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Energy Optimization on Preliminary Design of The Botani Museum using Sefaira®

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Abstract: The preliminary design of an architectural building is an essential stage to define its building performance. Not only the architectural visual and beauty, but the design process also plays an important role to obtain energy optimization. The decision of building shape, orientation as well as its material gives influence on the heating and cooling system, also controlling the lighting. It located in the tropical climate region giving the consequences on a more prolonged period of solar radiation. It provides the implications for cooling system sizing such as electric load shape, electrical demand, and it affects the using of energy. This study aims to describe and deliver the design process of the Botani Museum that use Sefaira®. Sefaira System is a software used to model to estimate its overall energy use, and determine its strengths and weaknesses in energy retention and conservation on Botani Museum. The HVAC (Heating, Ventilation, and Air Conditioning) then are common in dominating building energy use. Thus, the design responds to have optimum impact on HVAC system. The results of Sefaira simulation shows that the preliminary design of the Botani Museum is having energy unit intensity (EUI) as much as 82kWh/m2/yr.

Meanwhile, the 2030 challenge of Sefaira shows the EUI is 79 kWh/m2/yr. It means that the proper design process will deliver the optimum result. The building envelope, orientation, as well as wall window ratio, are some of the architectural elements that significantly impact on energy use.

Index Terms: Architectural design process, Energy Optimization, Sefaira ®, Tropical climate region

I. INTRODUCTION

Energy consumption of a building has an impact on the environment. This is due to human activities in it. Therefore, it is in line with the records of the International Energy Agency building and building sector, which is the sector with the greatest energy consumption. And Indonesia is one of the 23 countries with the highest energy consumption in the world (American Council for An Energy-Efficient Economy). Mostly energy needs for heating and cooling which requires 40% and lighting 35% of the total energy (1),(2).

A technology is needed to reduce building energy use, either by reducing use so that energy supply is low, or through processing technology in building facade designs. The technology of building facade design has been widely used and many types, one of which is the technology of the double skin façade design.

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This study discusses energy optimization by considering the technology of the double skin facade design of museum buildings. This study was aided by Sefaira System software with HVAC considerations, which was calculated based on ASHRAE 90.1 - 2013 standards (3). Before the building was tested with Sefaira System, the building was tested with plug in Sketch Up Sunhour for sun exposure period. The double skin façade design technology can reduce energy use because it is proven by using this technology, there is 32% reduced energy consumption

II. LITERATURE REVIEW

The Green Building Council Indonesia (GBCI) discusses the greenship assessment tool for new buildings version 1.2 regarding several criteria and the number of points on how the building can be considered sustainable (4). One of the benchmarks is the aspect of Energy Efficiency and Conservation (EEC) with a percentage of 25.7% (2,5). As for the aspects of assessment are the installation of Sub-Meters, OTTV calculations, energy saving measures, natural lighting, ventilation, the effect of change climate, renewable energy on the site. Some of these points are in line with the discussion of paper and benchmark paper namely HVAC System to find future energy optimization solutions.

The process of energy saving in buildings is closely related to building envelopes, therefore the focus of this discussion study is building facades. Because the facade of the building is directly adjacent to solar radiation. Figure 1 shows some examples of building facades that can be used as precedent studies for building facades:

Figure 1. Building Façades Design of Nanjing Hongfeng Technology Park

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Source: Arch Daily
https://www.archdaily.com/775426/nanjing-hongfeng-technology-park-building-a1-one-design

This paper is assisted by the Sketchup software plug-in, Sefaira System. Sefaira System is a software that functions to analyze the level of energy efficiency in a building (6). Some buildings have used this device to test buildings. This software is indeed able to analyze complex and large buildings, also can provide guidance and advice on how our buildings should be designed. And the results of the analysis provided can be important information about how optimal the building we are making. The use of Sefaira on energy performance has been used since this software launched, especially in sketch up plugin (7), (8). The use of Sefaira on design for building refurbishment Politecnico di Milano to find the energy efficiency (9). The result of energy use from Sefaira are comparable to actual building, meanwhile Vasari/GBS are much higher than the actual (10).

