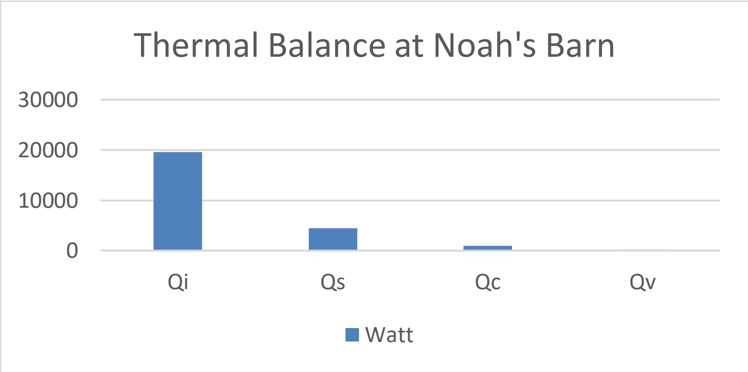
The heat source from the interior that most affects the thermal balance in this room is the heat that comes from the electronic equipment in the room. Electronic equipment which is dominated by equipment for making coffee which emits a total heat of 17,235 Watts (68.28% of the total heat in the room).

**Table 1**
**Thermal Balance at Noah's Barn**

| **Qm, space cooling load (kW)** | **Qi (Watt)** | **Qs (Watt)** | **Qc (Watt)** | **Qv (Watt)** |
|---|---|---|---|---|
| 25.2412504 | 19 615 | 4 402,94 | 960.467502 | 262.83894 |

Qi = *internal heat gain*
Qs= *solar heat flow*
Qc= *conduction heat flow*
Qv= *convection heat flow*
$Q_m$ = *mechanical cooling*

Source: Research Documentation



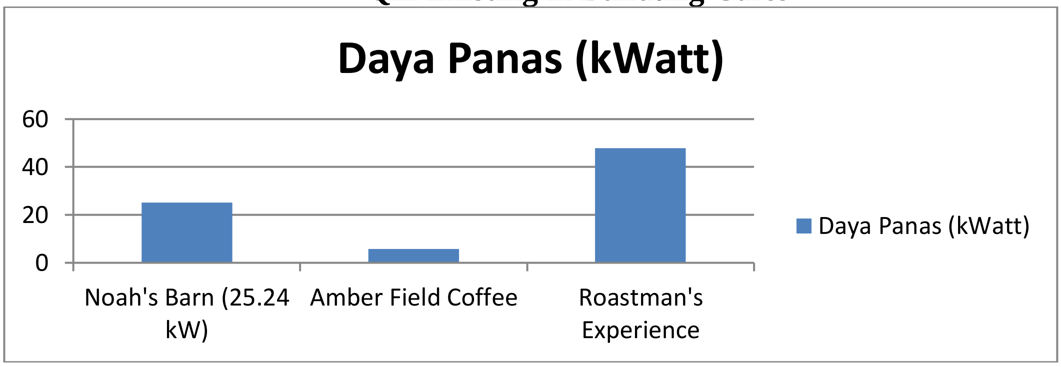

**Graphics 4**
**Thermal Balance at Noah's Barn**
Source: Research Documentation

Although Noah's Barn has many windows that cannot be opened, only the dead windows on the facade get direct sunlight. The windows are dead windows that separate Noah's Barn from Splash's Kitchen and the transition room. This cafe is one of the rooms that has the most electronic equipment. Although most of the heat comes from electronic equipment, electronic equipment is still needed for daily cafe operations. The heat source that can be reduced in this cafe is the heat source that comes from outside. Qs or heat from heat that penetrates glass and walls can be reduced. During the day and into the evening the glass facade is covered with *roller blinds* to avoid glare when the sun faces west. By replacing *tempered* glass with glass with *low e glass coating* , this *coating* can minimize ultraviolet and infrared light that enters through the glass and 82% of visible light that enters the room. The use of *tinted glass* is not recommended because the difference in the U value is not significant with the U value of ordinary 5 mm glass. By replacing glass with *low e glass coating* , 123.282432 Watts of heat are reduced at Noah's Barn. If the glass is replaced with *clear double glass* with a U value of 2.5, the cooling load of this building is reduced by 193.729536 Watts.

## CONCLUSION

Human comfort at Noah's Barn  Coffeenery , Amber Field Coffee cannot be separated from the thermal comfort factor. Based on the calculation of the thermal balance in the three cafes, more than 50% of the heat in the room comes from interior heat sources, especially electronic equipment and *lighting* and humans are the biggest heat contributor in the cafe dining area. Each cafe has a different heat source, therefore, each room has a different solution. The heat at Naoh's Barn Coffeenery is 25.2412504 kW. The heat in Amber Field Coffee is 5.76 kW . The heat in the Roastman's Experience is 47.82159577 kW.

