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# Evaluation of Energy Saving Potential at the Nurul Yaqin Mosque in Palu City through the Implementation of Passive Systems

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***Abstract***
*Houses of worship in tropical regions have significant energy demands, particularly for lighting and air conditioning. This study aims to evaluate the energy-saving potential of the Nurul Yaqin Mosque in Palu City through the implementation of passive systems in the form of natural lighting and ventilation. The research method used was a descriptive quantitative method, with direct field measurements of lighting intensity, airflow velocity, temperature, and humidity in the main mosque space. Data were collected using a lux meter, an anemometer, and a datalogger at several observation points in the morning, afternoon, and evening. The data were analyzed using descriptive statistics, multiple linear regression, and Pearson correlation analysis to determine the relationship between natural ventilation and thermal comfort.*

*The results showed that natural lighting in the prayer room was still suboptimal, with a daylight factor ranging from 0.6% to 1.8% and uneven light distribution. Regarding natural ventilation, the average indoor wind speed of 0.239 m/s remained below the ASHRAE thermal comfort standard. Regression analysis showed that increasing airflow velocity decreased the room temperature, while relative humidity tended to increase the sensation of heat. The coefficient of determination ($R^2$) of 68% indicates that natural ventilation and humidity have a fairly strong relationship with the thermal conditions of the room. Quantitative energy analysis indicates potential energy savings of 97.2 kWh/month, or approximately Rp165,240/month, through optimizing natural lighting and ventilation.*

*This study concludes that the implementation of passive systems at the Nurul Yaqin Mosque has significant potential to improve the energy efficiency and thermal comfort of tropical religious buildings. Optimizing openings, cross-ventilation, overhead ventilation, reflective materials, and vegetation are important strategies in supporting energy-efficient and sustainable mosque buildings.*

***Keywords:*** *passive systems, energy efficiency, natural ventilation, natural lighting, thermal comfort, tropical mosque.*

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## I. INTRODUCTION

Places of worship, such as mosques, are public facilities with high usage, particularly during the five daily prayers, religious activities, and community social activities. Consequently, energy consumption in mosques, particularly for artificial lighting and air conditioning, can be quite significant. In tropical areas like Palu City, the use of artificial lighting during the day and fans or air conditioning during high temperatures is a routine requirement for providing comfort for worshippers.

The application of passive design concepts is an important solution to reducing this energy consumption. Passive systems utilize the potential of natural resources such as sunlight and wind to meet lighting, ventilation, and thermal comfort needs without or by minimizing the use of mechanical devices. Through designs that consider building orientation, the size and position of openings, and material selection, mosques can remain comfortable while being more energy efficient.

The Nurul Yaqin Mosque in Palu City is one example of a mosque that has the potential to further study the application of passive systems. Scientific evaluation of the performance of natural lighting, natural ventilation, and thermal conditions is essential to determine the extent to which passive systems have been implemented and how they contribute to energy savings.

Research on passive systems in religious buildings in Indonesia is still dominated by partial evaluations of lighting or ventilation separately. Studies integrating natural lighting, ventilation, and thermal comfort in tropical coastal mosques are still limited, particularly in the context of Palu City.

## II. LITERATURE REVIEW

### 2.1 Passive System Concept in Tropical Architecture.

Passive systems in architecture are a building design approach that utilizes natural resources, such as sunlight, wind, and the properties of building materials, to create thermal and visual comfort without relying entirely on mechanical or electrical equipment (Olgyay, 2015). This approach is particularly relevant for buildings in tropical regions, such as Indonesia, which boasts substantial solar energy potential and natural airflow throughout the year. The main strategies of passive systems include:

- **Cross ventilation**: utilizes differences in pressure and wind direction to produce air flow across a room.
- **Natural lighting**: the use of sunlight through openings, skylights, or translucent materials to meet visual needs during the day.
- **Insulation and building materials**: use of materials with low thermal conductivity or reflective colors to reduce excess heat.

Through passive design, buildings are not only energy efficient but also support sustainability and quality of space for their users.

### 2.2 Natural Lighting.

Natural lighting plays a crucial role in creating a comfortable atmosphere and reducing electricity consumption due to the use of artificial lighting during the day. According to SNI 03-6575-2001, the minimum lighting level standard for worship spaces is approximately 250 lux on the work surface (floor or seating).

