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Research paper

Value engineering and lifecycle cost analysis to improve cost performance in green hospital project

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Abstract: In green concept hospital work, several provisions must be obeyed so that all processes, including material selection, project implementation, and building operations, must refer to green principles. Green building planning and construction costs higher than conventional by 10–20%. By using the Value Engineering (VE) method and combined with the Lifecycle Cost Analysis (LCCA), the researcher applies the green hospital concept to a project which is a case study but is still cost-effective even lower than the original Bill of Quantity. To see the strong influence of effectiveness on the hospital project, the researcher distributed a questionnaire to stakeholders. The results of the questionnaire were processed and analyzed using the Statistics Products and Solution Services (SPSS) tool. VE is implemented after first creating a Function Analysis System Technique (FAST) diagram, before and after adding functions for certain work items. It turns out that the use of the VE and LCCA methods is very influential in improving cost performance. From the calculation of the VE method, the resulting costs are up to 2.62% of the initial cost and LCCA shows the payback period of the Solar Power Plant with time = 9.64 years ≈ 9 years 7 months. The novelty of this research is the selection materials and the green concept of working methods is still cost efficient and the installation of Photovoltaics (PV) on the roof of Hospital reaches a payback period which is feasible for new investment.

Keywords: green hospital, SPSS, FAST, value engineering, lifecycle cost analysis, cost performance

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1. Introduction

Referring to the United Nations Environment Program (UNEP, 2009), if Green technology is applied properly it can save energy by 30–80%. Further, the economic savings due to the reduction in energy consumption need to be considered. At this point, it is worth highlighting the value of interior and daylight in the hospital building, because, at present, it is one of the facilities with the best payback [1].

The architecture, engineering, and construction (AEC) industry is often criticized for its negative impact on the environment, including environmental pollution, waste of energy, and loss of biodiversity [2]. Construction and demolition waste (CDW) are one of the largest worldwide waste streams, therefore, it is given great attention by all stakeholders (investors, contractors, authorities, etc.) [3]. Construction materials and systems for the thermal building envelope have played a key role in the improvement of energy efficiency in buildings [4]. The construction sector is responsible for the use of natural resources and excessive amounts of energy consumption. It is reported that buildings constitute 36% of CO2 emissions [5]. Hospital buildings consume 73 billion kilowatt-hours ($kW \cdot h$) of electricity annually, contributing to the fact that buildings are responsible for almost 70% of the total electricity use in the United States (DOE 2014) [6].

As for current cost performance, it was concluded that green building projects were generally over budget (4.5%, 7%), which was worse than traditional building projects [7]. Therefore, there were other potential incentive models in green building implementation, such as the Floor-to-Area Ratio (FAR), tax reduction, and expediting the permit process [8].

As the importance of sustainable design continues to grow, it becomes increasingly vital to develop methodologies capable of aiding designers in assessing if a project is sustainable and cost-effective while still in successful parallel with the owner's goals [9].

With this research, it is hoped that the construction of a hospital can be made more adaptable to the mandatory requirements for the provisions of Green Hospital. Value engineering has been used as a methodology to provide added value and to enhance maximum result for project development in terms of improvement on quality, technology, and innovation [10].

LCCA is a technical and economic optimization method whose main goal is to identify and choose the solution that generates the highest income throughout its service life or, in other words, has the lowest lifecycle cost [11]. The lifecycle cost analysis using the IRR and NPV approach confirms The Sunda Strait Bridge (SSB) project with additional functions increases the Internal Rate of Return (IRR) for the whole project by 7.56% that would provide a positive Net Present Value (NPV) [12].

In this case, the researcher uses the assistance of the SPSS (Statistical Products and Solution Services) data analysis program. This analysis is used to measure the level of closeness of the relationship between all independent variables / X (independent) aspects of Lifecycle Cost Analysis (LCCA) and Value Engineering (VE) in the Green Hospital (GH) Project to the dependent variable / Y (dependent) Increased Cost Performance.