**Graphics 5**
**Qm Existing in Bandung Cafes**




Source: Researcher documentation

From the data presented in Graph 1, it can be seen that the highest cooling load for buildings is in the Roastman's Experience of (47.82 kW) which is almost twice the cooling load of Noah's Barn cafe. This is due to the larger volume of the room, more windows that are exposed to direct sunlight and more windows and openings. In each different heat sources. Basically in every room where coffee is prepared, the largest source of heat in that room comes from the equipment, while in other rooms, and the second largest source of heat comes from heat that penetrates the windows and walls.

At Noah's Barn Coffeenery and Amber Field Coffee, the room for preparing or making coffee is the same room as the dining area. This is different from the Roastman's Experience, the cashier's room is a room for making coffee and the other room is only used for eating and there are several employees *standing by* at the place. Table 5.1 shows that most of the heat comes from inside the room, namely from machines for making coffee and food. However, these machines are indispensable and cannot be replaced. Therefore most solutions to reduce the load on cooling are replacement glass with lower U value such as *low e glass coating* and *Qc with 5mm Clear double glass 12mm/5mm clear* and use *of air curtain* .

**Table 2**
**Heat Source Presentation**

| No | Cafe Name | Interior Percentage (%) | Exterior Percentage (%) |
|---|---|---|---|
| 1 | Noah's Barn Coffeenery | 77.71 | 22.29 |
| 2 | Amber Field Coffee | 52.13 | 47.87 |
| 3 | Cashier | 56.66 | 43.34 |

| | | | |
|---|---|---|---|
| Roastman's Experience | Hall | 17.86292602 | 82.14 |
| | Sub-hall | 23.1 | 76.9 |
| | Area I | 17.4 | 82.6 |
| | Area II | 20.57 | 79.43 |
| | TOTAL | 41.55 | 58.45 |

Source: Research Documentation

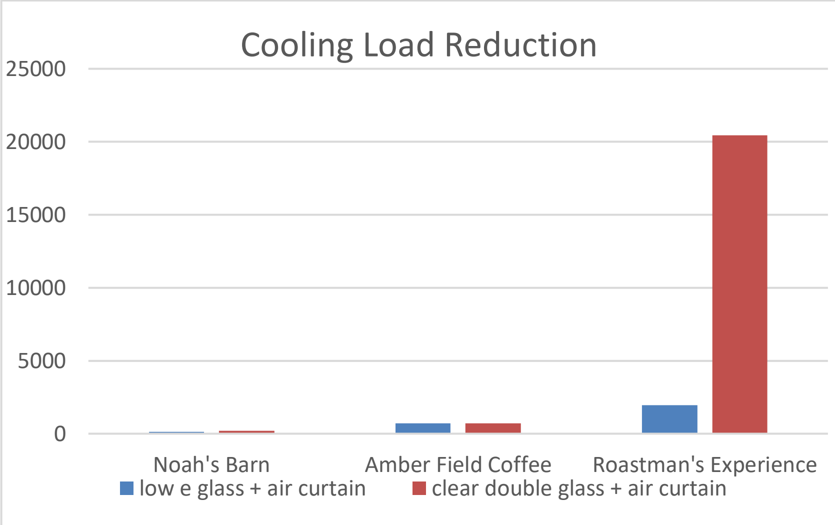
At Noah's Barn Coffeenery, by replacing the glass with *low e glass coating* , 123.282432 Watts of heat are reduced at Noah's Barn Coffeenery . If the glass is replaced with *clear double glass* with a U value of 2.5, the cooling load of this building is reduced by 193.729536 Watts. In Amber Field, by adding *an air curtain* and *low e glass coating* , 99,07512336 Watts of heat are reduced if they are replaced with *clear double glass* , the savings will be 156,09705408 Watts.

At the Roastman's Experience glass replacement is also recommended, because most of the heat in the rooms other than the cashier comes from the sun's heat that penetrates the windows and walls. In addition, the addition of an *air curtain* is needed so that cold air from an air-conditioned area cannot leak into a non-air-conditioned room, cashier. By changing the glass material to *low e glass*, the cooling load is reduced by 225.26 Watts and if the glass is replaced with *clear double glass* , the cooling load can be reduced by 302.21 Watts. Graph 5.2 and Table 5.2 show the total savings in each study object.

**Table 3**
**Cooling Load Reduction**

| No | Cafe Name | Reduced cooling load with *low e glass* and other interior changes | Reduced cooling load with *clear double glass* and other interior changes |
|---|---|---|---|
| 1 | Noah's Barn | 123.282432 Watt | 193.729536 Watt |
| 2 | Amber Field Coffee | 99.07512336 Watt + 709.872325461 Watt = 808.947448821 Watt | 156.09705408 Watts + 709.872325461 Watts = 865.969379541 |
| 3 | Roastman's Experience | 1967,14097 | 20444,08263 |

Source: Research Documentation




**Graphics 6**
**Cooling Load Reduction**
Source: Research Documentation

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