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# Energy Audit to Optimize Electrical Energy Consumption at Siti Khodijah Sepanjang Hospital Sidoarjo using The Analytical Hierarchy Process Method

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***Abstract:*** *Siti Khodijah Hospital, type B hospital, is one of Muhammadiyah's health charities which is located in 260 Pahlawan Road, Sepanjang, Sidoarjo, East Java. The majority of the operating activities in this hospital use electrical energy, such as the use of medical equipment and other medical equipment that requires the consumption of electrical energy with a large enough capacity. The use of the AHP (Analytical Hierarchy Process) method has the aim of obtaining optimal results in making a decision, namely by simplifying a complex problem that is not structured and systematic. The results of this energy audit are able to provide new ideas to the hospital head through savings programs designed based on the 4M+1E concept (Man, Machine, Method, Material and Environment). The implementation of the results of this study can reduce the cost of using electrical energy by 14%, which is IDR 375,800,000 of the year's electricity costs.*

***Keywords:*** *Demand side management, Energy audit, Electrical energy consumption, Analytical Hierarchy, Process Optimization.*

## 1. INTRODUCTION

The requirement for electrical energy in Indonesia is increasing along with the development of technology and industry. Based on data from State Electricity Company's 2019 annual report book that the amount of electrical energy sold in 2019 was 245,518 GWh, an increase of 3,6% from 234,618 GWh in 2018. The increase in electricity sales was due to increased sales of electricity in other customer segments (7.5 %), business customer segment (6,5%), and household customer segment (6%). Based on the 2015 report from the Minister of Energy and Mineral Resources of the Republic of Indonesia, it shows that energy management activities have been carried out in various energy user sectors, especially in Indonesia, one of which is the Hospital.

In the first annual report of Siti Khadijah Sepanjang Hospital, electrical energy consumption exceeds the planned target, especially in the 6-floor Main Building which has an installed power capacity of 550 kVA, because it is used as a vital facility for patient service activities from the emergency room, inpatient care, and ward operation, the demand for and consumption of electricity at the facility is very large and is of particular concern to management. For this reason, management is committed to making savings by first conducting an Energy Audit.

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The purpose of this study is to identify the source of electrical energy used by the hospital, conduct an energy audit to find out how much electrical energy is used to operate each month, identify what forms of electricity waste are in Siti Khadijah Hospital Sepanjang, and find out what tools are used. requires the largest electricity supply in its use, as well as providing alternative suggestions for what the company will do, especially in saving electricity consumption and for efficient use of electrical energy.

The use of the AHP method aims to optimize decision making by simplifying an unstructured complex problem. Then the level of importance of each variable is given a numerical value relative to the other variables. From these various considerations, a synthesis is then carried out to determine the variables that have high priority and play a role in influencing the results of the system. In addition, the AHP method is able to provide validity up to the tolerance limit for the inconsistency of various criteria and selected alternatives as well as the durability or resilience of the output sensitivity analysis of decision making in the Energy Audit.

## 2. METHOD

The energy management system is a method of continuous energy efficiency improvement by integrating energy efficiency activities into the existing management system, so that it can take into account cost, environmental, energy availability and business risk factors.

Research describes that energy audit is a technique used to calculate the amount of energy consumption in a building and identify ways to save it. AHP (Analytical Hierarchy Process) is a decision-making method that describes a complex multi-factor or multi-criteria problem into a hierarchy. while energy conservation can be explained as efficient and rational use of energy, without reducing the use of required energy.

Research discusses energy audits in industrial buildings in Klaten, Central Java. This study uses the Energy Consumption Intensity approach, which is the amount of electricity used per square meter of the building area during a certain period. The building area in this study is 3201,2 $m^2$. Meanwhile, the consumption of electrical energy during the period of January 2016 to December 2016 was 738744 kWh. Based on this research, confirmed that the value of energy consumption intensity is 230,7 $kWh/m^2$ per year, whereas the category is wastefully used of electrical energy.

Research was carried out in a school building. The results showed that every building that uses air conditioning cooling gets an energy consumption intensity value of 8,95 $kWh/m^2$. This still meets room efficiency standards. On the other hand, the part rooms that does not use air conditioning cooling gets an energy consumption intensity of 3,18 $kWh/m^2$, this shows that the use of electrical energy in a room without air conditioning is still quite wasteful.

Based on the three literature reviews above, then energy management activities in an organized company using management principles are carried out through energy audits.

**Energy Audit**

Energy audit is the process of evaluating energy users and identifying energy saving opportunities as well as recommendations for improving efficiency for users of energy sources and energy users in the context of energy conservation. Energy audits are carried out at least on the main energy processes and users on a regular basis at least once every three years. The audit process can be carried out by internal or external auditors.