Appropriate use of natural lighting can significantly reduce electricity consumption, as most visual needs can be met by sunlight. Previous research (Slamet et al., 2017) shows that utilizing openings, clerestory, or skylights can save up to 30–50% of lighting energy needs during the day, depending on the design and local climate conditions.

### 2.3 Natural Ventilation.

Natural ventilation aims to generate sufficient air circulation within a building to maintain thermal comfort and air quality. According to various literature, the ideal indoor wind speed to support thermal comfort is between 0.3–0.9 m/s (Szokolay, 2014; ASHRAE Standard 55).

The two main principles of natural ventilation are:

- **Cross ventilation**: utilizes openings on opposite sides of a building to create a pressure difference, so that air can flow effectively.
- **Stack effect:** utilizes the difference in air temperature between the bottom and top of the building, so that hot air rises and fresh air enters from below.

Good natural ventilation design can reduce reliance on fans or artificial cooling systems, while improving indoor air quality.

### 2.4 Thermal Comfort.

Thermal comfort is a condition where building occupants are satisfied with the ambient temperature without needing to turn on auxiliary equipment such as fans or air conditioning (ASHRAE, 2017). ASHRAE Standard 55 and SNI 03-6572-2001 state that the thermal comfort zone is generally between 23–27°C and relative humidity of around 40–60%.

The main parameters that determine thermal comfort include:

- Air temperature: affects the sensation of heat or cold.
- Relative humidity: affects the body's cooling process through evaporation.

Air flow rate: increases comfort through cooling effect (wind chill effect).

### 2.5 Previous Studies (Concise Review Literature).

Several previous studies have examined the application of passive systems in religious buildings. For example, Riyadi et al. (2018) conducted a study on mosques in Yogyakarta and found that cross-ventilation design and the use of reflective roofs successfully reduced room temperatures by 2–3°C. Nugroho and Putra (2020) evaluated natural lighting in mosques in Surabaya and found that large north-south openings were able to meet visual lighting needs during the day without additional lighting.

Another study by Alavi et al. (2016) in Malaysia showed that the combination of natural ventilation and the use of reflective materials can reduce cooling energy consumption by up to 25%. These findings reinforce the importance of evaluating passive systems to improve the energy efficiency of mosques in tropical climates.

## III. RESEARCH METHODS

### 3.1 Types of Research.

This study uses a **descriptive quantitative** method, with a direct field data collection approach to evaluate the performance of passive systems at the Nurul Yaqin Mosque in Palu City. This approach aims to describe the actual conditions of natural lighting, natural ventilation, and thermal comfort without manipulating variables.

### 3.2 Research Location.

The research was conducted at the Nurul Yaqin Mosque, located in Palu City, Central Sulawesi. This mosque was chosen as the object of study because of its tropical climate and architectural design that utilizes openings for natural light and air circulation.

**Figure 1: Nurul Yaqin Mosque, Palu City**

**Table 1:Building Parameter**

| Parameter | Value |
|---|---|
| Length of building | 18 m |
| Building width | 12 m |
| Ceiling height | 3 m |
| Aperture area | xx m² |
| Roofing materials | Cast concrete |
| Wall material | Cast walls |

**3.3 Measured Variables and Measurement Tools.**

**Table 1:Measured Variables and Measurement Tools**

| Variabel | Tools | Unit | Location | Measurement Time |
|---|---|---|---|---|
| Natural lighting | Lux Meter | Lux | In the prayer room | Morning, daytime, evening |
| Natural ventilation | Anemometer | m/s | Ventilation point | Daytime |
| Temperature & Humidity | Datalogger | °C & %RH | Inside and outside the mosque | For 24 hours |

**3.4 Data Analysis Techniques.**

The measurement data were analyzed using **descriptive statistics** to obtain the mean, minimum, maximum, and standard deviation values. These results were then compared against a reference standard to evaluate the extent to which the natural lighting, natural ventilation, and temperature/humidity conditions at the Nurul Yaqin Mosque supported energy efficiency and thermal comfort.

The measurement data obtained from the field were analyzed using descriptive statistics. This approach aims to describe and summarize the actual conditions of the variables studied: natural lighting intensity, airflow velocity (natural ventilation), and temperature and humidity (thermal comfort) in the main room of the Nurul Yaqin Mosque.