2. SPSS data analysis (Statistical Products and Solution Services)

There are many software solutions to this issue but one of the most famous is spss [13]. the data analysis process will use a simulation tool, namely spss ver. 21 (statistical products and solution services) accompanied by interviews and questionnaires, will be found the dominant things from several variables and their sub-factors that affect the cost performance that the author wants to examine. these stakeholders should represent the population in the building industry and consist of academics, consultants, contractors, developers, and officials in government institutions [14].

2.1. Linear regression analysis

The output from the regression will include, among others, a table providing the mean, standard deviation and number of repeated measures for all variables in the model (Descriptive Statistics), the correlations among all variables (Correlations) and the regression coefficients with the respective 95% confidence intervals (Coefficients and Residual Statistics) [15].

2.1.1. Effect of variable X partially on Y (T-Test)

The regression model is one of the statistical models by which you can examine the strength and dependence between individual variables [16].

As a basis for making decisions from the T-test by comparing t_{count} with t_{table}:

- The variable X1 (Green Hospital) has a positive and significant effect on Y, this is illustrated by sig. (X1) $0.006 < 0.05$, coordinate value $t_{\text{table}} = t(a/2; nk - 1) = t(0.05/2; 69 - 3 - 1) = t(0.025; 65)$, see table that $t_{\text{table}} = 1.997$; $t_{\text{count}} = 2.869$, $t_{\text{value}} = 2.869 > 1.997$, then H_0 is rejected and H_1 is accepted.
- The variable X2 (Lifecycle Cost) has a positive and significant effect on Y, this is illustrated by sig. (X2) $0.032 < 0.05$, coordinate value $t_{\text{table}} = t(a/2; nk - 1) = t(0.05/2; 69 - 3 - 1) = t(0.025; 65)$, see table that $t_{\text{table}} = 1.997$; $t_{\text{count}} = 2.193$, $t_{\text{value}} = 2.193 > 1.997$, then H_0 is rejected and H_2 is accepted.

Table 1. T-test

Coefficients						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5,984	2,741		2,183	0.033
	Green Hospital	0.106	0.037	0.276	2,869	0.006
	Lifecycle Cost	0.112	0.051	0.232	2,193	0.032
	Value Engineering	0.141	0.035	0.435	4,018	0.000

Dependent Variable: Cost Perform

– The variable X3 (Value Engineering) has a positive and significant effect on Y, this is illustrated by sig. (X3) 0.000 $<$ 0.05, coordinate value $t_{\text{table}} = t(a/2; nk - 1) = t(0.05/2; 69 - 3 - 1) = t(0.025; 65)$, see table that $t_{\text{table}} = 1,997$; $t_{\text{count}} = 4.018$, $t_{\text{value}} = 4.018 > 1.997$, then H_0 is rejected and H_3 is accepted.

Plug the numeric coefficient from column B into the equation:

Y = 5.984 + 0.106X1 + 0.112X2 + 0.141X3

Y – explained variable, $\beta_0, \beta_1, \beta_2, \ldots, \beta_{k+1}$ – regression coefficients (structural parameters) of the equation model in the collection, $X_1, X_2, \ldots, X_{k+1}$ – explanatory variables or functions of explanatory variables, E – random factor [16].

2.1.2. The effect of variable X simultaneously on X (Test F)

Basis for decision making by comparing f table and f count:

– The variables X1, X2, X3 have a positive and significant effect on Y, this is illustrated by sig. (F) 0.000 $<$ 0.05

– Coordinate value $f_{\text{table}} = f(k; nk) = t(3; 69 - 3) = t(3; 66)$

Table 2. F-Test

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	71,527	3	23,842	18,098	.000b
	Residual	85,633	65	1,317		
	Total	157,159	68			

a. Dependent Variable: Cost Perform

b. Predictors: (Constant), Value Engineering, Green Hospital, Lifecycle Cost

See the table, that $f_{\text{table}} = 2.78$; $f_{\text{count}} = 18,098$

Value $f_{\text{count}} = 18.098 > 2.78$, then H_0 is rejected and H_a is accepted.

