Optimization of Green Building-Based Facade Design Using Value Engineering Methods in The Construction of Hospital Buildings

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ABSTRACT

Sustainable construction is a way for the construction industry to achieve sustainable development by considering social, economic, environmental and cultural issues. Generally, in every commercial building, the largest energy consuming equipment is air conditioning equipment, including hospital buildings, which is influenced by the design concept of the building facade surface. so this research was created to optimize green building-based building facade designs through heat transfer values on building wall facades or Overall Thermal Transfer Value (OTTV) which refers to SNI 6389:2011 concerning Energy Conservation of Building Envelopes using value engineering methods. The results show that the use of 310 Wp Solar Panels, blue green Stopsol Glass, Aluminum Composite Panels (ACP), Mortar Plaster Walls, Wheatershield Paint and is better at reducing heat with the lowest OTTV value of 34.16 Wh/m2 and provides optimal electricity cost savings of 18% at the end of the material life cycle.

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1. INTRODUCTION

Infrastructure development is part of national development which can be a driver of economic growth, both locally, regionally and nationally. The success of this development is one of the key factors in activating the economy which can improve people's welfare, as well as playing a role in realizing sustainable development. Sustainable construction is a way for the construction industry to achieve sustainable development by considering social, economic, environmental and cultural issues [6]. The construction sector has become one of the main indicators of national economic growth, it is inevitable that sustainable construction is urgently needed to be implemented, including in hospital buildings. In every commercial building, in general, the largest energy consuming equipment is air conditioning equipment. Also in hospital buildings, where the largest energy consuming equipment is air conditioning equipment and is in third place among other commercial buildings, namely 63.9%, lights and sockets 27%, lifts and escalators 4.9%, etc. another 4.2% [4].
Material selection, it is necessary to consider the use of a glass frame material combination system and study the application of which materials will produce better environmental performance and

contribution [3]. In buildings with large glass surfaces, heat gain from glass windows and walls becomes the main part of the cooling load. This represents a huge energy savings opportunity through a carefully and appropriately designed building envelope to reduce air cooling loads [10].

The area of glass in high rise building that absorbs solar radiation energy has the potential to produce electrical energy and is efficient in electricity costs. From the application of energy use in buildings which is adjusted to the direction of the building facade, shadows, the type of panels used and the intensity of the weather, the use of semi-transparent type solar panels as a replacement for windows has a Performance Ratio (PR) of 85% and this system can be said to be feasible. technical to install [11]. The application of value engineering in developing sustainable and more energy conscious building concepts with solar panels can be applied. The methods used to support value engineering analysis on building facades can be carried out with OTTV analysis, electrical energy consumption analysis, LCCA analysis [1].

Energy waste in a building's air conditioning system can be minimized by reducing external heat entering through the building envelope. Opportunities for saving energy in the building envelope can be achieved by reducing OTTV [7]. The purpose of this research is to determine the most optimal design for changing the facade of a hospital building in reducing external heat entering through the building envelope by reducing OTTV using a value engineering method that has never been carried out by other research before.

2. METHODS

The research method in this scientific article uses case study analysis with 2 methods, namely value engineering analysis which aims to obtain the most efficient type of facade material in terms of function and initial cost. After the value engineering analysis, a Life Cycle Cost (LCC) analysis is then carried out. The flow of the research method can be seen in Figure 1.