The descriptive statistics used included calculating the mean, maximum, minimum, and standard deviation of the data obtained. This analysis helps to:

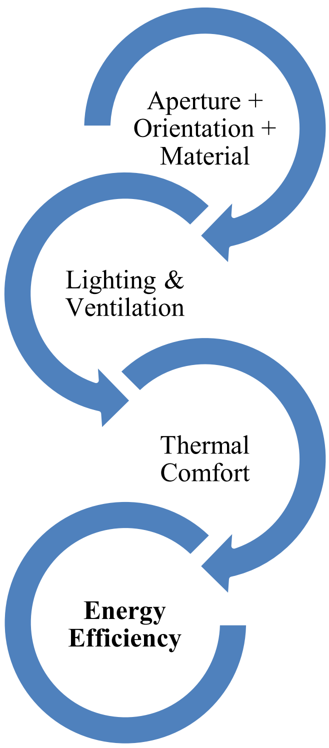
- Demonstrate fluctuations and variations in prayer room conditions over time.
- Determine whether natural lighting is sufficiently stable in the morning, afternoon, and evening.
- Assess whether natural ventilation consistently produces airflow rates that support comfort.
- Describe the stability of temperature and humidity inside the prayer room, especially compared to conditions outside the building.

The results of the analysis are then compared with national and international standards as a reference, namely:

- SNI 03-6575-2001 for standard lighting levels for worship spaces (≥ 250 lux).
- ASHRAE Standard 55 and SNI 03-6572-2001 for the thermal comfort zone, which is generally at a temperature of 23–27°C and a relative humidity of around 40–60%, with a wind speed in the range of 0.3–0.9 m/s.

With this approach, it can be evaluated to what extent the implementation of passive systems at the Nurul Yaqin Mosque has been effective in supporting energy efficiency and thermal comfort for the congregation.

**3.4 Conceptual Framework Diagram.**



## IV. ANALYSIS AND DISCUSSION

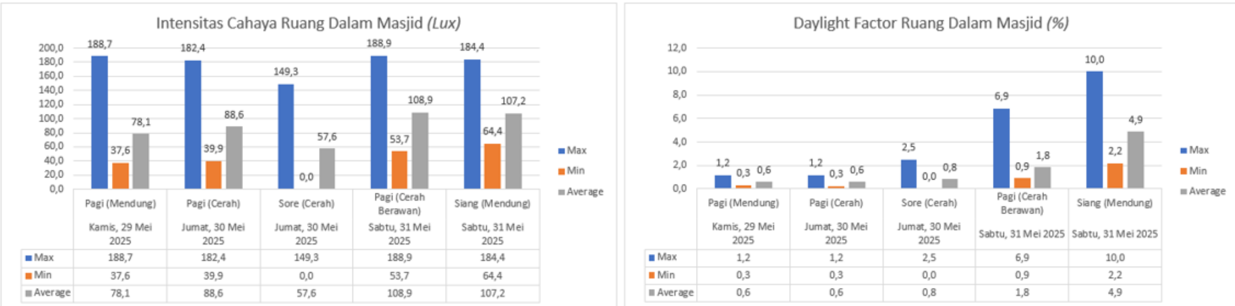
### 4.1 Natural Lighting Evaluation.

Research on natural lighting in the prayer hall of the Nurul Yaqin Mosque indicates that the building's natural lighting is still suboptimal. Based on measurements at 187 locations, taking into account variations in time (morning, afternoon, evening) and weather conditions (sunny, cloudy, overcast), the average daylight factor (DF) ranged from only 0.6% to 1.8%, well below the minimum standard of 2% according to SNI 6197:2011. Only during cloudy days did the DF reach 4.9%, the only time the standard for natural lighting was met.

The distribution of lighting was also uneven. Areas close to the openings received adequate lighting, while the center of the room tended to be dark, with some locations even experiencing 0 lux on sunny afternoons. This demonstrates the urgent need for improvements in natural lighting design.

These findings reinforce findings in leading journals that natural lighting has the potential to save energy during the day, but in reality, there are still shortcomings in light distribution and intensity. Therefore, design interventions such as adding clerestory, light shelves, or increasing the size and position of openings are important to achieve better and more even light distribution within a space.

With optimal natural lighting, the potential for energy savings in the lighting sector will be much more significant, reducing reliance on artificial lighting, especially during the day.




**Graphic 1: Results of Measurement of Light Intensity (Lux) and Daylight Factor (%) in the Mosque Prayer Room**

#### 4.1.1 Relationship with Energy Efficiency and Comfort.

Suboptimal natural lighting conditions directly impact the building's energy efficiency. Although natural ventilation at the Nurul Yaqin Mosque is quite effective in maintaining thermal comfort, the lack of natural lighting results in high energy requirements for lighting, particularly in the morning and evening or on clear, cloudless days.