Energy audit is divided into 3 levels. Level 1, namely data collection activities (general), short visual observations, and interviews. The initial audit is the second level of the energy audit activity level. This activity is intended to find out the potential for energy savings that is more complete than a level one audit, the data and information used are based on measurement results, identify sources of energy wastage and simple actions that can be taken to improve energy efficiency in the short term. Detailed energy audit is the 3rd and highest level of energy audit activity. This audit is more in-depth with a wider scope, the recommendations are based on engineering studies in a clear order of priority.

**Analytical Hierarchy Process (AHP)**

The Analytical Hierarchy Process (AHP) is a method for solving a complex, unstructured situation into several components in a hierarchical arrangement, by assigning subjective values to the relative importance of each variable, and determining which variable has the highest priority in order to influence the outcome of the situation. The decision-making process is basically choosing the best alternative. Such as structuring the problem, determining alternatives, determining possible values for alleatory variables, setting values, time preference requirements, and specification of risks. No matter how wide the range of alternatives that can be determined or the detailed assessment of possible values, the limitation that still surrounds is the basis for comparison in the form of a single criterion. The steps of AHP process are shown in figure 1.

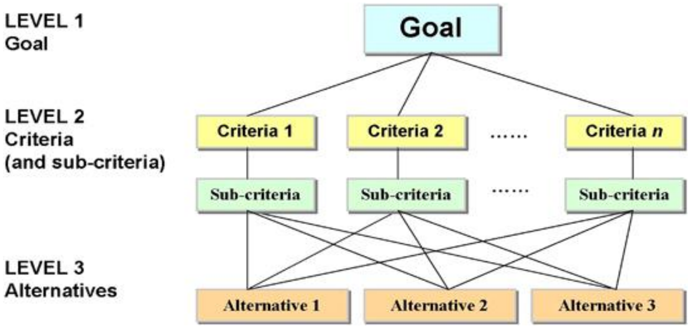


**Figure 1. AHP process**

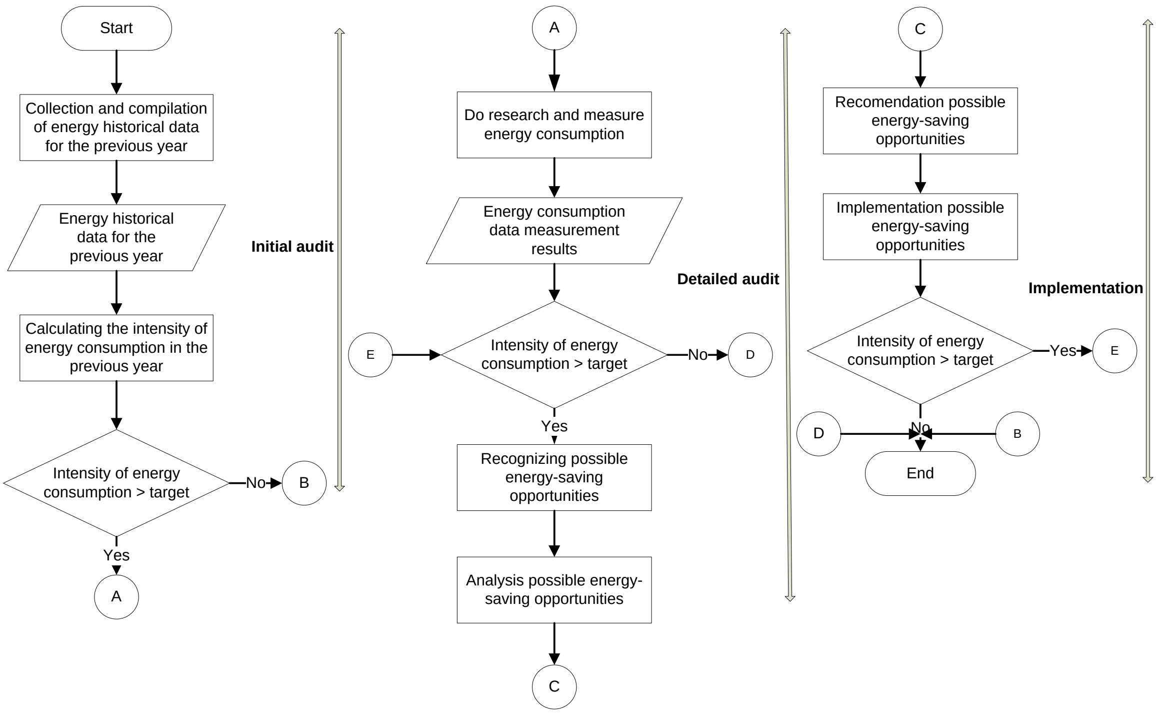


**Figure 2. Energy audit process flowchart**

- Defining problems and setting goals. If AHP is used to select alternatives or set alternative priorities, at this stage the development of alternatives is carried out.
- Arrange problems into a hierarchy. So, the problems can be viewed from a detailed and measurable perspective.
- Prioritization for each problem element in the hierarchy. This process generates the weight or contribution of the element to the achievement of the goal so that the element with the highest weight has priority for handling. Priority is generated from a pairwise comparison matrix between all elements at the same hierarchical level.
- Perform consistency testing on comparisons between elements obtained at each level of the hierarchy.

$$\lambda_{max} = \frac{Total\ Eigen\ Max}{Number\ Order\ matrix} \quad (1)$$

$$CI\ (Consistency\ Index) = \frac{\lambda_{max} - n}{n-1} \quad (2)$$

$$CR\ (Consistency\ Ratio) = \frac{CI}{RI} \quad (3)$$

Where $\lambda_{max}$ means data normalization, *n* indicates amount of data normalization, and *RI* is ratio index.

