Sefaira Simulation in Residential Houses to Determine the Energy Use of Wall Materials

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Abstract. Wall material popularly used in Indonesia is a masonry wall, where the process takes longer than prefabrication wall materials or houses built-in components such as panels or modules. In this study, four types of prefabrication wall materials will be analyzed based on the annual energy use of each material. The wall materials chosen are Hebel, Alderon, Glassfibre Reinforced Cement Board (GRC), and metal deck. The calculation of energy consumption uses a simulation of a 27 m² one-floor residential building located in Bandung City, West Java, Indonesia. Furthermore, the simulation is analyzed with Sefaira software based on ASHRAE 90.1 - 2013. From the results of this Sefaira analysis, it is obtained that the Energy Use Intensity (EUI) value for Hebel wall material is 58 kWh/m²/yr, Alderon wall 90 kWh/m²/yr, Glassfiber Reinforced Cement Board (GRC) 83 kWh/m²/yr, and metal deck 89 kWh/m²/yr. Among the four recommended prefabricated wall materials, Hebel materials are considered to have the least energy use. Meanwhile, the EUI target of the 2030 Challenge for residential houses is 38 kWh/m²/yr, so it must reduce as much as 45 kWh/m²/yr for Hebel material.

Keywords: energy consumption, low carbon, prefabrication material, Sefaira simulation

1. Introduction
In 2019, the percentage of decent and affordable housing for living in Indonesia decreased from 39.19% [1], requiring housing of around 800 thousand units per year due to population growth of 1.4% per year. During the last five years, housing needs have only met around 400 to 500 thousand units, while the housing backlog has reached 13.5 million units [2]. The Ministry of Public Works and Public Housing estimates that by 2025 the number of housing needs in Indonesia will reach 30 million units.

Indonesia usually use bricks to make house walls. Constructing houses on an in-site / conventional basis requires a long time, costs are high and is usually of low technical quality. From these problems, to be able to fulfill the housing backlog, prefab houses are highly recommended. Prefab houses also support incremental housing, where this type of building is more suitable to be applied to low-cost housing [3]. The development of prefab houses is relatively new, so that it has not been widely accepted by the Indonesian housing market. Negative consumer perceptions are a significant barrier to developing a large market for prefabricated housing. This is related to the opinion that prefab houses are not of good quality, are massively constructed and do not have a good architectural image [4]. In a study on the preference for prefab houses in Jabodetabek, it was found that only 45% of the total respondents would choose this system house, even though 70% of respondents are interested in it. This is also ultimately the reason why 57% of respondents expressed willingness to buy prefab houses. Respondents said that
they choose conventional houses even though it is 10% more expensive than prefab houses [5]. Despite the fact that these prefab houses are less popular, they are proven to reduce construction time (within 2-3 weeks), are environmentally friendly (40% of recycled material).

The large number of Indonesians needing housing causes the supply of building materials to increase, some of which are not good for the environment. The volume of building materials has an effect on the value of the embodiment energy. The greater the volume of building materials, the greater the value of the energy embodiment produced [6]. This fact should be a concern how the use of building materials in small volumes of which 40% of the material is recycled so that the life cycle is low. Prefab houses with parametric designs are also proven to have a 5% lower carbon footprint than conventional systems [7].

This study will analyze four types of prefab modular wall material samples that are easily found in each region, (1) Hebel, (2) Alderon, (3) Glassfiber Reinforced Cement Board (GRC), and (4) metal deck on a lightweight steel frame house measuring 27m² [8]. Of the four samples of this material wall then measure the effect on the intensity of energy consumption, which is then compared with the Energy Use Intensity (EUI) value simulated using the Sefaira Plugin.

2. Literature Review

Choosing building materials to build building envelope components such as roofs, walls, floors, to ventilation greatly affects the comfort in space, which will also affect the energy needed in the building. High-performance building facades are building envelopes that use a minimum amount of energy to maintain a comfortable indoor environment for occupants and improve occupant’s health and productivity. High-performance facades don’t act as barriers between the interior and exterior environment; rather, they participate as active systems in minimizing building energy consumption by responding to external environmental conditions. [9]

In addition, climate also plays an important role in determining energy use in buildings. The need to know the climatic conditions in the building to be designed. Whether the design strategy for high-performance facades in the “Hot & Humid” region or “Hot & Dry” region is quite different.