This aligns with the results of a similar study on educational buildings by Sanitha et al. (2025), which found that a high daylight factor near windows does not automatically guarantee even lighting distribution throughout the room. This context is relevant for the Nurul Yaqin Mosque, which faces similar challenges.

#### 4.1.2 Design Implications for Passive System Optimization.

The integration of daylighting research results provides several recommendations that strengthen the energy saving strategy at the Nurul Yaqin Mosque, namely:

- Addition of Vertical Openings:
  Clerestory or upper window design to increase light penetration into the central area.
- Application of Light Shelf:
  Installing a light shelf to reflect light into the interior of the room so that the distribution is more even.
- Reflective Material:
  Use of light-colored paint or interior finishes with a high reflectance index to improve light distribution.
- Shading Devices:
  Adding shading such as sun louvers or fins to avoid excessive glare in sunny weather without reducing diffuse light.
- Vegetation Optimization:
  Vegetation is not only for thermal shading, but also to regulate softer indirect lighting into the space.

With this intervention, not only will visual comfort increase, but the potential for energy savings will also increase significantly, thus supporting the main objective of implementing passive systems in this building.

**4.2 Evaluation of Natural Ventilation.**

Based on the results of the natural ventilation study at the Nurul Yaqin Mosque, it was found that the natural ventilation performance is still not optimal to support overall thermal comfort. The results of wind speed measurements showed that the average wind speed outdoors was 0.639 m/s, while indoors it was only 0.239 m/s, indicating significant obstacles to the penetration of air from outside into the prayer room.

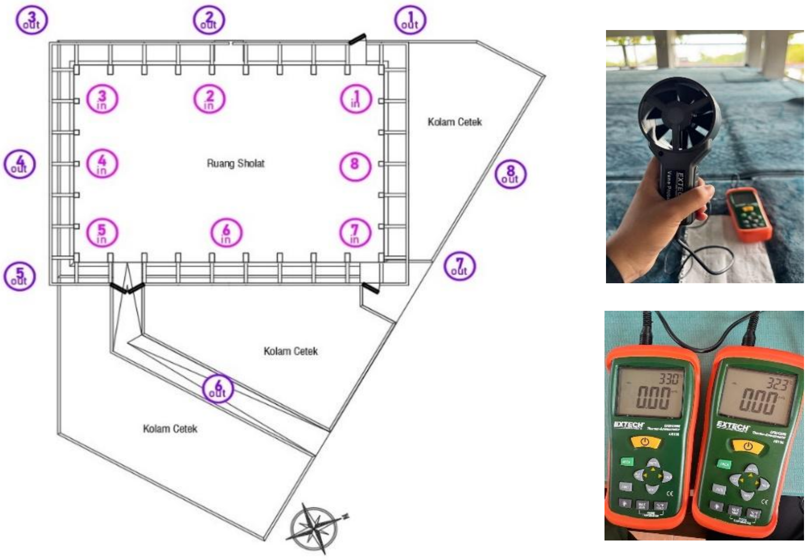


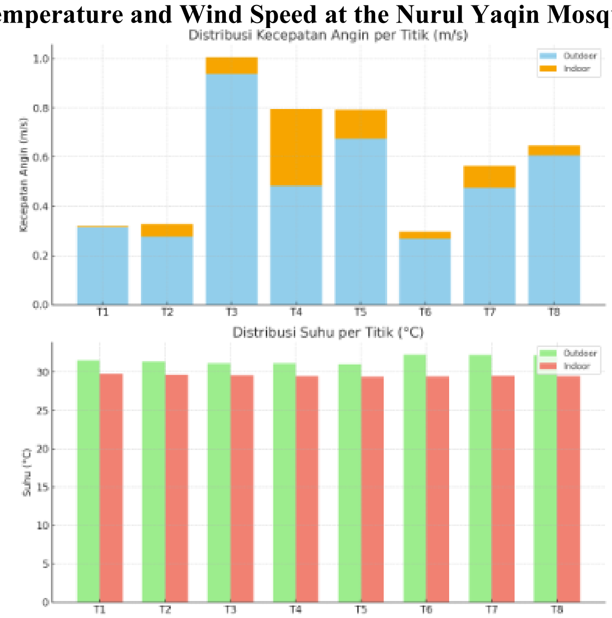

**Figure 2. Anemometer Measuring Instrument Placement**

Airflow distribution is also uneven. Points close to dominant wind openings (such as the south and west sides) exhibit better airflow, while areas on the north and northwest sides tend to experience stagnation. This phenomenon was confirmed through smoke tests, which showed smoke dissipation times on the north side reached up to 5 minutes, significantly slower than the south side, which only took about 90 seconds. This indicates poor cross-ventilation on that side.