**Lightning Analysis Method**

Electrical load is a component that requires electrical energy. Equation 4 shows how to determine the number of light points in a room.

$$N = \frac{E\ .L\ .W}{\phi\ .LLF\ .CU\ .n} \quad (4)$$

$$\phi = \frac{E\ .A}{K_p\ .K_d} \quad (5)$$

$$\phi_0 = \frac{E\ .A}{\eta} \quad (6)$$

Where *N* is the number of light points in a room, *E* indicates the light intensity (lux), *L* and *W* are the length and width of the room (meters), $\phi$ indicates the level of light lumens, *LLF* is Light Loss Factor (0.7 – 0.8), *CU* is the Coefficient of Utilization (50% – 65%), *n* shown the number of lights, *Kp* and *Kd* means usage and depreciation coefficient. The estimated lumen intensity data based on the type and power of the lamp is shown in table 1 and 2.

**Table 1. Luminance Data based on Type and Power of The Lamp**

| Lumen | Incandescent Lamps (Watt) | Halogen Lamps (Watt) | CFL (Watt) | LED (Watt) |
|---|---|---|---|---|
| 450 | 40 | 28 | 9 | 6-8 |
| 800 | 60 | 42 | 12 | 9-11 |
| 1100 | 75 | 53 | 15 | 13-15 |
| 1600 | 100 | 70 | 20 | 18-20 |

**Table 2. Table of Lighting Strength in Buildings**

| Buldings | Lightning Strength (Lux) |
|---|---|
| Office / Restaurant / Store / Shop | 200 – 500 |
| Apartment | 100 – 250 |
| Hotel | 200 – 400 |
| Hospital / School | 200 – 800 |
| Basement Apartment / Toilet / Corridor / Hall / Warehouse / Lobby | 100 – 200 |

## 3. RESULTS AND DISCUSSION

The calculation of the electrical load is used to determine the cost of using electrical energy in terms of the pattern of its use every day. To find out the amount of electricity usage, it can be seen by observing the pattern of activities carried out by employees in working according to a predetermined schedule, interviews with the person in charge of the area and direct observations as well as through theoretical studies based on existing theories, it is found that the difference in load usage time is due to different work patterns and activity intensity in each area.

**Real Energy Usage Analysis Per Day**

Calculation of real energy use per day is obtained by determining the total hours of use in one day multiplied by the total power. The analytical value can be seen in table 3. From the calculation of real energy consumption per day in the building, it was found that the Cathlab Equipment and the electricity distribution on the roof floor consumed the most energy, respectively 981.6 kW and 981.12 kW.

**Energy Consumption Intensity Value Analysis**

Energy consumption intensity is the term used to define the energy consumption of the system (building). The IKE value can be found by dividing the total energy consumed by the building in one year by the total gross floor area of the building.

From the calculation of the intensity of energy consumption in several areas, the result is that there are several floors that exceed the energy consumption intensity standard for hospitals (> 380), including:

- Equipment Cathlab with energy consumption 532,9
- Roof electricity distribution (Water Treatment Plant) 532,7

**Electrical Energy Analysis in Lighting Systems**

Based on the results of lighting measurements carried out at 7 points (table 5), the results obtained light intensity of 4 - 359 lux. 7 items are considered to meet the lighting standards according to table 2.