2.2. Mean and ranking

Project manager's 10 core competencies (necessary for their superior performance) comprise group capabilities, language proficiency, leveraging diversity, stress tolerance (management), flexibility, relationship building, leadership, maintaining order, achievement orientation, and understanding others [17].

Based on the ranking of research and questionnaires that have been conducted, that every cost planning, work methods and material specification must be checked again whether it meets the previous green concept, then the performance by a team led by a project manager who is competent in realizing the green concept.

Government policies such as tax free, permit relief, etc. Government regulations, such as not issuing permits if the building does not have a Green concept or is prohibited from standing, building regulations are not Green concept etc.

These are all coercion and the government's strategy so that everything goes towards building a Green concept, in order to ease the burden on the environment and make the quality of life better.

Table 3. Mean and rank table

Rank	No. Sort	Sub Factors	Mean	Sub Factors
1	2	X1_02	4.68	Competence of project manager
2	6	X1_06	4.67	Policies and regulations
3	14	X2_01	4.48	Initial Cost
4	17	X2_04	4.42	Operational and Maintenance Costs (OM Cost)
5	19	X2_06	4.39	Analysis Period (n)
6	22	X2_09	4.33	Modeling without residual value
7	24	X3_01	4.29	Selection of the right material alternative
8	28	X3_05	4.19	There is a multidisciplinary VE Team
9	32	X3_09	4.17	Input information and communication as well as possible
10	34	X3_11	4.16	Primary function

3. Research result

Applying this Green concept, the writer tries to validate the hypothesis to the hospital project as the object of research is the construction project of the Hospital, by applying the Green Hospital concept using the Value Engineering and Lifecycle Cost Analysis (LCCA) method to achieve cost performance. The building project should thus be considered in terms of its entire lifecycle. In this relation, the BLCC approach (Building Lifecycle Costs) plays an important role as it focuses on cost optimization throughout the entire lifecycle [18].

3.1. Value engineering

Value Engineering is an engineering technology theory, the basic idea is the minimum cost in exchange for the required function (Ren 2010) [19]. Value Engineering is conducted to produce innovative ideas that potentially could be integrated into the project by using the Function Analysis System Technique (FAST) diagram [20].

	Architecture	Structure	MEP Works	Etc Works	Preparation	Earthworks
Amount (Euro)	453 484	328 989	296 912	81 312	30 277	20 693
1.211.667						
Percentage (%)	37,4%	27,2%	24,5%	6,7%	2,5%	1,7%

Fig. 1. Highest to lowest percentage of costs with pareto

So that the FAST diagram will look like the image below, describing its function and looking for alternative substitutes (Fig. 2).