In terms of temperature, indoor temperatures ranged from 28°C to 31°C, with relatively high relative humidity of 70% to 87%, depending on the observation time. This condition indicates heat accumulation, particularly during the day and evening, due to the ineffectiveness of the ventilation system in removing heat from the room.

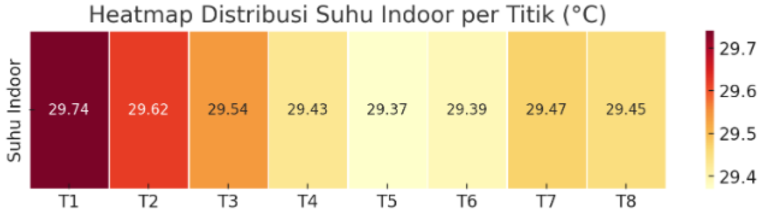
The dominant wind direction was from south to north. However, the "wind shadow" effect from supporting buildings on the north side, such as the ablution area and offices, caused airflow to weaken when it reached those areas. This directly impacted uneven thermal comfort and reduced potential energy savings due to the greater need for fans or artificial cooling systems in stagnant areas.

**Graphic 2. Temperature and Wind Speed at the Nurul Yaqin Mosque in Palu City**



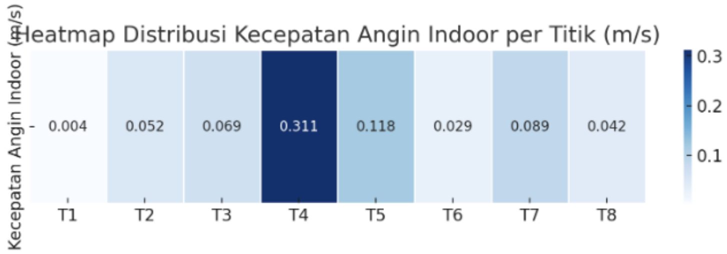
- The top graph shows the distribution of wind speeds at each observation point. It can be seen that the wind speeds outside are much higher than indoors, indicating a restriction of natural ventilation to the room.
- The bottom graph shows the temperature distribution at each point. The indoor temperature is slightly lower than outdoors, but still indicates heat accumulation in some areas, especially in areas with poor ventilation.

**Graphic 3. Temperature and Wind Speed at the Nurul Yaqin Mosque in Palu City**



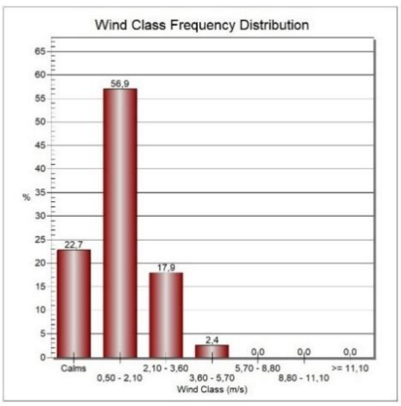

- Lighter colors indicate areas with higher temperatures.
- The temperature at all points is fairly even, ranging from 29.3°C to 29.7°C, but points like T1 and T2 tend to be hotter, indicating potential heat accumulation in those areas.

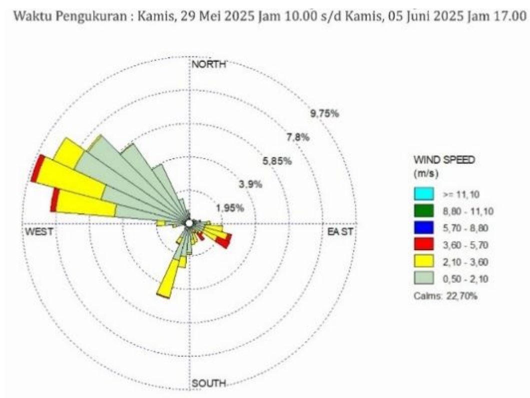
**Graphic 4. Heatmap of Wind Speed Distribution at the Nurul Yaqin Mosque in Palu City**