**Table 3. Total Real Energy Consumption per Day in Hospital Building**

| Panel | Loc. | Burden (Watt) | FK % | Load (Watt) | Total Real Energy Consumtion per Day (kW) | Total Hours | Peak Load (Hours) | Out. Peak Load (Hours) | Power Peak Load (kWh) | Power Out. Peak Load (kWh) | Total Power Consumtion (kWh per Day) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pump AB | Basement | 10000 | 0,5 | 5000 | 5 | 8 | 3 | 5 | 15,00 | 25,00 | 40,00 |
| SDP Pump | Pump Room | 29000 | 0,8 | 23200 | 23 | 8 | 3 | 5 | 69,60 | 116,00 | 185,60 |
| PP B | Basement | 2200 | 0,7 | 1540 | 2 | 24 | 5 | 19 | 7,70 | 29,26 | 36,96 |
| LP 1 | 1st Flo | 14100 | 0,7 | 9870 | 10 | 24 | 5 | 19 | 49,35 | 187,53 | 236,88 |
| PPAC 1 | 1st Flo | 20100 | 0,8 | 16080 | 16 | 24 | 5 | 19 | 80,40 | 305,52 | 385,92 |
| LP 2 | 2nd Flo | 14600 | 0,7 | 10220 | 10 | 24 | 5 | 19 | 51,10 | 194,18 | 245,28 |
| PPAC 2 | 2nd Flo | 25000 | 0,8 | 20000 | 20 | 24 | 5 | 19 | 100,00 | 380,00 | 480,00 |
| LP 3 | 3rd Flo | 14800 | 0,7 | 10360 | 10 | 24 | 5 | 19 | 51,80 | 196,84 | 248,64 |
| PPAC 3 | 3rd Flo | 24900 | 0,8 | 19920 | 20 | 24 | 5 | 19 | 99,60 | 378,48 | 478,08 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LP 4 | 4th Flo | 11500 | 0,7 | 8050 | 8 | 24 | 5 | 19 | 40,25 | 152,95 | 193,20 |
| PPAC 4 | 4th Flo | 24900 | 0,8 | 19920 | 20 | 24 | 5 | 19 | 99,60 | 378,48 | 478,08 |
| PPICU 4 | 4th Flo | 7400 | 0,7 | 5180 | 5 | 24 | 5 | 19 | 25,90 | 98,42 | 124,32 |
| LP 5 | 5th Flo | 8200 | 0,7 | 5740 | 6 | 24 | 5 | 19 | 28,70 | 109,06 | 137,76 |
| PPAC 5 | 5th Flo | 27000 | 0,8 | 21600 | 22 | 24 | 5 | 19 | 108 | 410,40 | 518,40 |
| PP CSSD | 5th Flo | 50600 | 0,7 | 35420 | 35 | 12 | 3 | 9 | 106,26 | 318,78 | 425,04 |
| PPICU 5 | 5th Flo | 5500 | 0,7 | 3850 | 4 | 24 | 5 | 19 | 19,25 | 73,15 | 92,40 |
| LP 6 | 6th Flo | 8000 | 0,7 | 5600 | 6 | 24 | 5 | 19 | 28,00 | 106,40 | 134,40 |
| PPAC 6 | 6th Flo | 28600 | 0,8 | 22880 | 23 | 24 | 5 | 19 | 114,40 | 434,72 | 549,12 |
| PP CATH LAB | Rooftop | 81800 | 1 | 81800 | 82 | 12 | 3 | 9 | 245,40 | 736,2 | 981,60 |
| SDP Rooftop | Rooftop | 58400 | 0,7 | 40880 | 41 | 24 | 5 | 19 | 204,40 | 776,72 | 981,12 |
| Total | | 466600 | | 367110 | 367 | 424 | 92 | 332 | 1544,71 | 5408,09 | 6952,80 |

**Table 4. Calculation of the Intensity of Energy Consumption Intensity (ECI) of Hospital Buildings**

| Location | Actual Power | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Total Hours | Peak Load | Out. Peak Load | Peak Load Power (kWh) | Out. Peak Load Power (kWh) | Total Power Consumption (kWh per year) | Building Wide | ECI |
| Clean Water and Drain Pump (Basement) | 8 | 3 | 5 | 15 | 25 | 14.400 | 663 | 21,71946 |
| Clean Water Pump and Regional STP | 8 | 3 | 5 | 69,6 | 116 | 66.816 | 663 | 100,7 |
| Lightning and Contacts (Basement) | 24 | 5 | 19 | 7,7 | 29,26 | 13305,6 | 663 | 20,0 |
| Lightning and Contacts (1st Floor) | 24 | 5 | 19 | 49,35 | 187,53 | 85276,8 | 663 | 128,6 |
| AC and Mechanical Ventilation (1st Floor) | 24 | 5 | 19 | 80,4 | 305,52 | 138931,2 | 663 | 209,5 |
| Lightning and Contacts (2nd Floor) | 24 | 5 | 19 | 51,1 | 194,18 | 88300,8 | 663 | 133,1 |
| AC and Mechanical Ventilation (2nd Floor) | 24 | 5 | 19 | 100 | 380 | 172800 | 663 | 260,6 |
| Lightning and Contacts (3rd Floor) | 24 | 5 | 19 | 51,8 | 196,84 | 89510,4 | 663 | 135,0 |
| AC and Mechanical Ventilation (3rd Floor) | 24 | 5 | 19 | 99,6 | 378,48 | 172108,8 | 663 | 259,5 |
| Lightning and Contacts (4th Floor) | 24 | 5 | 19 | 40,25 | 152,95 | 69552 | 663 | 104,9 |
| AC and Mechanical Ventilation (4th Floor) | 24 | 5 | 19 | 99,6 | 378,48 | 172108,8 | 663 | 259,5 |
| Equipment ICU (4th Floor) | 24 | 5 | 19 | 25,9 | 98,42 | 44755,2 | 663 | 67,50 |
| Lightning and Contacts (5th Floor) | 24 | 5 | 19 | 28,7 | 109,06 | 49593,6 | 663 | 74,80 |
| AC and Mechanical Ventilation (5th Floor) | 24 | 5 | 19 | 108 | 410,4 | 186624 | 663 | 281,4 |
| Equipment CSSD (Central Sterile Supply Department) (5th Floor) | 12 | 3 | 9 | 106,26 | 318,78 | 153014,4 | 663 | 230,7 |
| Equipment ICU (5th Floor) | 24 | 5 | 19 | 19,25 | 73,15 | 33264 | 663 | 50,17 |
| Lightning and Contacts (6th Floor) | 24 | 5 | 19 | 28 | 106,4 | 48384 | 663 | 72,9 |
| AC and Mechanical Ventilation (6th Floor) | 24 | 5 | 19 | 114,4 | 434,72 | 197683,2 | 663 | 298,1 |
| Equipment CATHLAB (Rooftop) | 12 | 3 | 9 | 245,4 | 736,2 | 353376 | 663 | 532,9 |
| Electric Distribution (Rooftop) | 24 | 5 | 19 | 204,4 | 776,72 | 353203,2 | 663 | 532,7 |