Later, the site is located in the tropical climate region, which is facing solar radiation more than 10hours since its low latitude. The HVAC system in this area mostly to deal with high index thermal comfort correlated with the high temperature and high humidity. Thus, building orientation then, having significant influence to play the role on energy saving. The parallel plot with N-S orientation found the most beneficial orientation (11)

III. DESIGN REVIEW

This paper will produce a facade solution that can optimize energy, with the flow of discussion of problems that exist in the design of a museum, and also the design standards of the museum, then carried out an analysis so that it will get results that are the environmental energy optimization solutions. The design process will be conducted as seen at figure 2.

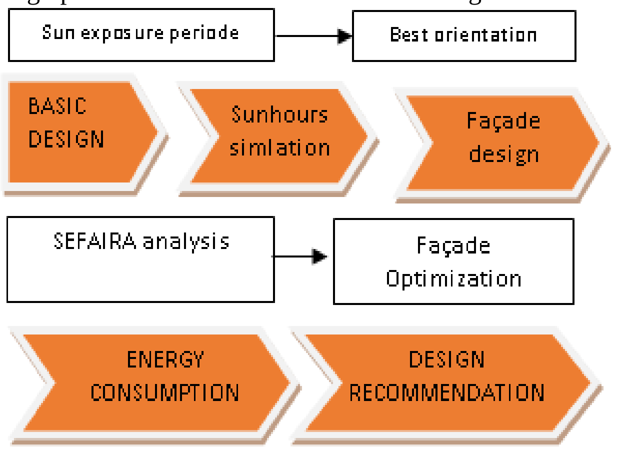

Figure 2. Design Process

A. Geographical Location

The botanical museum to be designed, is located on Jl. Jakarta, Kiaracondong District, Bandung City, West Java. Geographically located at 6.93º S 107.64º E and 6.8 m from sea level. The total area is 9,146 m², with a built-in area of 5,024 m².

This area is remained as hot and humid climate region. The average annual temperature is 26.8°C. The highest temperature is recorded in October with 34.1°C, meanwhile the lowest temperature occurred in July with 19.6°C. The average annual rainfall is 2120 mm with August is the driest and January is the wettest season (12)

B. Site Review

The site area consists of one mass of 2-storey buildings, one forest park, surrounded by a pavement area with a central part of a forest building. The site plan is described at figure 3.

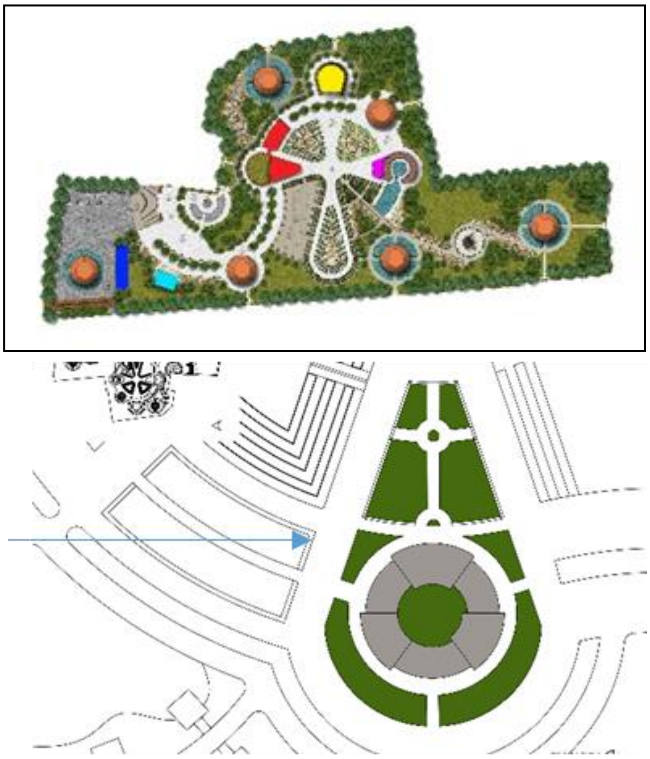

Figure 3. Site Plan

IV. SETTING AND ANALYSIS

A. Climate Analysis – Solar Radiation

The longest sun exposure is on the east side of the building, this can be seen when tested using plug in sketch up, namely *sunhour*.