- Darker blue indicates areas with higher wind speeds.
- Point T4 has the highest wind speed (0.311 m/s) compared to the other points, indicating this area is better able to receive airflow.
- Conversely, points such as T1, T6, and T8 show very low wind speeds, indicating stagnant zones that impact thermal comfort.
- Based on observations:
- Dominant wind direction:
  ➡️ West (270°)
  ➡️ Southwest (225°)
  ➡️ South (180°)
- Wind speed distribution:
  - 56,9% winds were at low speeds (0,5–2,1 m/s)
  - 17,9% at medium speeds (2,1–3,6 m/s)
  - 22,7% were calm (almost no wind)
  - Only 2.4% were high-speed winds (>3.6 m/s)

**Graphic 5. Wind Speed Distribution and Wind Direction Patterns**



- Winds also often come from the Southwest (SW) and West (W).
- The northern side of the mosque is a stagnant zone, as it serves as the wind outlet but is obstructed by surrounding supporting structures.

**4.2.1 Relationship with Energy Efficiency and Passive Systems.**

The results of this study further reinforce the importance of developing natural ventilation design strategies to support energy-saving potential. Although most areas receive adequate airflow during the day, certain areas still require additional intervention to prevent heat buildup, which ultimately requires additional energy consumption for cooling.

This phenomenon aligns with findings of uneven natural lighting, demonstrating that holistic optimization of passive systems is key to achieving truly energy-efficient buildings. Ineffective natural ventilation throughout all areas can potentially increase energy costs, particularly for fans or air conditioners at certain times.

**4.2.2 Design Implications for Passive System Optimization**

These findings provide a strong basis for making several design development recommendations, including:

- Addition of High-Level Vents
  To maximize the stack effect, allowing accumulated hot air to escape vertically.
- Increased Openings on the North Side
  To address airflow stagnation caused by the wind shadow effect of supporting buildings.
- Optimization of Cross Ventilation
  By enlarging or adding openings on the downwind side, thereby improving airflow.
- Adjustment of the Layout of Supporting Buildings
  Reducing physical obstacles that obstruct airflow, such as widening corridors or modifying the position of ablution rooms and offices.
- Implementation of Strategic Vegetation Elements
  In addition to controlling thermal and solar radiation, vegetation also functions as a wind guide, helping to accelerate airflow into the space.

**4.3 Quantitative Analysis of Energy Saving Potential.**

To strengthen the discussion on energy efficiency at the Nurul Yaqin Mosque, a quantitative analysis was conducted of the potential energy savings from implementing passive systems, specifically natural lighting and ventilation.

This analysis was conducted by comparing the electrical energy requirements under existing conditions with those when the passive systems are operating optimally during the day.

**4.3.1 Lighting Energy Savings Analysis.**

- **Existing Conditions**

The main hall of the Nurul Yaqin Mosque uses lamps as a supplemental source of illumination, especially in the morning and evening, and in conditions where natural light is uneven.

Assumed lighting requirements:

| ***Component*** | **value** |
|---|---|
| *Number of lights* | 24 unit |
| *Power per lamp* | 18 Watt |
| *Total power* | 432 Watt |
| *Average operating time* | 10 hour/day |

Daily energy requirements:
$E = P \times t$
$E = 432\ \text{Watt} \times 10\ \text{hour}$
$E = 4320\ \text{Wh/day} = 4{,}32\ \text{kWh/day}$
Monthly energy needs:
$E_{month} = 4{,}32 \times 30$
$E_{month} = 129{,}6\ \text{kWh/month}$

- **Potential Savings through Natural Lighting**

Based on daylight factor and natural light intensity measurements, most prayer rooms can benefit from approximately five hours of natural light during the day. This allows for approximately 50% reduction in lighting usage during the daytime.