The 7 locations are ICU room, operating room, inpatient room, lobby, pharmacy, and office. While other items still have to go through a review process, because these items have not reached the standard target.

**Table 5. Lighting Intensity Measurement Value**

| Rooms | Test Point | Lightning Source | Window Area ($m^2$) | Light Intensity (Lux) | | Measurement Type (General/Local) |
|---|---|---|---|---|---|---|
| | | | | Result | Standart | |
| ICU | Middle Area | Synthetic | - | 310 | 200-800 | Local |
| Doctor's Room | Middle Area | Synthetic | 1,104 | 225 | 200-800 | Local |
| Inpatient | Middle Area | Synthetic | 0,913 | 230 | 200-800 | Local |
| Surgery room | Middle Area | Synthetic | - | 380 | 200-800 | Local |
| Office | Middle Area | Synthetic | 5,5 | 205 | 200-800 | Local |
| Corridor | Middle Area | Synthetic | - | 210 | 200-800 | Local |
| Pharmacy | Middle Area | Synthetic | 5,5 | 205 | 200-800 | Local |

## Criteria Consistency Test Results

The following are the stages of determining the weight of the criteria and validity (consistency test between criteria): Create a pairwise comparison matrix in decimal, Determine the Eigen value, Determine priority weight, Calculating Total Amount, Divide each column by the total number, Calculating synthesis weight, Calculating Eigen max, Calculating (Lamda) max, Calculating CI (Consistency Index), and Calculating CR (Consistency Ratio).

**Table 6. Pairwise Comparison Matrix in Decimal**

| Pairwise comparison matrix in decimal | | | | | | | 0,2 |
|---|---|---|---|---|---|---|---|
| Criteria | Employee Behavior | Operational Pattern | Technology | Standard Operational Use of Electricity | Number of Equipment | Eigen Value | Priority Weight |
| Employee Behavior | 1,000 | 0,200 | 7,000 | 5,000 | 5,000 | 2,0362 | 0,2635 |
| Operational Pattern | 5,000 | 1,000 | 7,000 | 7,000 | 5,000 | 4,1460 | 0,5365 |
| Technology | 0,143 | 0,143 | 1,000 | 2,000 | 5,000 | 0,7277 | 0,0942 |
| Standard Operational | 0,200 | 0,143 | 0,500 | 1,000 | 0,333 | 0,3432 | 0,0444 |
| Number of Equipment | 0,200 | 0,200 | 0,200 | 3,000 | 1,000 | 0,4743 | 0,0614 |
| Total Number | 6,5429 | 1,6857 | 15,7000 | 18,0000 | 16,3333 | 7,7274 | 1,0000 |

Each column is summed to then normalize the results of pairwise comparisons (value equals one). The normalized rows are summed and divided by a number of columns to get the Eigen Vector (EV) value.

