Energy Efficiency in Church Building Based on Sefaira Energy Use Intensity Standard

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Abstract. The occupancy for buildings with religious purposes has infrequent periods of use that are near full occupancy to minimal or no occupancy. Thus, energy usage in buildings such as churches has lower overall energy intensity than other commercial buildings. The purpose of this study aims to analyze the use of energy in a church building by using Sefaira extension in SketchUp modeling application and to provide solutions so that the building’s Energy Use Intensity (EUI) value can be within Sefaira standard. This research was conducted by simulating a church building model into Sefaira application, which includes aspects of the assessment, namely building orientation, wind, openings, and material. This study describes the energy efficiency of buildings by changing the materials that are more optimal to respond to the heat received by the building. Changes applied to buildings by optimizing materials such as the application of insulations, ventilation, and solar screen reduce the value of Solar Heat Gain Coefficient (SHGC). This change significantly reduces the energy consumption from 125 kWh/m²/yr to 67 kWh/m²/yr in the building.

Keywords: Church, Energy Use Intensity (EUI), Sefaira

1. Introduction

Globalization, improvement of living conditions, and the development of communication networks lead to patterns of enormous energy consumption, which, without doubt, will exhaust fossil fuel resources and have a severe impact on the environment. As for now, the global contributions from buildings towards energy consumption have increased and raised concerns over problems of supply, the exhaustion of energy resources, and severe environmental impacts such as ozone layer depletion, global warming, climate change, and many more [1]. In developed countries, the building sector is responsible for about 40% of the total energy use [2] and produces almost 35% of the carbon dioxide emitted into the atmosphere [3]. Moreover, today’s building designs tend to pay more attention to aesthetics and less attention to adjusting their design with the environment where the building is built, resulting in high-energy consumption [4]. Not only for the building’s energy usage, but the construction industry is also responsible for significant energy consumption, with approximately 40-50% of all energy usage and anthropogenic greenhouse gas emissions globally. For this reason, energy efficiency in buildings with minimal environmental impact became a primary goal for energy policy at regional, national, and international levels [5]. For the current and future energy, people started to develop advanced tools and methods for designing buildings and the associated energy and thermal systems.

Regardless of the building types, studying the energy consumption of buildings is crucial to understand the patterns and characteristics. Especially in early-stage design decisions, forecasting of building energy consumption through accurate modeling enables better energy management and efficient applications, such as the estimation of improvements to building energy performance [6]. In
this paper, the object studied is a church with a unique energy intensity usage than other commercial buildings because of its infrequent occupancy. Furthermore, correct air conditioning in churches is necessary because there are many religious objects that needed preservation stored in churches. Therefore, the most extensive use of energy for churches is devoted to space conditioning by 70%. As the dominant use is for heating and cooling, it is necessary to design churches that can maintain their air condition by passive design that could save energy and cost through reducing energy use intensity [7].

To verify design performances and estimate their impact on the environment, it is necessary to use energy simulation software to evaluate building energy consumption. There are many simulation software with different usability levels, intelligence, interoperability, process adaptability, and accuracies, such as HEED, eQuest, IES, DesignBuilder, and many more. In this paper, Sefaira is the simulation software used to analyze energy efficiency in the building. This software can analyze complicated and broad buildings and guide how they should be designed [8]. Along with the simulation software, there are building simulation standards and guidelines established by professional organizations for the validation process, such as the International Energy Agency (IEA), The Building Simulation Test (BESTEST), and ASHRAE Standards [9]. Sefaira uses ASHRAE 90.1-2013 Standard, as seen in table 1, to analyze building envelope with detailed openings and complete covered layers, while the Energy Use Intensity (EUI) standard usage is within an ideal value of 79 kWh/m2/yr [10].

**Table 1. ASHRAE 90.1 – 2013 Baseline**

| Variable                       | Energy Standard |
|--------------------------------|-----------------|
| ASHRAE Climate Zone            | 2               |
| Wall Insulation                | 0.86 W/m².k     |
| Floor Insulation               | 0.61 W/m².k     |
| Roof Insulation                | 0.22 W/m².k     |
| Glazing U-Factor               | 2.27 W/m².k     |
| Visible Light Transmittance    | 0.42            |
| Solar Heat Gain Coefficient     | 0.25 SHGC       |
| Infiltration Rate              | 7.2 m³/m².h     |
| Ventilation Rate               | 15 L/s.person   |
| Equipment                      | 25 W/m²         |
| Lighting                       | 10 W/m²         |

Based on various studies, the factors that could reduce the value of EUI consist of 3 factors below:

1.1. Ventilation

Ventilation serves to move outdoor air into the building to distribute it throughout the indoor building [11]. Whether it is natural ventilation, mechanical ventilation, or hybrid ventilation, the primary purpose of the application of ventilation in buildings is to provide healthy air for the user to breathe.
1.2. Insulation

Insulation blocked the wall, roof, or floor from exposure to the sun’s radiation. The insulation application affects restrain the solar radiation inside the building to provide more efficient energy on air conditioning usage inside the room [12].