Energy Savings Calculation:
$E_{savings} = 432\ \text{Watt} \times 5\ \text{hour}$

$E_{savings}$ = 2160 Wh/day = 2,16 kWh/day
Potential monthly savings:
2,16 × 30 = 64,8 kWh/month
If the average electricity tariff is IDR 1,700/kWh, then the potential savings in electricity costs are: 64,8 × 1.700 = Rp110.160/month

**4.3.2 Cooling Energy Savings Analysis.**

- **Existing Conditions**

In conditions where natural ventilation is less than optimal, some areas of the prayer room may require the assistance of fans to improve thermal comfort.
Assuming fan use:

| ***Component*** | **value** |
|---|---|
| *Number of fans* | 10 unit |
| *Fan power* | 45 Watt |
| *Total power* | 450 Watt |
| *Operating hours* | 8 hour/day |

Cooling energy requirements:
E = 450 × 8
E = 3600 Wh/day = 3,6 kWh/day
Monthly energy:
3,6 × 30 = 108 kWh/month

- **Potential Savings through Natural Ventilation**

Ventilation analysis results indicate that improving cross-ventilation performance and optimizing openings can reduce fan usage requirements by approximately 30%.
Energy savings calculation:
$E_{savings}$ = 30% × 108
$E_{savings}$ = 32,4 kWh/month
Estimated cost savings:
32,4 × 1.700 = Rp55.080/month

**4.3.3 Total Energy Savings Potential.**

| ***Source of Savings*** | **Energy Saving** |
|---|---|
| *Natural lighting* | 64,8 kWh/month |
| *Natural ventilation* | 32,4 kWh/ month |
| *Total* | 97,2 kWh/ month |

Estimated total electricity cost savings:
97,2 × 1.700 = Rp165.240/month

**4.3.4 Building Energy Efficiency Analysis.**

The analysis shows that the implementation of passive systems at the Nurul Yaqin Mosque significantly reduced the building's operational energy needs.

Natural lighting contributed the most to reducing energy consumption, especially during the day. Meanwhile, natural ventilation helped reduce the use of mechanical fans by naturally improving thermal comfort. While the monthly energy savings may appear moderate, the annual savings potential is substantial.

Annual calculation:
97,2 × 12 = 1166,4 kWh/year
Estimated annual cost savings:
1166,4 × 1.700 = Rp1.983.000/year

**4.3.5 Implications for Energy-Efficient Tropical Buildings.**

These findings show that optimizing passive systems in tropical religious buildings not only improves thermal and visual comfort, but also has a real impact on the building's energy efficiency.

Strategies such as:

- Optimizing openings,
- Cross ventilation,
- Top ventilation,
- Use of reflective materials,
- and vegetation management,

It has been proven to help reduce dependence on mechanical systems.

Thus, the application of passive design to the Nurul Yaqin Mosque can serve as a model for developing tropical religious buildings that are more energy-efficient, sustainable, and adaptable to the climate conditions of Palu City.

**4.4 Thermal Comfort Evaluation.**

Based on temperature and humidity data recorded over a 24-hour period, the temperature inside the main hall of the Nurul Yaqin Mosque ranged between 25°C and 28°C, with a relative humidity of 55% to 65%. Although the temperature still slightly exceeds the upper limit of the ASHRAE comfort zone (23–27°C), these conditions remain tolerable, primarily due to adequate airflow (wind chill effect) from cross-ventilation.

Humidity, which tends to exceed 60% at certain times, has the potential to reduce thermal comfort because it inhibits the body's cooling process through evaporation. This is a common challenge in buildings in humid tropical regions like Palu.

The use of roof and wall covering materials with low reflectivity is suspected to be one of the causes of heat accumulation during the day. Therefore, the application of materials with high reflective properties or the addition of thermal insulation is important to improve thermal comfort.

**4.5 Implications for Energy Saving Potential.**

The evaluation results show that the application of passive systems at the Nurul Yaqin Mosque has a significant contribution to energy savings, especially in two main aspects.:

1. Lighting:
   Natural lighting is able to replace most of the need for lamps during the day, so that the potential energy savings for lighting reaches 30–50%, as also supported by previous research. (Slamet et al., 2017).
2. Air Cooling:

Effective natural ventilation reduces the need for fans or air conditioning. While not yet fully optimal, reducing room temperature by 2–3°C has the potential to reduce cooling energy consumption, in line with the findings of Riyadi et al. (2018) and Alavi et al. (2016).

**4.6 Design Development Recommendations.**

Based on research findings, several recommendations for optimizing the passive system at the Nurul Yaqin Mosque include:

- Aperture Optimization:
  Adding high-level windows to maximize the stack effect and increasing the size of openings on certain sides to strengthen cross ventilation.
- Reflective Material:
  Replacing or adding roof and wall coverings with light-colored materials or those with a high reflectivity index to reduce heat absorption.
- Skylight or Clerestory:
  Installing skylights or upper windows (clerestory) to increase the distribution of natural light, especially in areas far from horizontal openings.
- Shade Vegetation:

Planting vegetation around buildings to help lower the temperature of the surrounding environment and reduce direct heat radiation to the building.