**Table 7. Synthesis Weight and Maximum Eigen**

| Divide each column by the total number | | | | | | |
|---|---|---|---|---|---|---|
| Employee Behavior | Operational Pattern | Technology | Standard Operational Use of Electricity | Number of Equipment | Synthesis Weight | Max Eigen (X) |
| 0,1528 | 0,1186 | 0,4459 | 0,2778 | 0,3061 | 1,3012 | 4,9383 |
| 0,7642 | 0,5932 | 0,4459 | 0,3889 | 0,3061 | 2,4983 | 4,6563 |
| 0,0218 | 0,0847 | 0,0637 | 0,1111 | 0,3061 | 0,5875 | 6,2386 |
| 0,0306 | 0,0847 | 0,0318 | 0,0556 | 0,0204 | 0,2231 | 5,0237 |
| 0,0306 | 0,1186 | 0,0127 | 0,1667 | 0,0612 | 0,3898 | 6,3515 |
| | | | Total | | | 27,2084 |

From the calculation results, the EV value for each criterion is obtained. To calculate the consistency of these values, a Consistency Ratio (CR) is calculated. And to get the CR value, it is necessary to calculate the Consistency Index (CI). The CI calculation is as follows:

$$\lambda_{max} = \frac{Total\ Eigen\ Max}{Number\ Order\ matrix} = \frac{27{,}2084}{5} = \mathbf{5{,}4417}$$

$$CI\ (Consistency\ Index) = \frac{\lambda_{max} - n}{n-1} = \frac{5{,}4417 - 5}{5-1} = \frac{0{,}4417}{4} = \mathbf{0{,}1104}$$

To determine the IR (Ratio Index), pay attention to the data in the table, based on the Random Index table by Saaty based on the order matrix. From the calculation results, the CR value is less than 0,1 or 10%, so the comparison results are considered consistent.

**Table 8. Random Saaty Index based on Order of Matrix**

| N | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $R_1$ | 0,00 | 0,00 | 0,58 | 0,90 | 1,12 | 1,24 | 1,32 | 1,41 | 1,45 | 1,49 | 1,51 |

The Random Index for the 5x5 order matrix is equal to 1,12.

$$CR\ (Consistency\ Ratio) = \frac{CI}{RI} = \frac{0{,}1104}{1{,}12} = \mathbf{0{,}00986}$$

**AHP Method Implementation Results**

After making pairwise comparisons and testing the consistency between the criteria, the next step is to compile a summary of the results of the application of the AHP method, while the results of the implementation are shown in table 9.

**Table 9. Summary of AHP Implementation Results**

| Summary | Employee Behavior | | Operational Pattern | | Technology | | Standard Operational Use of Electricity | | Number of Equipment | | Final Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weight | Score | Weight | Score | Weight | Score | Weight | Score | Weight | Score | |
| Man | 0,260 | 0,547 | 0,500 | 0,328 | 0,118 | 0,164 | 0,045 | 0,317 | 0,078 | 0,279 | 0,362 |
| Machine | 0,260 | 0,115 | 0,500 | 0,046 | 0,118 | 0,042 | 0,045 | 0,063 | 0,078 | 0,050 | 0,065 |
| Material | 0,260 | 0,047 | 0,500 | 0,120 | 0,118 | 0,286 | 0,045 | 0,089 | 0,078 | 0,104 | 0,117 |
| Method | 0,260 | 0,291 | 0,500 | 0,506 | 0,118 | 0,508 | 0,045 | 0,531 | 0,078 | 0,567 | 0,456 |

Based on table 9, refer that the results of the calculations using the AHP method are as follows.

- The Man factor is the employee's energy utilization and saving system equal to 0,362
- Machine factor, namely the existing technology saving system (as is Condition) equal to 0,065
- Material factor, which is an energy-efficient technology saving system equal to 0,117
- Methode factor, namely the operational method savings system is equal to 0,456

From these data, it can be concluded that the method factor, namely the operational method saving system, is the highest result with a value of 0.456, followed by the Man factor, namely the employee energy utilization and saving system with a value of 0.362, so these two items will be the main focus for energy efficiency programs. Data plot data can be seen in Figure 3.

**Energy Saving Implementation**

Based on the results of the implementation of the AHP method, the next energy saving program can be arranged based on priorities, namely Capital Expenditure with the order of the smallest value with the fastest payback period. The list of energy saving programs for the next 5 years at Siti Khadijah Sepanjang Hospital is shown in table 10.

Based on table 10, Siti Khadijah Sepanjang Hospital will implement a priority energy efficiency program based on the results of the analysis of the AHP method, namely the Man factor (employee energy utilization and saving system) and Method (operational method saving system) in items 5, 8, 16, and 17.

From table 11, it was decided that the total savings was IDR 375.800.000. Thus, the savings obtained are 14% of Year-to-Date (YTD) costs as shown in table 12.