Figure 4a. North Orientation

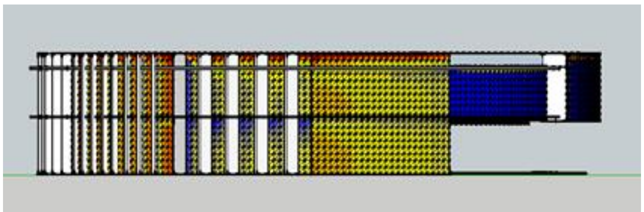

Figure 4b. South Orientation

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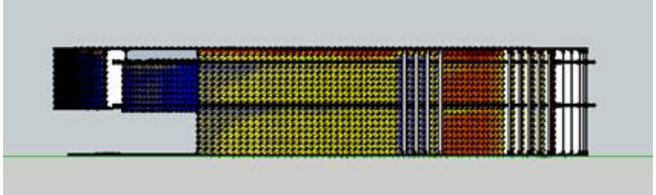

Figure 4c. West Orientation

Figure 4d. East Orientation

Figure 4a shows the north orientation facing the solar radiation longer than any other orientation. South orientation at figure 4b with the strip façade helps to reduce solar radiation. Figure 4c describes that west orientation also facing solar radiation more than nine hours. Meanwhile figure 4d which shows east orientation is having the lowest solar radiation duration that is only 2-4 hours. This, the façade design recommendation is to obtain a minimize heat exposure originating from the north, then on the north orientation be given a double skin facade in the form of aluminum iron coated with wood texture.

B. Wind Velocity

The average wind speed in the area is 7km / h with the largest wind direction being from the north of the building. The building's response to wind is to provide open space in the middle of the building. Providing open space in the middle of the building serves to eliminate turbulence in the building.

C. Sefaira® System

Sefaira is a web-based performance analysis platform specifically built for conceptual design. The software is useful for designing sustainable buildings and optimising their energy efficiency and carbon footprint. Sefaira also provides education program that empowering students to integrate Performance-Based Design into their design process. Sefaira® accessible at https://sefaira.com/ and build using Sketch-Up. The energy analysis of Sefaira include annual energy performance, annual CO2 production and the annual heating and cooling loads. It uses ASHRAE 90.1-2013 Standard to analysis building envelope with detailed openings and complete cover layers. The building envelope then is divided into parts of each building i.e. roof, wall, and window as seen at figure 5. The setting for building envelope includes insulation, glazing, daylight, heat gain, infiltration, ventilation, equipment and lighting. The building typology uses "school" or classified as an educational building and located in Bandung, Indonesia. Those setting are shown at figure 6 and table 1.

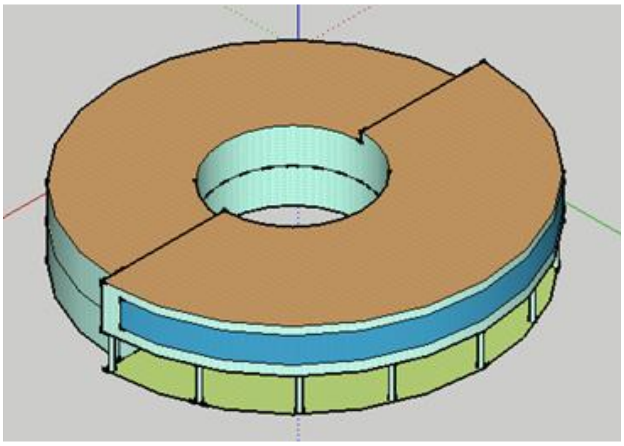

Figure 5. Building Envelope

Figure 6. Sefaira Setting system

Table 1. Building element properties information

No	Criteria	Value
1	Wall Insulation	0,9 w/m^2-k
2	Floor Insulation	0,61 w/m^2-k
3	Roof Insulation	0,22 w/m^2-k
4	Glazing U Factor	2,27 w/m^2-k
5	Visible Light	0,42
6	Solar Heat Gain	0,25 SHGC
7	Infiltration	7,2 m^3/m^2h
8	Ventilation	l/s-Person
9	Equipment	10 w/m^2
10	Lighting	15 w/m^2

V. RESULT AND DISCUSSION

Sefaira, in this study focused on energy performance based on the building envelope and specified with their properties. The simulation then resulting an information for gains or losses for each building element. Bandung, as located in tropical climate, the heat gain significantly impact on the cooling load. The EUI (Energy Use Intensity) shows the annual site energy use per square meter of the building. The measurement of EUI is used as a contextual benchmark that can be compared with similar building typology and region. It is stated on Sefaira's 2030 Challenge EUI which derived from similar climate zone's project.

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The energy performance for this building is shown at table 2.