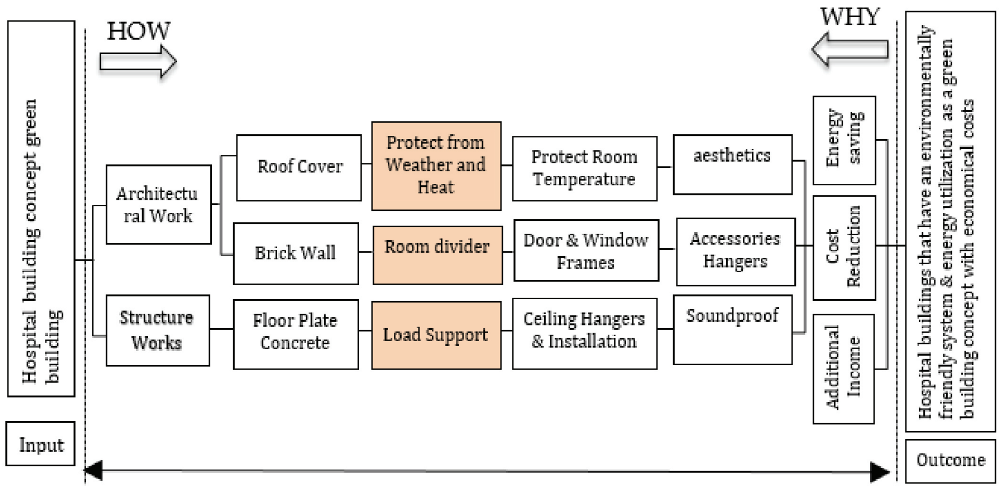


Fig. 2. Technical FAST diagram before additional function

The "how-why" logical model is used to identify, classify, develop and select functions that could create greater value and benefit to the project development [20].

From the FAST diagram, it is obtained several work items can be carried out by the VE process without reducing functions at a cheaper cost and environmentally friendly.

Table 4. Identification of roof cover finishing job functions

No.	Work item	Function Analysis
1	Glazing Roof Tile Covering Work	Protect from Weather and Heat
		Protect Room Temperature
		Aesthetics

Because the roof covering from glazing tile is heavy so that the frame requires a lot, so it is not by the principle of the green concept, namely saving material, it can be replaced without reducing all its functions, namely metal tile.

Table 5. Identification of brick wall pairs work functions

No.	Work item	Function Analysis
2	Pair of red brick walls with a thickness of 1 brick	Room divider
		Door & Window Frames
		Hangers Accessories

The basic material of red brick, because in the process it uses wood or husk as fuel, so it is necessary to find a substitute material that does not leave too much carbon footprint so that it is more environmentally friendly, namely light brick with a wall thickness of 1/2 (half) brick because the main function is still being achieved.

The location of the work is in the hospital area which is still operational, the operational costs of using conventional concrete cause noise, dust, and excess formwork to be replaced with an alternative floor deck material with one layer wire mesh M10 reinforcement.

Table 6. Identification of floor plate concrete work Functions

No.	Work item	Function Analysis
3	Second Floor Slab Concrete Work	Load Support
		Ceiling Hangers & Installation
		Soundproof

The Evaluation Phase is to purify all ideas for VE. The material selection ideas included in the Green concept are recapitulated and counted to be included in the Value Engineering requirements. All materials included in the drawing and BOQ are sorted and selected without exception, that all must be included in the environmentally friendly category. VE analysis results that can be directly felt by the Project.

Table 7. Recapitulation of value engineering function analysis

Component	Function			Cost	After VE
	Verb	Noun	Kind	(EUR)	(EUR)
Roof Cover	Protecting	Building	Primary	19,877.49	17,587.48
Brick Wall	Dividing	Room	Primary	68,186.91	54,112.83
Floor Plate Concrete	Supporting	Load	Primary	76,132.80	60,802.68
Total Amount				164,197.20	132,502.99
Total VE (Cost – After VE)					31,694.21
Project Total Amount				1,211,666.93	1,179,972.72
Savings Percentage Value Engineering Green					2,62%

3.2. Lifecycle cost analysis (LCCA)

The LCC calculation for all scenarios shows that the PBC application has potential in generating an LCC efficiency of 9.4% compared to the traditional contact ([21].

The main objective at first hierarchy level that was green hospital buildings that provided ecology, water-saving, energy-saving, waste reduction and healthy environmental for patient and staff [22].

In the case study work item section that the researcher carried out, Lifecycle Cost Analysis (LCCA), there are two items, which are included in the Green building requirements, namely the provision of photovoltaic (PV) solar panel energy and the destruction of B3 waste (Hazardous and Toxic Materials). Both are mandatory requirements for Green buildings, namely Save Energy and Waste Reduce, moreover, hospitals produce a lot of standard B3 and infectious waste that needs to be destroyed immediately.