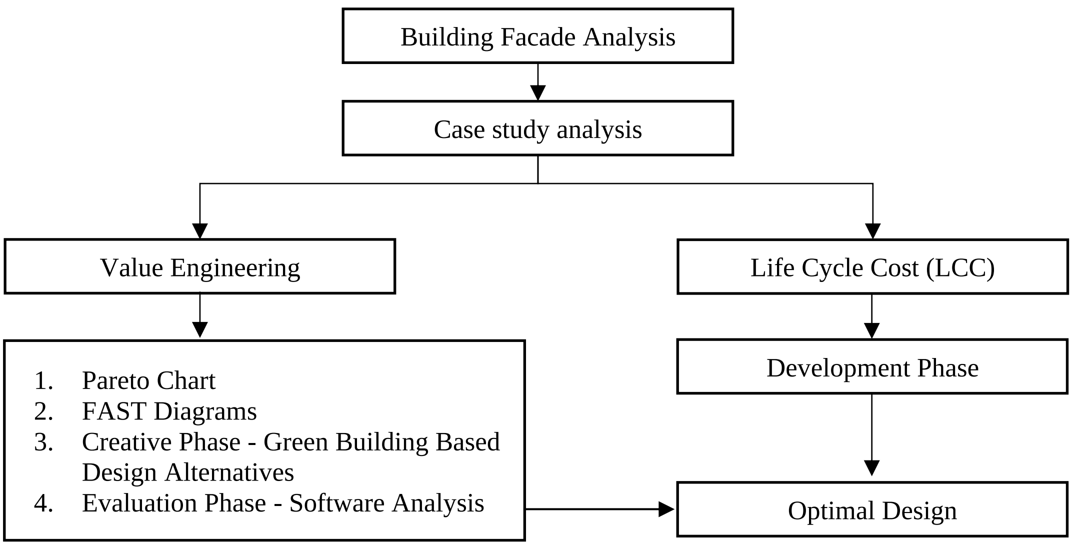

Figure 1. Research Method

2.1 Value Engineering Process

Sequentially, the stages of value engineering include the information stage, function analysis stage, creative stage, evaluation stage and development stage [14]. Using the value engineering method with the first stage in the form of data processing. The following is the Cost Model Breakdown of the initial budget plan in Table 1.

Table 1. Initial Cost of Facade Work for Floors 4 to 7

Work item	Cost (Rp)
Aluminum composite panel (ACP) 5 mm thick alloy	1.208.129.856
8 mm blue green tempered glass	387.260.228
Light Brick Walls, Mortar plaster	297.544.598
Light Brick Wall + Plaster behind ACP	212.765.557
Topping ACP t500 (1330x500x 1150), elevation +13,260, parapet	142.953.077
Aluminum louvre	85.490.079
Painting the exterior with weathershield paint	42.488.306
Topping ACP t500 (1330x400x 1150), elevation +29,580, parapet	38.312.085
ACP window frame t=250 (700 x 250 x700)	30.675.500
Amount	**2.445.619.286**

Analysis of facade work functions at this stage is identified by determining primary, secondary and supporting functions which are depicted in the FAST diagram, once the function of the building is determined, costs are allocated to each function. Target cost (worth) is a value engineering estimate of the costs required to carry out a special function/specification [5].

At the creative stage, discussions were held with experts who were used to designing similar buildings and several experts who were used to building similar buildings to discuss the design concept [15]. So we get 2 alternatives used in value engineering as in Figure 3 and Figure 4. The evaluation stage of the green building concept on the facade with OTTV (Overall thermal transfer value), is energy conservation in buildings which regulates the heat transfer value on the building wall facade. In this case the value cannot exceed 35 watts/m² (SNI 6389:2011).

Next, the development stage involves an LCC (Life Cycle Cost) analysis for 25 years which aims to see whether the chosen alternative can increase value in the future. The use of several alternative materials capable of producing clean and sustainable energy designed for greenhouses in buildings contributes to their operational life cycle [13].

2.2 Simulation Analysis Tools

The value engineering analysis is supported by Autodesk Ecotect Analysis Simulation to determine the effect of room thermal comfort performance on building envelope materials through the output of OTTV values based on climate, shape, direction and building materials [18]. To get the electrical energy produced, use the PVSyst Analysis simulation, which is software used to analyze solar panel systems (Kumar, et al., 2021).

3. RESULTS AND DISCUSSION

3.1 Information and Function Analysis

According to Pareto's law of distribution (Pareto’s Law Distribution-Vilfedro Pareto, 1848-1923 Italian Political Economist and Engineer) 20% of the important part of an item or system will represent 80% of the cost of determining research targets. The Pareto graph against initial costs is shown in Figure 2.