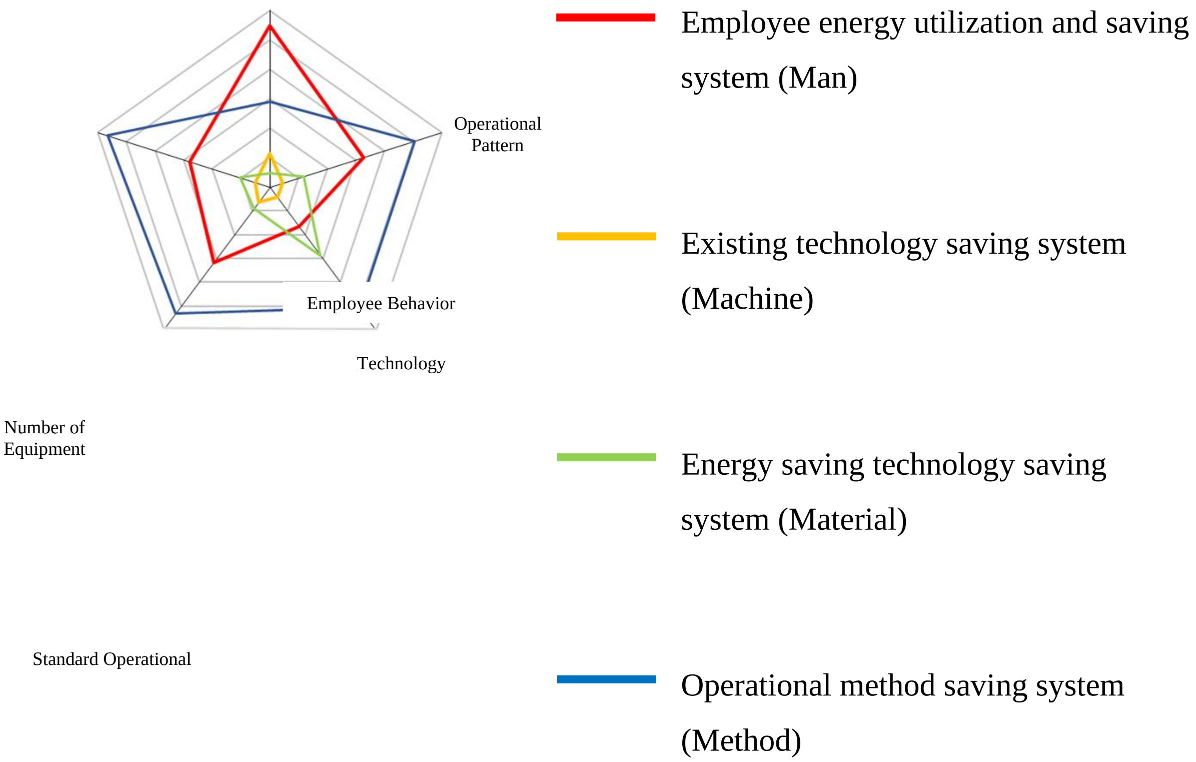


**Figure 3. Radar graph of the distribution of calculated data using the AHP method**

**Table 10. Siti Khadijah Hospital Energy Efficiency Data**

| Factor | Description of Opportunity | Capital Cost (IDR) | Potential Payback | Saving Actual | |
|---|---|---|---|---|---|
| | | | | Bill (IDR) | Power Saving (kWh) |
| Material | Capacitor bank installation | 120.000.000 | 0,67 | 120.000.000 | 88.889 |
| Material | Replacement of TL to LED | 600.000.000 | 2 | 63.600.000 | 47.111 |
| Material | Inverter installation in server room | 200.000.000 | 1,8 | 216.000.000 | 160.000 |
| Material | Timer installation in office | 50.000.000 | 1,2 | 42.000.000 | 31.111 |
| Man | Turning off the lights during breaks | | - | 4.200.000 | 3.111 |
| Material | Replacement of AC non-inverter to inverter | 48.000.000 | 1,6 | 19.200.000 | 14.222 |
| Machine | Overhaul genset | 60.000.000 | 1,3 | 48.000.000 | 35.556 |
| Method | Turn off the lights in an empty room, min 2 hours | | - | 12.600.000 | 9.333 |
| Material | Using sensors in lighting systems | 15.000.000 | 0,8 | 9.600.000 | 7.111 |
| Material | Using standing AC | 50.000.000 | 0,7 | 8.400.000 | 6.222 |
| Material | Genset optimalization | | - | 6.000.000 | 4.444 |
| Material | Reducing the number of genset standby backup | | - | 4.200.000 | 3.111 |
| Material | Reducing genset utilization | | - | 3.084.000.000 | 2.284.444 |
| Material | Soft starter in fuel pump | 10.000.000 | 0,6 | 19.200.000 | 14.222 |
| Material | Maintenance genset | | - | 14.400.000 | 10.667 |
| Method | Genset switch to grid | 45.000.000 | 0,4 | 114.000.000 | 84.444 |
| Method | Shifting the operational pattern of the load | 15.000.000 | - | 245.000.000 | 181.481 |
| | Total | 1.213.000.000 | | 4.030.400.000 | 2.985.481 |

**Table 11. Results of Implementing Energy Saving Opportunities at Buildings**

| No | Factor | Activity | Saving (IDR) | Power Saving (kWh) | Progres s |
|---|---|---|---|---|---|
| 1 | Man | Turning off the lights during breaks | 42.600.000 | 31.566 | Done |
| 2 | Method | Power cuts on Sundays and holidays for at least 2 hours | 21.000.000 | 15.556 | Done |
| 3 | Method | Switching the generator to PLN at the power house | 114.000.000 | 84.444 | Done |
| 4 | Method | Shift operational patterns from peak load time to off peak load time without reducing productivity | 245.000.000 | 77.778 | Done |
| | | Total | 375.800.000 | 174.667 | |