Deterministic LCCA is the traditional methodology in which the user assigns each input variable (e.g., service life, analysis period, discount rate, timing and cost of maintenance activities) a fixed value usually based on historical data and user judgment [23].

In general, the LCC calculation steps are as follows:

- Lifecycle Cost Analysis
- Cost Breakdown Structure (CBS) – LCC Modelling Without Residual Value – Lifecycle Cost Analysis – Sensitivity Analysis – Efficiency [24].
- Green building is emphasized in the whole lifecycle of the building. It includes building materials production, planning, design, construction, operation and maintenance and removal, recycling scrap the whole process, all links can be an efficient use of building resources, land saving, energy-saving and water saving [25].
- Sustainable development principles in the built environment have encouraged researchers to focus on more efficient building envelopes [26].

They acknowledge the associated parties (project owner, project planners, designers, and contractors) in green building construction projects need to intensively plan which aspects should be closely regarded in the pre-project planning process [27].

LCCA has a unique opportunity to connect initial cost and ownership cost to optimize total cost. This will allow an owner/manager to make an informed decision about the facility [28].

3.2.1. The utilization of the roof sheath area

The roof covering area of the project under review 2.306,9 m^2. From the fast diagram (Fig. 3) it is considered to install solar panels. With the existing modules, from the total area of the roof sheath, photovoltaic area of 1,156.30 m^2 or 50.12% of the total roof area can be installed.

The main function of the roof is to protect the building from weather and heat, an additional function by utilizing the area of the roof and its construction, we can place solar panels as a renewable energy source that does not leave a carbon footprint, is environmentally friendly and saves energy costs to the hospital. Implementation of on-site photovoltaic (PV) systems provides the highest reduction potential for both operational and total lifecycle GHG emissions, with potential reductions of 92% to 100% and 48% to 66%, respectively [29].

The available roof area will be covered with solar panels. The closing process depends on the size of the existing panel modules. By knowing the size of the solar panel module and adapting it to the model and roof area, the number of solar panels will be optimal. The application of photovoltaic systems to buildings requires in-depth analyses to make this energy option perform well in terms of its energy efficiency, economic issues, spatial effects, as well as the esthetic values of buildings, their components, and even the plot layout [30].

The energy pay-back time for a multicolored PV façade is 8.1 years, which decreases by 35% to 5.3 years when replacing the glass rain cladding in an existing façade, leaving 25 years for surplus electricity generation [31].

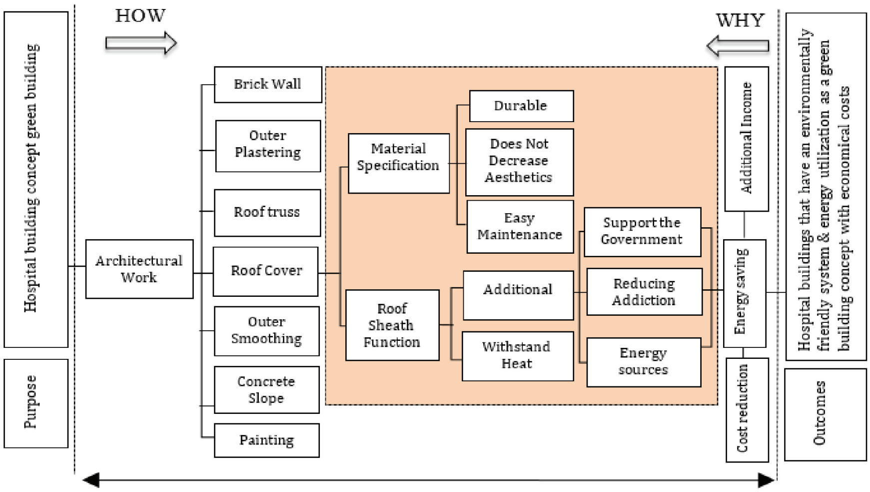


Fig. 3. Technical FAST diagram after additional function

Solar energy modeling is increasingly popular, important, and of economic significance in solving the energy crisis for big cities. Implementing a photovoltaic system (PV) in urban areas is one of the best options to solve the power crisis over the expansion of urban and the growth of population [32].