Knowing the heat storage capability of some building envelope components, such as walls, can help control indoor temperatures without the need for a mechanical system. [10] There are sustainable approaches to achieve thermal comfort in buildings without utilizing significant amounts of energy, especially for cooling or heating. [11]

The thermal conditions in buildings are determined by the thermal performance of the building and climatic conditions. This condition is caused by heat transfer between the two of them to achieve a balanced condition. Thermal transmittance is the rate of transfer of heat through matter. The thermal transmittance of a material (such as insulation or concrete) or an assembly (such as a wall or window) is expressed as a U-value. Building a wall with lower thermal transmittance (U) value has better capability to reduce indoor surface temperature variations. Thermal transmittance (U) is a measure of the rate of heat loss of building components; it is expressed as Wm-2K-1. [12]

2.1 EUI (Energy Use Intensity)

Energy Use Intensity (EUI) is a benchmarking metric used to express a building’s energy fitness[13]. EUI is a building’s annual energy use per unit area. It is typically measured in kilowatt-hour per square meter per year (kWh/m²/yr). Determining the EUI target, in this case, is needed to run a simulation using Sefaira, that a kind of software that serves to calculate the performance of a building[14]. Baseline EUI is calculated using the following formula (Equation 2).

\[
\text{EUI} = \frac{\text{Annual Energy Use (kWh)}}{\text{Building(s) Area (m²)}}
\]

**Equation 1. EUI calculation formula**
3. Method

3.1. Design Object
The research object is a residential house located on Jl. Dr. Setiabudhi, West Java, Bandung, Indonesia. One-floor houses with an area of 27m² consisting of 1 living room, one toilet, one kitchen, and one bedroom (figure 1). The facade faces the Southwest with one door 210cm x 90cm. For air circulation and sunlight, there are three operable windows measuring 150cm x 140 cm in the Southeast, Northwest, and Southwest. And two fixed windows in the Northeast and Southwest. [6] This residence uses a lightweight steel frame (figure 2), which then selects four types of prefab modular wall material samples, (1) Hebel, (2) Alderon, (3) Glassfiber Reinforced Cement Board (GRC), and (4) metal deck. To be able to simulate Sefaira, a U-Value value is needed for each material sample (Table 1).

![Figure 1. Lightweight frame house plan][1]

![Figure 2. The use of lightweight steel frames in residential houses][2]

| Wall materials | U-Value  |
|----------------|---------|
| Hebel wall     | 0.25 W/m²K |
| Alderon        | 5.56 W/m²K |
| GRC            | 3.57 W/m²K |
Metal deck | 5.55 W/m²K

### 3.2. Climatic Condition

Climatic conditions really need to be simulated in Sefaira’s Real-Time Analysis plugin. When the ASHRAE Baseline is selected, Sefaira automatically selects the appropriate ASHRAE Climate Zone 2 based on the project location (figure 3).

![Figure 3. Climate Zone](image)

Sefaira calculates the ASHRAE Climate Zone based upon temperature data from the weather file associated with project location, using the criteria described in ANSI/ASHRAE/IESNA Standard 90.1-2013 Normative Appendix B – Building Envelope Climate Criteria. These criteria are based upon Heating Degree Days (HDD) and Cooling Degree Days (CDD) [14].

### 3.3. Sefaira Simulation

The energy consumption was simulated and analyzed using Sefaira’s real-time analysis plugin. Previously, residential modeling was made using SketchUp software, after which each part of the building envelope was divided according to its function (figure 4). The side division of the building is intended so that there are no useless functions of the building so that the calculation is more accurate [15].

![Figure 4. Entity types the model](image)
In the first stage, energy simulation was conducted without using insulation materials on residential buildings’ walls. Sefaira will provide more appropriate design recommendations to maximize the design [15] to achieve the 2030 Challenge in residential homes, which is 38 kWh / m² / yr. But the analysis results that the color of the dial shows does not meet the target of the 2030 Challenge (colored red). The house has EUI of 66 kWh/m²/yr and is lighting dominated.

![Energy Use Intensity](image)

**Figure 5. EUI 2030 Challenge**

In the final stage, change the U-Value according to the wall material sample (Table 1). After all the required data has been inputted, the model is ready to be analyzed, and the results are compared with and without the use of insulation materials to the sample materials walls of the case study residential building.

4. Analysis and Result

4.1. Hebel wall material

The results of the EUI value from the simulation analysis of Sefaira are 58 kWh / m² / year, where the largest energy use is in the interior segment, the use of lights reaches 41% of total use.