1.3. Solar Heat Gain Coefficient (SHGC)

Solar Heat Gain Coefficient is the window glass’s channel power capability, whether the window glass can transmit light and absorb sunlight [13]. The application of internal blinds, such as solar screens, would reduce the Solar Heat Gain Coefficient’s value.
2. Methodology

2.1. Research Object

The church is located in between two arterial paths, Jl. Kaum Dalam and Jl. Asia Afrika and geographically located in -6°9’ and 107°61’ and above 686 asl. The total area is 8,974 m². This area is categorized as a hot and humid region with relative humidity between 57% - 99%, wind speed 1-19 km/h, and temperature between 25-19°C. This object is still a design study and hasn’t been built.

The design of this building using tropical architecture as its concept with the consideration of the climate aspects and environment, which gave impact to the building envelope, openings, and building’s orientation.

![Building mass](image)

**Figure 4. Building mass**

![Building’s floorplan](image)

**Figure 5. Building’s floorplan**

![Building mass with Sefaira analysis](image)

**Figure 6. Building mass with Sefaira analysis**
This study uses a descriptive quantitative approach, with objective measurements and numerical data collected through computational analysis using software, namely Sefaira. The building mass-form of the object was prepared in SketchUp to simulate it with Sefaira. The first analysis result is given from Sefaira to analyze which aspects significantly impact the solar heat gain. The changes are made based on the first analysis to get the ideal value of EUI and re-run the simulation to get the second analysis. The changes are the value of Ventilation, Insulation, and Solar Heat Gain Coefficient (SHGC).

![Diagram with arrows showing first and second analysis results]

**Table 2. Indicator value changes between 1st analysis and 2nd analysis**

| Indicators                  | 1st analysis result            | 2nd analysis result            |
|----------------------------|--------------------------------|--------------------------------|
| Wall Insulation            | 0.86 W/m² – k (Poorly Insulated) | 0.5 W/m² – k (Insulated)      |
| Ventilation Rate           | 15 L/S (Typical Ventilation)   | 12.4 L/S (Typical Ventilation) |
| Solar Heat Gain Coefficient| 0.25 SHGC (Reflective)         | 0.19 SHGC (internal blind)     |

2.2. **Sefaira**

Sefaira is a Sketch Up plug-in for designing sustainable buildings and optimizing its carbon footprint and energy efficiency based on ASHRAE 90.1 – 2013. Sefaira calculates Energy Use Intensity (EUI) with building model input, and its setting includes insulation, glazing, ventilation, equipment, daylight, heat gain, lighting, and infiltration. The building envelope is divided into parts such as roof, wall, and window. The typology for the building is classified as “office” located in Bandung, Indonesia. Sefaira provides annual energy performance, annual CO2 production, and the annual heating and cooling loads [9].

3. **Findings and Discussion**

Figure 2 shows the energy use due to several factors, such as the projection of energy use by electronics per square meter (Equipment Dominated), Energy Use Intensity (EUI), and the percentage of light entering the building (Mostly Lit / Mostly Underlit). The factor that affects Equipment Dominated is the cooling system’s use on building elements due to sun exposure, building leaks, and conduction to glass elements.
It can be seen in Figure 7 that the EUI value reaches 125 kWh/$m^2$/yr. This value is not following the standards at Sefaira for buildings with an ideal value of 79 kWh/$m^2$/yr, so that a minimum energy reduction of 46 kWh/$m^2$/yr is required. It shows that the value of Equipment contributes the most, followed by cooling, so the best solution is to reduce the sun’s exposure to the building by the application of insulation, ventilation, and optimal strategies of the building envelope.

**Table 3. Energy audits on Sefaira 1st analysis**

| Impact on Cooling       | Gains     | Losses    |
|-------------------------|-----------|-----------|
| Equipment and People    | 522,179   | 0         |
| Wall Conduction         | 160,538   | 171,731   |
| Roof Conduction         | 77,779    | 72,866    |
| Lighting                | 139,248   | 0         |
| North Solar             | 2,128     | 0         |
| East Solar              | 36,110    | 0         |
| West Solar              | 26,807    | 0         |
| South Solar             | 2,909     | 0         |
| Floor Conduction        | 10        | 34,167    |
| Glazing Conduction      | 12,498    | 8,285     |
| Infiltration            | 9,871     | 1,886     |