3.2.2. Analysis of the resulting output of solar panels

General data below is a table of the average monthly solar radiation for regions in Indonesia taken from the Meteorology and Geophysics Agency of the Climatology Station.

Table 8. Average sun insolation per month ($kW \cdot h/m^2/day$)

Month	Year			Average	Shine	Sun insulation
	2014	2017	2018			
	(%)	(%)	(%)	(%)	(hours/day)	(hour/day)
January	27	42	46	38.33	8	3.07
February	31	54	74	53.00	8	4.24
March	52	67	65	61.33	8	4.91
April	51	69	76	65.33	8	5.23
May	85	73	76	78.00	8	6.24
June	64	68	76	69.33	8	5,55
July	46	73	80	66.33	8	5.31
August	66	68	72	68.67	8	5.49
September	71	72	72	71.67	8	5.73
October	71	69	63	67.67	8	5.41
November	49	54	49	50.67	8	4.05
December	31	57	49	45.67	8	3.65

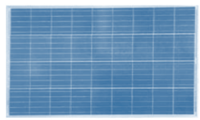
Based on BMKG data from three different years, the duration of sunshine in one day is estimated to be 8 hours. So that the amount of solar insolation can be calculated by multiplying the percentage of irradiation by the length of sunshine. From the table above, it can be seen that the insolation of the sun varies every month.

The lowest solar insolation is 3.07 (hours/day).

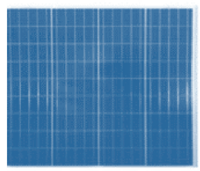
The output power generated from these solar panels can be calculated based on the specifications of the solar panels used, and also by using the equation: $P_G = A_G \cdot S \cdot t \cdot \eta$

3.2.3. Solar panel selection

By considering that the roof area can be optimized, 2 types of solar panel modules were selected in this case study, namely:



Solar Panel Specifications CPS SP 100WP 18V Polycrystalline:
Peak power (P_{max}) 100 W
Efficiency module 17.50%
Dimensions 1000 × 670 × 30 mm
Glass type High transmits, Low iron, 3.2 mm
Frame Aluminium alloy
Irradiance 1000 W/m^2, Module temperature 250°C, AM = 1.5



Solar Panel Specifications CPS SP 50WP 18V Polycrystalline:
Peak power (P_{max}) 50 W
Efficiency module 17.50%
Dimensions 540 × 670 × 30 mm
Glass type High transmits, Low iron, 3.2 mm
Frame Aluminium alloy
STC: Irradiance 1000 W/m^2, Module temperature 250°C, AM = 1.5

Table 9. Area and weight of solar panels

No.	Type /Type	Specification				
		Dimensions				Panel Area (m^2)
		P (m)	L (m)	T (m)	Weight (Kg)	
A	SP100-18P model	1.00	0.67	0.03	7,2	0.67
B	SP50-18P model	0.54	0.67	0.03	3.8	0.36

Table 10. Solar panel prices and installation costs

No.	Type/Type	Max PV Power (W)	1 Watt Peak (EUR)	Price of 1 PV Panel (EUR)	1 Set of PV Mounting (EUR)
A	SP100-18P model	100	0.79	78.84	53.46
B	SP50-18P model	50	0.79	39.44	35.05

Calculating solar panel power output:
$P_G = A_G \cdot S \cdot t \cdot \eta$

Information:
A_G – area of the solar panel,
S – average solar insolation,
t – duration of sun exposure,
η – efficiency of solar panels.
CPS Model SP100-18P Mono & Polycrystalline (or equivalent)
$P_G = 0.67\ \text{m}^2 \times 3.07\ \text{(hours/day)} \times (\text{kW/m}^2) \times 0.175 P_G = 0.360\ \text{(kW/day)}$
CPS Model SP50-18P Mono & Polycrystalline (or equivalent)
$P_G = 0.36\ \text{m}^2 \times 3.07\ \text{hours/day)} \times (\text{kW/m}^2) \times 0.175 P_G = 0.194\ \text{(kW/day)}$