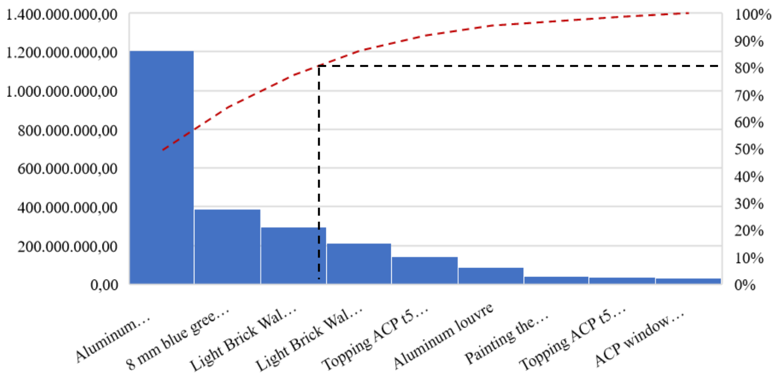

Figure 2. Pareto Diagram

From Figure 2 it is known that 80% of the costs are represented by aluminum composite panels (ACP), blue green tempered glass, and light brick walls, plaster and mortar. Analysis of facade work functions at this stage is identified by determining primary, secondary and supporting functions which are depicted in the FAST diagram which can be seen in Figure 3.

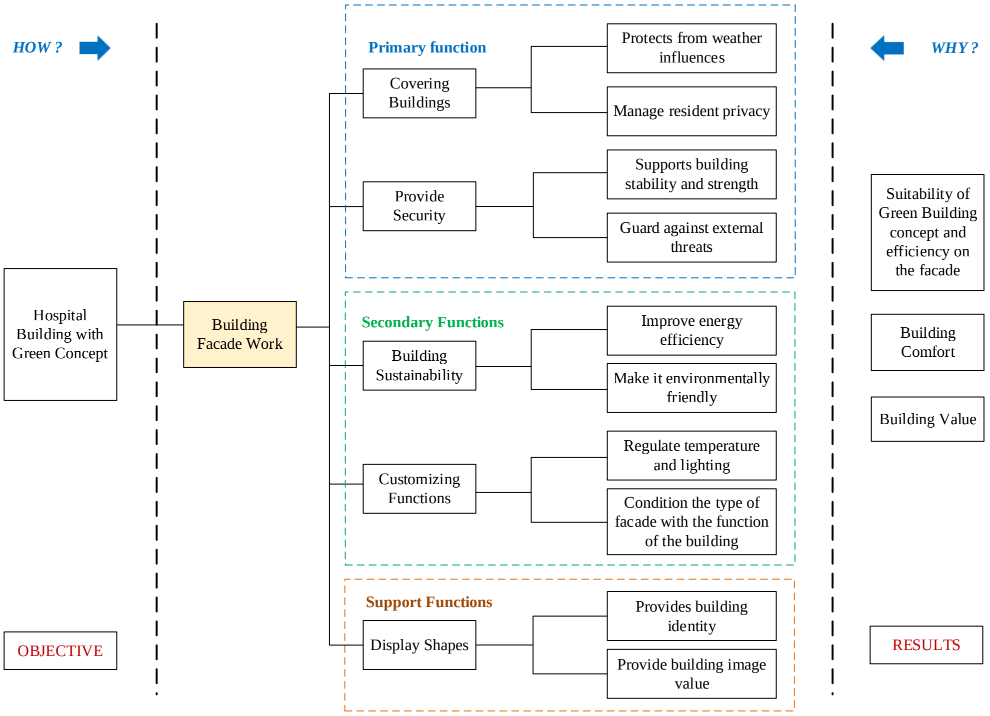

Figure 3. FAST Diagram

From the results of the functional analysis, it was found that two works had a C/W greater than two, in Table 2 the Facade work was ACP installation and in Table 3 the Curtain Wall job was Glass to Glass Work. This means that the work needs to be reviewed and continued at the next stage.

Table 2. Cost Worth Function Analysis of ACP Work

Description	Function		Type	Cost (Rp)	Worth (Rp)
	Verb	Noun			
ACP	Decorate	Building	S	950,213,666	-
Galvanized Iron Hollow	Support	Construction	B	259,868,184	259,868,184
Aluminum Sealant/Glue	Support	Construction	S	56,493,084	-
Accessories (screws, bolts, clamps)	Support	Construction	S	97,620,048	97,620,048
Angle Iron, Spigot, Stiffener (Bracket)	Support	Construction	B	135,583,401	135,583,401
	Total			1,499,778,383	493,071,633
	C/W			3.041704861	