## V. CONCLUSION

Research evaluating the energy-saving potential of the Nurul Yaqin Mosque in Palu City through the implementation of passive systems indicates that natural lighting and ventilation strategies significantly contribute to the energy efficiency and thermal comfort of religious buildings in tropical regions.

The natural lighting evaluation results indicate that lighting performance in the main mosque space is still suboptimal. The daylight factor values obtained are mostly in the range of 0.6%–1.8%, thus not meeting the minimum natural lighting standards according to SNI 6197:2011 for all prayer areas. Uneven light distribution means that some areas still require artificial lighting, particularly in the morning and evening. This situation indicates that the natural lighting system still has significant potential for development through optimizing openings, clerestory, and light shelves to improve lighting energy efficiency.

Regarding natural ventilation, the research results indicate that the cross-ventilation system at the Nurul Yaqin Mosque is capable of generating natural airflow, but it does not function optimally throughout the building. The average indoor wind speed of 0.239 m/s remains below the ASHRAE thermal comfort standard of 0.3–0.9 m/s. Several areas experience air stagnation due to obstructions from supporting structures on the north side of the mosque, causing a wind shadow effect and heat accumulation in the room.

Linear regression analysis shows that airflow velocity has a negative effect on room temperature, while relative humidity has a positive effect on increasing the sensation of heat. The coefficient of determination ($R^2$) of 68% indicates that room temperature variations are strongly influenced by natural ventilation and air humidity. Pearson correlation analysis also shows a strong negative relationship between wind speed and room temperature ($r = -0.74$), confirming that increasing natural airflow can effectively reduce room temperature.

Quantitative energy analysis indicates that the implementation of passive systems has the potential to save 97.2 kWh/month, or approximately 1,166.4 kWh/year. These potential savings come from reduced daytime lighting use through natural lighting and the reduced need for mechanical fans due to increased thermal comfort from natural ventilation. These findings demonstrate that passive design strategies have a significant contribution to supporting energy-efficient buildings in tropical regions.

Overall, this study demonstrates that the implementation of passive systems in tropical mosque buildings not only impacts energy efficiency but also the quality of thermal and visual comfort for congregants. Optimizing opening design, cross-ventilation, overhead ventilation, the use of reflective materials, and vegetation management are important strategies for improving the performance of passive systems at the Nurul Yaqin Mosque.

This research is expected to serve as a reference in developing designs for tropical worship buildings that are more energy-efficient, sustainable, and adaptable to local climate conditions, particularly in tropical coastal areas like Palu City.

## REFERENCES


[1]. Alavi, A., Zain-Ahmed, A., & Surat, M. (2016). An analysis of passive cooling strategies in tropical climates: A case study of Malaysia. Renewable and Sustainable Energy Reviews, 65, 705–713. https://doi.org/10.1016/j.rser.2016.07.036.

[2]. ASHRAE. (2017). ANSI/ASHRAE Standard 55-2017: Thermal Environmental Conditions for Human Occupancy. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

[3]. Nugroho, R., & Putra, H. (2020). Pemanfaatan pencahayaan alami pada bangunan ibadah di kawasan tropis. Jurnal Arsitektur Tropis, 8(1), 14–21.

[4]. Olgyay, V. (2015). Design with Climate: Bioclimatic Approach to Architectural Regionalism (New and Expanded Edition). Princeton University Press.

[5]. Riyadi, R., Pramudito, A., & Hadi, S. (2018). Efektivitas ventilasi silang untuk kenyamanan termal pada masjid di Yogyakarta. Jurnal Ilmiah Teknik Sipil, 22(3), 135–142.

[6]. Slamet, S., Handayani, L., & Nugraha, R. (2017). Studi pencahayaan alami pada ruang ibadah di iklim tropis basah. Jurnal Rekayasa, 20(2), 45–52.

[7]. SNI 03-6572-2001. (2001). Tata cara perancangan sistem ventilasi dan pengkondisian udara pada bangunan gedung. Jakarta: Badan Standardisasi Nasional.

[8]. SNI 03-6575-2001. (2001). Tata cara perancangan sistem pencahayaan alami pada bangunan gedung. Jakarta: Badan Standardisasi Nasional.

[9]. Szokolay, S. V. (2014). Introduction to Architectural Science: The Basis of Sustainable Design (3rd ed.). Routledge.