Table 11. Total solar panel capacity

No.	Type/Type	PV Power Output (kW/day)	Total PV (Set)	Total PV Capacity (kW)
A	SP100-18P model	0.360	1,501	540.19
B	SP50-18P model	0.194	417	81.03

Table 12. Initial costs of solar panels

No.	Type/Type	Number (Modules)	Unit Price Incl. Install (EUR)	Total price (EUR)
A	SP100-18P model	1,501	132,33	198,585.40
B	SP50-18P model	417	74,49	31,051.80
	Initial fee amount			229,637.20

3.2.4. Investment calculate

Calculate the investment price in the 8 (eight) year of operation using [24]:
$F = P \times (1 + i)^n$,
F – future sum of money,
P – present sum of money,
i – interest rate,

n – number of interest periods.
Source: Engineering Economic Analysis book page 51
If the initial investment price P = EUR 229,637.20; i = 10%; n = 8 years
F = EUR $229,637.20 \times (1 + 0.1)^8$ = EUR 492,247.73
Initial costs = EUR $492,247.73/(12 \times 8)$ months= EUR 5,127.28 /month

Table 13. Investment value of solar panels

Investment Costs			EUR 229,637.20
Depreciation		8 years	
Unit Cost/month			EUR 5,127.28
Operational Cost			
A	Electricity cost		
	Cost per kWh	EUR 0.04	
	Total Consumption / day (KWH)	0	
	Total Electricity Cost / day	0	
	Total Electricity Cost / month		0
B	Operator Fee		
	No. Operator	2 persons	
	Salary / month	EUR 248.30	
	Total salary/month		EUR 496.59
C	Maintenance / Consumable Costs		
	Maintenance costs	EUR 4,592.74	
	Maintenance costs / month		EUR 4,592.74
D	Periodic Test		
	Test		
	per year		
	Cost per month		0
	Total Operating Costs/month (A + B + C + D)		EUR 5,089.34
	Total Cost per Month (+ Depreciation)		EUR 10,216.92
	Total costs up to 8 years		EUR 980,823.94

Payback for the Solar Power Plant Installation:
Electricity consumption / day ($\text{kW} \cdot \text{h}$) 8,000
Cost / $\text{kW} \cdot \text{h}$ EUR 0.04; Cost / day EUR 282.77
The total cost of electricity usage per month EUR 8,482.95
Savings per year EUR 101,795.44
Payback Period = Amount of Investment / Savings per year
Payback Period = EUR 980,823.94 / EUR 8,482.95
Payback Period = 9.64 years $\approx$ 9 years 7 months

4. Conclusions

Based on research from the BOQ, technical specifications, and plan drawings, in the Green material selection process and the LCC process, the following conclusions are obtained:

– Replacement of conventional materials to green with Value Engineering analysis turns out to be able to save costs that can be felt directly by the Project, namely 2.62% or EUR 31,694.21
– The payback for the procurement of this solar power plant takes time = 9,64 Years ≈ 9 Years 7 Months for Break Event Point (BEP). Without calculating the residual value (residual value), that investment as an addition to the function of this Solar Power Plant can be environmentally friendly and profitable in terms of investment.
– The novelty of this research is the selection materials and the green concept of working methods is still cost efficient and the installation of Photovoltaics (PV) on the roof of Hospital reaches a payback period which is feasible for new investment.
– Based on the results of the analysis, the hypothesis is that the increase in cost performance using value engineering methods and lifecycle costs in green hospital projects can be realized, environmentally friendly, and more profitable in the future.

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