Table 2. Simulation result

No	Criteria	Gains	Losses
1	Wall Conduction	8.052	11.893
2	Roof Conduction	5.308	6.354
3	Infiltration	1.240	4.409
4	Floor Conduction	-	4.017
5	North Solar	2.423	-
6	East Solar	1.382	-
7	Glazing Conduction	-	823
8	West Solar	1.002	-
9	South Solar	153	-

The simulation results show the energy use intensity (EUI) of museum building reach 82kWh/m²/yr. Meanwhile the EUI for 2030 challenge targets as much as 79 kWh/m²/yr that shown at figure 6.

It means that the Botani Museum building still need to optimize its design to achieve the energy challenge.

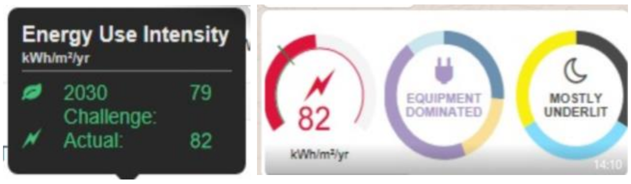

Figure 6. Sefaira for EUI results

A. Design Strategies

The design recommendation then need to elaborate with several strategies to reduce the energy consumption:

a. Reduce Cooling Loads
- Form Efficient Cooling
- Climate responsive Building Facades
- Passive Light and Cooling : Shading Device
- Passive Light and Heat : Solar Shading
- Passive Light and Heat : East/West Shading
- Controls for Daylighting : Light Shelves
- Envelope Optimization : Glazing SHGC
- Passive Cooling : Double Roof
- Envelope Optimization : Infiltration Rates

b. Manage Equipment Loads
- Managing Internal Loads : Efficient Equipment

c. Manage Lighting
- Form for Daylighting
- Fenestration for Daylighting: Single Side, Top, Multi Sided

d. Reduce Heating Loads
- Form for efficient Heating
- Climate responsive building facades
- Managing solar Heat Gain
- Envelope Optimizations: High Insulation, Glazing U Factor, Infiltration Rates

B. Design Synthesis

Building façade found as the significant element since it is directly facing the solar radiation. The heat gain toward the material of façade can be reduced using the solar shading device as seen at figure 7. Figure 8 until 12 illustrates the design synthesis from the basic building envelope and then optimized using the Sefaira analysis.

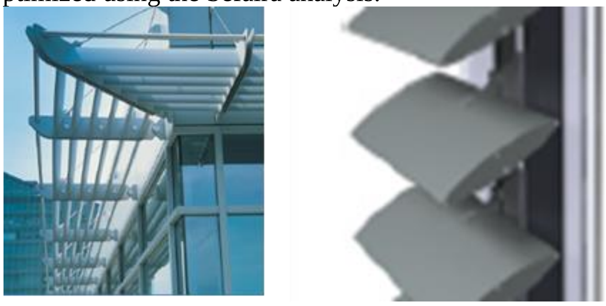

Figure 7. Solar shading device

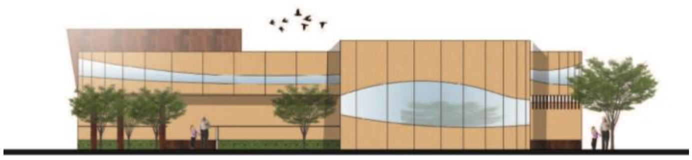

Figure 8. West Orientation

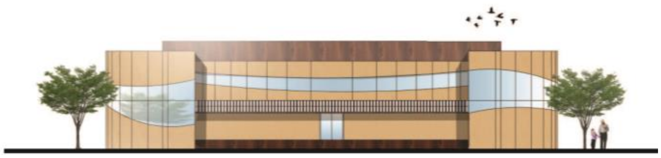

Figure 9. South Orientation

Figure 10. East Orientation

Figure 11. North Orientation

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Figure 12. 3D model

VI. CONCLUSION

Building envelope plays the significant aspect both on visual attraction and energy performance. As located in the tropical climate zone, with the long duration of solar radiation, the heat gain is the most important issue in the architectural design. The design phase by consideration on building orientation, opening (window wall ratio) and the shape of building masses proved to be able to contribute to the energy efficiency. The properties of building element, especially wall as a main façade needs to consider its conductivity. The design of Botani Museum gives the synthesis to minimize opening on east and west orientation since the solar gain are higher. The north orientation uses solar shading device since this gains the highest solar radiation.

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