Table 3. Cost Worth Function Analysis of Glass Work

Description	Function		Type	Cost (Rp)	Worth (Rp)
	Verb	Noun			
Blue Green Tempered Glass	Decorate	Building	S	245,007,429	-
Aluminum Profile Frame	Support	Construction	B	99,190,887	99,190,887
Accessories (screws, bolts, clamps)	Support	Construction	B	35,637,444	35,637,444
*Sealant*glass	Support	Construction	S	7,424,468	-
	Total			387.260.228	134,828,331
	C/W			2.872246694	

3.2 Creative and Evaluation Stage

Figure 4 shows the initial condition of the facade design with a window to wall ratio of 40.6% and produces an OTTV value of 50.07 W/m2, greater than the SNI 6389:2011 standard, namely 35 W/m2. This condition creates the potential for air cooling in all areas of the building, resulting in large electrical energy consumption. So, through functional analysis of the facade, alternative materials are used to reduce electrical energy consumption.

Through FAST Diagram analysis in Figure 3. Two alternative designs are used, alternative design 1 with the use of materials (310 Wp Solar Panel, Blue Green Stopsol Glass (window), ACP, Acian Plaster Wall, Wheatershield Paint) can be seen in Figure 5. And in Figure 6 as an alternative design 2 with the use of materials (ACP (Full Facade), blue green Stopsol Glass (Windows), Acian Wall Plaster, Wheatershield Paint).