**Table 4. Variable change on 2nd analysis**

| Indicators               | Energy Standard | Standard energy change |
|--------------------------|-----------------|------------------------|
| HVAC Type                | VAV – Return Air Package (System 5/6) | VAV – Return Air Package (System 5/6) |
| Baseline                 | ASHRAE 90.1 - 2013 | ASHRAE 90.1 - 2013 |
| ASHRAE Climate Zone      | 2               | 2                      |
| Wall Insulation          | 0.86 W/m2 – k (Poorly Insulated) | 0.5 W/m2 – k (Insulated) |
| Floor Insulation         | 0.61 W/m2 – k   | 0.61 W/m2 – k (Insulated) |
| Roof Insulation          | 0.22 W/m2 - k   | 0.22 W/m2 - k (Well Insulated) |
| Glazing U-Factor         | 2.27 W/m2 –k    | 1.92 W/m2 –k (3 pane) |
Visible Light Transmittance and Solar Heat Gain Coefficient

| Aspect         | First Analysis | Second Analysis |
|----------------|----------------|-----------------|
| Visible Light Transmittance | 42%            | 42%             |
| Solar Heat Coefficient Gain | 0.25 SHGC (Reflective) | 0.19 SHGC (internal blind) |
| Infiltration Rate | 7.2 m3/m2h     | 7.2 m3/m2h     |
| Ventilation Rate | 15 L/S (Typical Ventilation) | 12.4 L/S (Typical Ventilation) |
| Equipment Lighting | 25 W/m2 (Poor) | 7.5 W/m2 (Good) |
| Ventilation Rate | 15 L/S (Typical Ventilation) | 12.4 L/S (Typical Ventilation) |

Based on the analysis results in table 4 shows a significant change from the EUI. The initial EUI value of 125 kWh/m²/yr was successfully reduced by 58 kWh/m²/yr to 67 kWh/m²/yr. Also, all aspects tend to decrease significantly.

The buildings analyzed were not changed in orientation, area, and facade apart from applying the material of insulations, ventilations, and internal blinds to reduce the Solar Heat Gain Coefficient (SHGC). The results show the significant result of reducing buildings’ energy consumption by optimizing these three aspects.

Table 5. Comparison of energy audits from 1st and 2nd analysis

| Indicators                  | First analysis | Second analysis | Status     |
|-----------------------------|----------------|-----------------|------------|
| Total Area Floor            | 6,648 m²       | 6,648 m²        |            |
| Energy Use Intensity (EUI)  | 125 kWh/m²/yr  | 67 kWh/m²/yr    | Decrease   |
| Equipment Dominated Cooling: Lighting: Equipment: Fans: | 268,394 | 137,010 | Decrease |
| 139,404 | 138,024 | 342,298 | 103,518 | |
| 106,467 | 49,422 |               |            |
| Equipment and People        | 522,179 (Gains) | 278,495 (Gains) | Decrease   |
| Wall Conduction             | 160,538 (Gains) | 184,266 (Gains) | Increase   |
| 171,731 (Losses)            | 187,395 (Losses) |                 |            |
| Roof Conduction             | 77,779 (Gains) | 79,843 (Gains) | Increase   |
| 72,866 (Losses)             | 73,530 (Losses) |                 |            |
| Lighting                    | 139,248 (Gains) | 129,500 (Gains) | Decrease   |
| East Solar                  | 36,110 (Gains) | 24,895 (Gains)  | Decrease   |
| West Solar                  | 26,807 (Gains) | 18,481 (Gains)  | Decrease   |
| Floor Conduction            | 10 (Gains)     | 12 (Gains)      | Increase   |
| 34,167 (Losses)             | 25,358 (Losses) |       | Decrease   |
| Glazing Conduction          | 12,498 (Gains) | 11,179 (Gains)  | Decrease   |
| 8,285 (Losses)              | 7,514 (Losses) |                 |            |
| Infiltration                | 9,871 (Gains)  | 8,722 (Gains)   | Decrease   |
| 1,886 (Losses)              | 2,564 (Losses) |                 | Increase   |
| North Solar                 | 2,128 (Gains)  | 1,467 (Gains)   | Decrease   |
| South Solar                 | 2,909 (Gains)  | 1,826 (Gains)   | Decrease   |
4. Conclusion
Sefaira simulation results show that the building’s initial EUI value reaches 125 kWh/m²/yr. The standard on Sefaira is in the ideal value range of 79 kWh/m²/yr, so that a minimum energy cut of 46 kWh/m²/yr is required. Changes applied to buildings are not in the orientation, area, and facade of the building, but from optimizing materials such as the application of insulations, ventilation, and solar screen to reduce the value of Solar Heat Gain Coefficient (SHGC). This change significantly reduces the value of EUI from 125 kWh/m²/yr to 67 kWh/m²/yr, so the buildings’ energy consumption is considered efficient.

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