![Total Energy](image)

**Figure 6. Annual Energy Use of Hebel wall**
4.2. Alderon wall material
Sefaira analysis results obtained EUI value of 90 kWh / m² / yr, and total energy in the design of a house with Alderon walls is 2,420 kWh / year where the largest energy use is in the interior segment, the use of lights reaches 26% of total use.

| Segment     | kWh per year | % of total use |
|-------------|--------------|----------------|
| Heating     | 57           | 2 %            |
| AHU         | 0            | 0 %            |
| Zones       | 57           | 2 %            |
| Humidification | 0          | 0 %            |
| Cooling     | 814          | 34 %           |
| AHU         | 168          | 7 %            |
| Heat Rejection | 93        | 4 %            |
| Zones       | 553          | 23 %           |
| Fans        | 233          | 10 %           |
| AHU         | 78           | 3 %            |
| Zones       | 155          | 6 %            |
| Interior    | 957          | 40 %           |
| Lighting    | 638          | 26 %           |
| Equipment   | 319          | 13 %           |
| Pumps       | 359          | 15 %           |

Figure 7. Annual Energy Use of Alderon

4.3. GRC wall material
Sefaira analysis results obtained EUI value of 83 kWh / m² / yr and total energy in the design of a house with GRC walls is 2,230 kWh / year where the largest energy use is in the interior segment, the use of lights reaches 29% of total use.

| Segment     | kWh per year | % of total use |
|-------------|--------------|----------------|
| Heating     | 36           | 2 %            |
| AHU         | 0            | 0 %            |
| Zones       | 36           | 2 %            |
| Humidification | 0          | 0 %            |
| Cooling     | 714          | 32 %           |
| AHU         | 167          | 7 %            |
| Heat Rejection | 81        | 4 %            |
| Zones       | 466          | 21 %           |
| Fans        | 209          | 9 %            |
| AHU         | 78           | 3 %            |
| Zones       | 131          | 6 %            |
| Interior    | 957          | 43 %           |
| Lighting    | 638          | 29 %           |
| Equipment   | 319          | 14 %           |
| Pumps       | 314          | 14 %           |

Figure 8. Annual Energy Use of GRC wall

4.4. Metal deck wall material
Sefaira analysis results obtained EUI value of 89 kWh / m² / yr, and total energy in the design of a house with metal deck walls is 2,408 kWh / year where the largest energy use is in the interior segment, the use of lights reaches 26% of total use.

From the comparison of the diagrams shown in Figures 6 - 9, the results are that none of the material samples reached the 2030 Challenge target. However, from the four material samples, the Hebel wall had the smallest EUI value, which was 58 kWh / m² / yr (Table 2).

![Total Energy](image)

**Figure 9.** Annual Energy Use of metal deck

**Table 2.** Sefaira analysis results on the four samples of residential wall material.

| Wall Material | Energy Use Intensity (EUI) | Annual energy use |
|---------------|----------------------------|-------------------|
| Hebel         | 58 kWh / m² / yr           | 1,564 kWh/yr      |
| Alderon       | 90 kWh / m² / yr           | 2,420 kWh/yr      |
| GRC           | 83 kWh / m² / yr           | 2,230 kWh/yr      |
| Metal deck    | 89 kWh / m² / yr           | 2,408 kWh/yr      |

Energy consumption in dwellings contributes significantly to their total negative environmental impact [16]. Thus, as a result, it is evident that according to the energy simulations, there is high-energy consumption in residential buildings in all material samples, with the biggest issue causing a high demand for energy is the high level of electricity consumption for lighting and cooling. Therefore it is necessary to design a building form that can reduce energy use. Among other energy conservation measures, a lack of optimal architectural design and construction materials has been the cause of this high energy demand in residential buildings [17]. Has earlier specified that, as an example, 33–60% of energy can be saved by using efficiently designed external walls [18][10].

5. Conclusion
The energy consumption of a residential building case study lightweight steel frame is located in Indonesia with hot-humid climatic conditions. One-floor houses of 27m$^2$ area have been investigated by examining data from energy simulations conducted using the SefaIra energy analysis software. The energy efficiency measure for the building envelope design considered in this study was wall insulation associated with four types of prefab modular exterior walls materials, which is (1) Hebel, (2) Alderon, (3) Glassfiber Reinforced Cement Board (GRC), and (4) Metal deck.

The results of the study are EUI of Alderon wall material is 90 kWh / m2 / yr that the most energy use intensity. So the authors suggest the use of Hebel wall material to be applied to homes, although none of the EUI wall material samples reached the energy use intensity 2030 Challenge target, however the need for some design changes could have a significant impact on the energy performance of residential buildings.

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