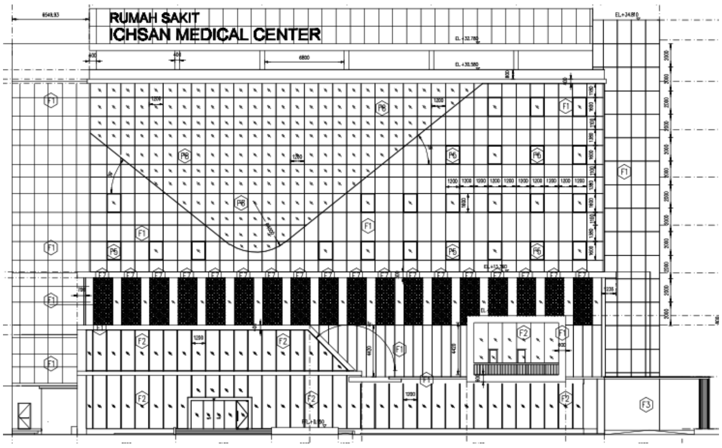

Figure 4. Initial Condition of the Facade Design

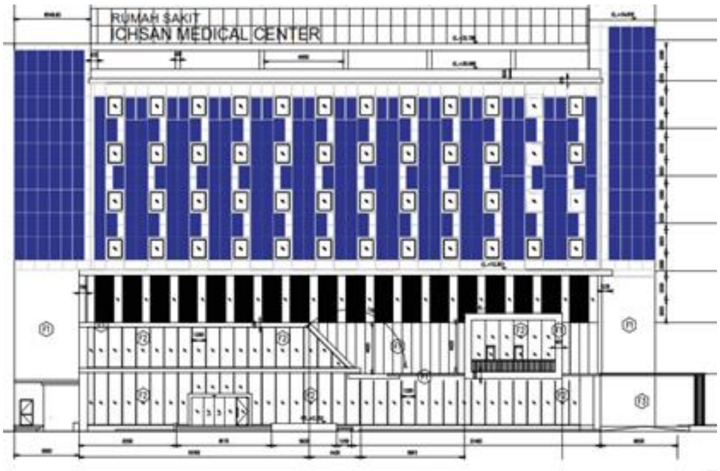

Figure 5. Alternative facade design 1

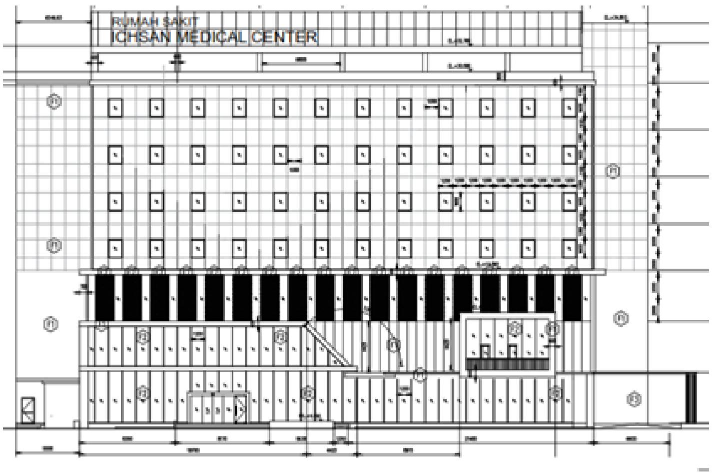

Figure 6. Alternative facade design 2

At the creative stage, this cost-benefit analysis produces a ranking of alternatives that is used in value engineering to assess material applicability [5]. Table 4 alternative 1 shows a weight value of 45 and Table 5 alternative 2 shows a weight value of 42.5.

Table 4. Profit and Loss Analysis for alternative 1

Profit and Loss Analysis Stage			
Items: Solar panel facade work **Alternative (1)**: Facade uses Polycrystallin solar panels ± 2x1 m, 315Wp, 72-Cell, combined with curtainwall frame and ACP			
Criteria	**Profit**	**Loss**	**Weight**
Cost	Polycrystallin solar panel material (quite cheap)	-	7.5
Aesthetics	Gives the impression of a sustainable green hospital (Simply Beautiful)	Locked with the color of the panel display, but with the combination of ACP it will cover the shortcomings	7.5
Implementation	Frame and mounting systems are quite common skills and tools.	Solar Panel work specialist. (Quite difficult)	5
Durability	Has a durability of up to 25 years	There is a decrease in efficiency of 0.5% every year	7.5
Maintenance	Solar panel maintenance is generally not too difficult. Currently there is a monitoring system using Android media/Apps. (Quite easy)	-	7.5
Efficiency	Solar panel efficiency can reach 16.21%	-	10
Total			45

Table 5. Profit and Loss Analysis for alternative 2

Profit and Loss Analysis Stage			
Items: ACP and light brick facade work **Alternative (2)**: The facade uses Aluminum Compsite Panel material and is reinforced with an aluminum frame with the addition of a massive light brick wall.			
Criteria	**Profit**	**Loss**	**Weight**
Cost	ACP materials and lightweight bricks installed are not too expensive. (Cheap enough)	-	7.5
Aesthetics	Depends on facade theme and color (Quite Beautiful)	-	7.5
Implementation	ACP frame systems and fabrication are quite common skills and tools. (Quite easy)	-	7.5
Durability	Has quite high resistance to weather. (Durable)	-	7.5
Maintenance	Need to maintain color quality and cleaning. (Quite easy)	The cost of re-coloring is quite expensive	7.5
Efficiency	ACP and lightweight bricks contribute to air conditioning efficiency (Not Good)	Cannot produce alternative energy	5
Total			42.5

The OTTV value analysis was carried out by simulation using Autodesk Ecotect software using the Solar Access Analysis Absorbed/Transmitted Solar Radiation analysis type because it will simulate the envelope heat load with the specified period average hourly value [12]. Figure 7 shows the analysis output of all facade directions adjusted to the Object in Module on all facade walls. Then you can find out the Avg value. Radiation Transmitted Every Hour 34.16 W/m2.

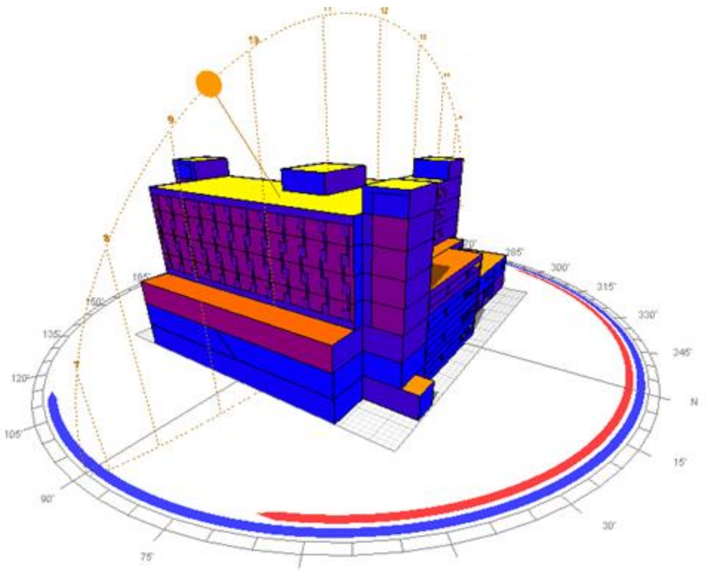

Figure 7. Avrg. Hourly Absorted Radiation Alternatif 1

In Figure 8, the simulation results with Avg values. Radiation Transmitted Every Hour 39.48 W/m2. The resulting value is greater than SNI 6389-2011 of 35 watts/m2 so it does not meet SNI standards.