**Table 12. Electricity Cost Saving Results**

| Month | Energy Bill (IDR) | Power Outside Peak Load Time (kWh) | Power Peak Load Time (kWh) | Power Usage (kWh) |
|---|---|---|---|---|
| Jan -21 | 214.919.985 | 152.419 | 29.053 | 181.472 |
| Feb-21 | 208.558.132 | 148.161 | 28.021 | 176.182 |
| Mar-21 | 193.583.972 | 137.212 | 26.220 | 163.432 |
| Apr-21 | 228.480.993 | 161.928 | 30.861 | 192.789 |
| May-21 | 225.480.993 | 159.431 | 30.805 | 190.236 |
| Jun-21 | 237.045.080 | 167.283 | 32.605 | 199.888 |
| Jul-21 | 239.955.621 | 169.844 | 32.661 | 202.506 |
| Aug-21 | 225.482.253 | 159.927 | 30.469 | 190.396 |
| Sep-21 | 231.078.308 | 163.313 | 31.621 | 194.934 |
| Oct-21 | 219.344.705 | 155.637 | 29.597 | 185.234 |
| Nov-21 | 241.936.571 | 174.398 | 33.110 | 207.508 |
| Dec-21 | 213.738.549 | 152.395 | 28.341 | 180.736 |
| Total | 2.679.445.211 | 1.901.949 | 363.365 | 2.265.314 |
| Average | 223.287.101 | 158.496 | 30.280 | 188.776 |
| Saving | 375.800.000 | | | |
| Percentage | 14% | | | |

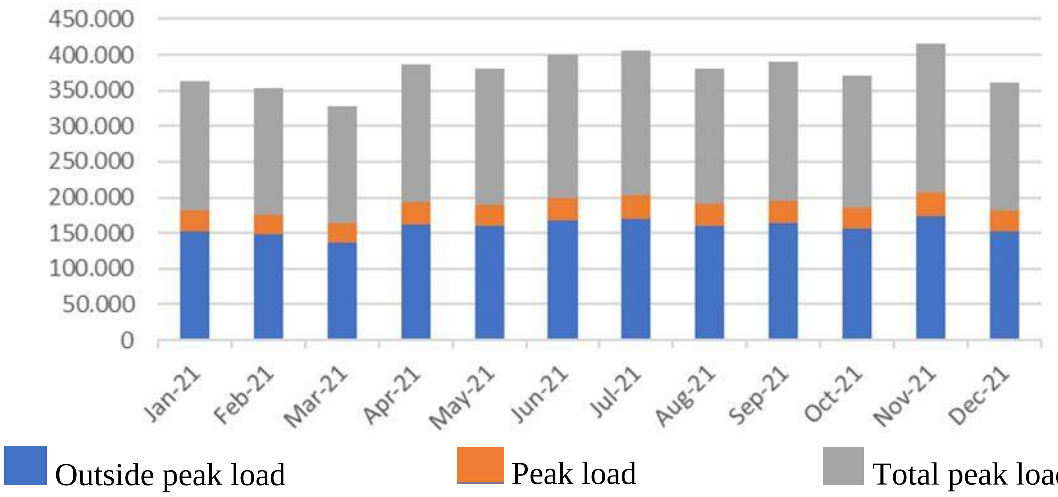


**Figure 4. Graph of power consumed (peak load + outside peak load) (kWh) against electricity costs**

## 4. CONCLUSION

From the results of the audit process using the AHP method and the implementation of savings opportunities, it can be concluded that as follows:

1. Based on the existing load data, it is known that the electricity usage at Siti Khadijah Sepanjang Hospital is quite large with an average year-to-date electricity bill of IDR 2,679,445,211. While, power usage is equal to 2,265,314 kWh, consisting of 1,901,949 kWh outside of power peak time and 363,365 kWh inside of power peak time usage.
2. The results of calculations with the AHP method obtained a hierarchy of results as follows:
   a. The Man factor, namely the employee's energy utilization and saving system, is equal to 0,362
   b. Machine factor, namely the existing technology saving system (as is condition), is equal to 0,065
   c. Material factor, namely energy saving technology system, is equal to 0,117
   d. Methode factor, namely the operational method savings system, is equal to 0,456
3. The results of the implementation of savings with the program proposed in this study are able to shift operations from inside to outside peak load times in hospitals. This has managed to contribute IDR 245,000,000 annually.
4. The results of the implementation of savings with the method and man factors are IDR 130,800,000. Thus, the total cost savings is IDR 375,800,000, equivalent to 14% of the year-to-date electricity costs

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