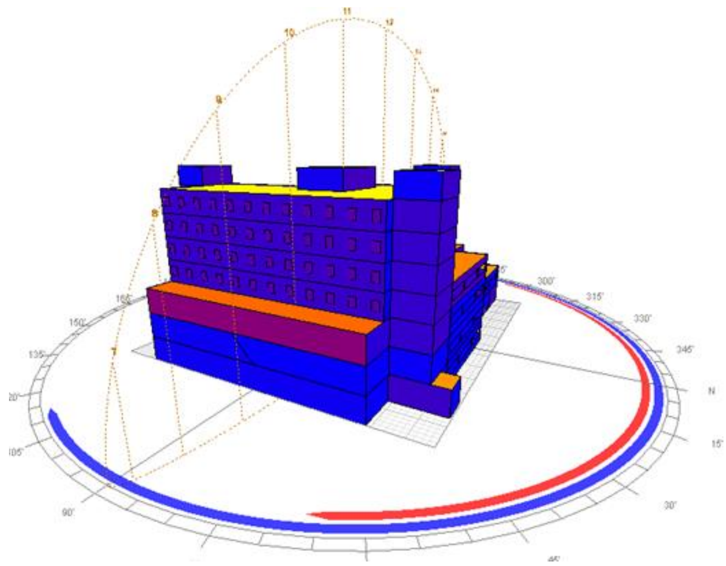

Figure 8. Avrg. Hourly Absorted Radiation Alternatif 2

The simulation results in alternative 1 shown in Figure 9 are based on the input of using a 310Wp Polycrystallin solar panel and which is located in South Jakarta, Indonesia with a grid connection system from PVSyst software. The nominal power output for a 596 m2 solar panel is 96.4 kWp or 96,400 Wp with an annual Performance Ratio (PR) of 77.9% and an annual power of 47,062 kWh. The system can be said to be technically feasible if the PR ranges from 70% – 90% [11].

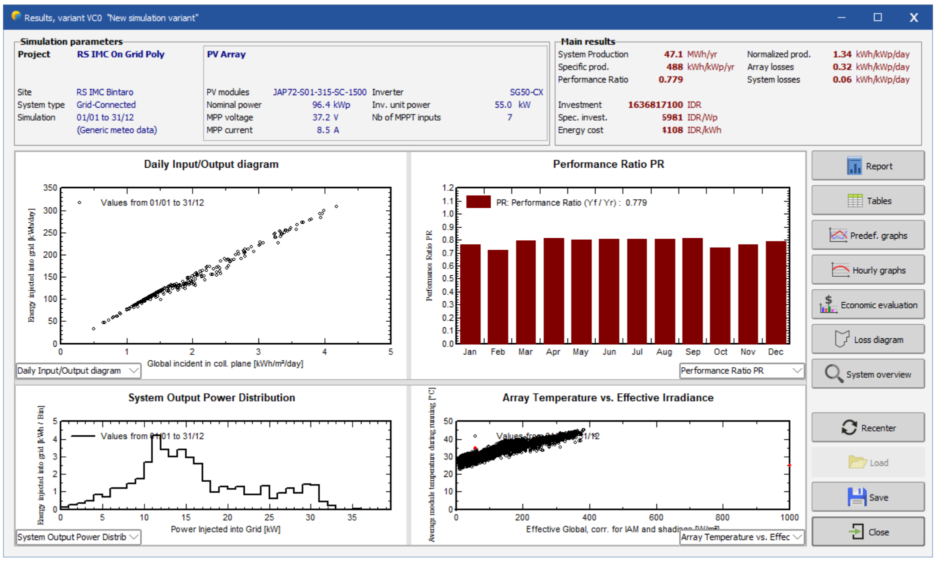

Figure 9. Analysis Result PVSyst

3.3 Development Stage

The use of several alternative materials capable of producing clean and sustainable energy designed for greenhouses in buildings contributes to their operational life cycle [13]. The large percentage reduction in OTTV value has the potential to provide efficiency in reducing cooling loads [2]. In alternative 1, from the potential savings obtained through reducing the OTTV value at 34,16 W/m2 and based on the initial monthly electricity costs of Rp. 256,836,096 where in hospital buildings the equipment that uses the greatest energy is air conditioning equipment at 63.9% [4]. So the design change in monthly electricity costs compared to the initial electricity costs has an efficiency of 13%.

Coupled with the effect of adding solar panels which contribute to the electrical efficiency of the Hospital building. Electricity costs are based on PLN Medium Voltage Class S-3 (S-3/TM) electricity tariffs with power above 220 KVA for hospitals whose price at peak load is IDR. 1,114.74 per kWh. After using solar panels, the efficiency of 20.16% can be seen in Table 6.

Table 6. Electric power with PLN and Solar Panels

Work item	Power (Rp/Watt)	Power paid (Rp/month)
Without solar panel facade (Normal Rate, 1kva = 0.8 kWatt)	250.6 kVa 200.5 kWatts	223,507,910
Solar panel facade installation 298 polycristalline panel modules 96.4 kWp = 488 kWh/kWp/Years or 40.67 kWh/kWp/Month	50.52 kVa 40,416 kWatts	45,053,332
After using solar panels, the efficiency is 20.16%	200.08 kVa 160.08 kWatts	**178,454,578**

Alternative 2 uses ACP (Full Facade) and blue green Stopsol glass (Windows). Based on a decrease in OTTV of 39.48 W/m2, the change in electricity costs decreased by a cost efficiency of 8.6%. Recapitulation of the Life Cycle Cost analysis results for alternative 1 and alternative 2 facade designs in Table 7.

Table 7. Life Cycle Cost Recapitulation

Fee Type	Information	Initial conditions	Alternative 1	Alternative 2
Initial Cost	Construction Costs	2,445,619,286	3,225,081,509	2,069,385,409
Replacement Cost	All materials are planned to be able to meet the project's economic needs for 25 years	-	-	-
Salvage Cost	All components provide no residual value at the end of the project	-	-	-
Operational	There are no operational costs for all design alternatives, because using digital monitoring systems from solar panel product	-	-	-
Maintenance Cost	25th year	624,636,293	803.952.385	716,739,885
OTTV (Overal Thermal Transfer Value)		50.07 W/m2	34,160 W/m2	39.48 W/m2
Electricity Consumption Cost Efficiency		0% or (not yet)	18 % or 13.877.908.188	8.6 % or 6.654.101.100
Total costs over 25 year life cycle		**-**	**9.848.874.294**	**3.867.975.806**

Table 7 shows a comparison of initial design conditions with implementation using 2 alternative materials. In the initial condition of the facade design, the OTTV value was 50.07 W/m2, this value clearly does not meet SNI standards and has no electrical efficiency benefits during the life cycle of the material used. Alternative 1 has an OTTV value of 34,160 W/m2, this value meets the building envelope energy conservation value standard of 35 W/m2 plus has an efficiency value over a 25 Year life cycle of Rp. 9,848,874,294 or 18%. In alternative 2, the OTTV value is obtained at 39.48 W/m2 which does not meet the standard but still has efficiency from the impact of decreasing the OTTV value of 8.6% or Rp. 3,867,975,806 over a 25 Year life cycle.

4. CONCLUSION

a. Based on SNI 6389:2011, it is 35 Watt/m2. By using Autodesk Ecotect Software the lowest OTTV value in Alternative 1 was obtained at 34.16 W/m2 with the use of materials (310 Wp Solar Panels, blue green Stopsol (Window) Glass, ACP, Acian Wall Plaster, Wheatershield Paint) and according to green building standards with energy conservation.
b. Life Cycle Cost Analysis uses value engineering on facade work to obtain the most optimal design obtained in alternative 1 because up to the end of the material life cycle of 25 years provides the highest potential electricity cost savings of IDR. 9,848,874,294 or Efficiency of 18%.

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