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Efficiency of Electrical Energy in Building Base on DSM with AHP Method

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Abstract

*In the modern world, electrical energy is very important to support all activities in office buildings, educational facilities, industrial complexes and household activities. The problem that occurs in the use of electricity is the lack of understanding of energy conservation from the consumer side. This causes the waste of electrical energy. An alternative solution to this problem is an effort to make efficient use of electrical energy from the consumer side.By applying Demand Side Management (DSM) to the building, an efficient and rational use of electrical energy is obtained. To implement DSM it is necessary to conduct an energy audit of the building. By conducting an energy audit then Energy Use Intensity (EUI**)** and the profile of electrical energy usage is obtained. After EUI and the energy use profile are known then energy policy recommendations are determined in the building. By using the Analytical Hierarchy Process (AHP) an alternative set of decisions is made that is right in reducing electricity consumption so that it reaches the desired efficiency point in accordance with building management policies. The results of processing from AHP obtained an alternative set of electrical energy efficiency according to its weight is the regulation of the use of office facilities by 48.5%, maintenance of existing equipment by 31.1%, utilization of new energy-saving technologies by 20.4%.*

Keywords*: Energy Audit, EUI, DSM, AHP.*

1. Introduction

Demand Side Management in electrical energy is the process of using energy efficiently and rationally without reducing the use of existing energy [1]. DSM uses the principle of energy conservation, namely by encouraging consumers to use electricity supplied efficiently in their daily activities, office activities, educational activities and industrial activities.

Inefficient use of electrical energy in buildings causes wasteful, uncontrolled consumption of electrical energy and increases the burden of electricity costs. Many building management in Indonesia do not pay attention to energy management so that the use of electrical energy is not measurable and less efficient. With DSM through the energy audit process, profiles of electrical energy usage and opportunities for saving energy in the building will be obtained.

The purpose of this study is to determine the profile of energy use and electrical energy savings opportunities in buildings. Conduct an analysis of the use of electrical energy and electrical energy savings opportunities in buildings. Develop AHP-based decision support systems for the best recommendations for alternative proposals for saving electricity consumption and for increasing the efficiency of using electricity as a reference used by building managers to make savings.

2. Research Method

DSM in buildings is a method used to achieve efficient use of electric power in buildings that are carried out based on energy audits. Energy audits are evaluations of energy use and identify opportunities for energy savings and recommendations for increasing efficiency in energy use and use of energy sources in the context of energy conservation.

Energy Use Intensity (EUI)

The intensity of energy performance for buildings in general is kWh/m²/month or kWh/m²/year. EUI are used as a reference to determine the criteria for energy use in buildings that are wasteful or efficient. Determination of energy intensity is as follows [2]:

a. If the percentage of the ratio of air-conditioned floor area to total floor area is < 10%, it is considered as a non-AC building.
b. If the percentage of the comparison of the floor area with AC to total floor area > 90%, it is considered as an air-conditioned building.
c. If the percentage of air-conditioned floor area to total floor area is 10% - 90%, it is considered as an air-conditioned and non-AC building.

Energy Use Intensity is the amount of energy used by a building to expand a conditioned area within one month or one year. To get the EUI, the formula is:

$$\text{Energy Use Intensity } (EUI) = \frac{General\ Usage\ (kWh/month)}{Total\ Square\ Footage\ (m^2)}$$

Analytical Hierarchy Process (AHP)

AHP is a method of decision making that outlines multi-factor or complex multi- criteria problems into a hierarchy [3]. The AHP principle consists of compiling a hierarchy, determining priorities of assessment and testing consistency.

3. Results and Analysis

The building used in this study is the Management Center building which functions as a main building at the educational institution.

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Data Collection

Before carrying out data collection at the MC building, preparations should be made including administrative preparation, personnel preparation and equipment preparation. Administrative preparation in the form of licensing for conducting energy audits, companion of the object being audited, access to obtain secondary data needed, licensing in carrying out measurements and taking pictures.

MC Building Technical Data

The MC building is a 4-storey building that functions as a rector's building. That is the building that serves to support all activities in STIMART "AMNI" Semarang, base on division of space in the buildings:

1. Total floor area : 1011 m²
2. Air-conditioned floor area : 918 m²
3. Floor area without air conditioning : 93 m²

The floor area with air conditioning in the MC building is 90,8 %, then the MC building can be categorized as a building with air conditioning.

a. Lighting Load Analysis

Arrangement the MC building lighting system in a more efficient direction can reduce energy consumption and peak load on the electrical system. The principle of saving energy in the MC building lighting system must refer to the provisions of the lighting guidelines on buildings. The energy efficiency level of the lighting system in the MC building is highly efficient in the category with the highest value of 1,5 W/m² and the lowest 4 W/m² with an average of 2,272 W/m². For the lighting level, it can be seen that the measurement results obtained are on average lower than the established ISO standard.

b. Cooling Load Analysis

The efficiency level of the AC system in the MC building is included in the efficient category with an average COP value of 2,777, EER 8,506 and kW / TR 1,016.

c. Office Equipment Electrical Consumption Analysis

The biggest electrical energy consumption in the MC building is computer equipment at 76% and dispensers at 20% of the total energy consumed by office equipment. To get efficiency in the use of office equipment, it is necessary to regulate the use of office equipment.

d. Energy Use Intensity (EUI)

The total consumption of electrical energy in the MC building in July 2019 was 12288,367 W with a total building area of 1011 m² then it was obtained:

$$EUI = \frac{12288.367}{1011}$$

$$= 12{,}154 \text{ kWh/m}^2$$

From daily load measurements, it is obtained that EUI on MC buildings is 12,154 kWh/m², so in the air-conditioned building category the MC building is stated to be quite efficient.

Alternative Electric Energy Efficiency

a. Compile AHP Hierarchy

Hierarchy in this study there are 2 levels, namely level 0, level 1 and level 2. Where the explanation for each level is as follows:

1. *Level* 0 is the goal to be achieved, where the objective in this study is to determine the Efficiency Recommendations for the Use of Electric Power in the MC building. The reason for choosing the title is to know the profile of energy use and energy saving opportunities in MC building to minimize the use of electrical energy.
2. *Level* 1 is a factor that influences energy efficiency. These factors include:
    a. Arrangement of working hours, Arrangement of good working hours according to employee activity time. Use of office equipment outside the specified hours can cause waste.
    b. Lamp settings, the level of lighting in the MC building compared to ISO is still lacking so there needs to be an increase in lighting systems in accordance with ISO standards without causing energy waste.
    c. Air conditioning settings, MC building based on its classification are included as air-conditioned buildings so it is necessary to arrange so there is no waste. Based on the existing measurements, the use of AC in the MC building is efficient, but based on the level of comfort compared to ISO, it is still lacking, so there is a need for regulation.
    d. Office equipment usage settings, habit or cultural attitudes and actions against the use of electrical equipment in accordance with the needs are very important. Waste often occurs as a result of employees turning on existing office equipment and not turning it off when not in use.
    e. Placement of electrical equipment and facilities, by placing electrical equipment and good facilities in the MC building as well as placing an AC compressor in a place that is not exposed to sunlight and placing translucent glass in locations exposed to light can reduce the use of lights thereby increasing energy efficiency.
    f. New technology, replacement of outdated old equipment and replacing them with new equipment with more efficient technology can improve electrical energy efficiency.
3. *Level* 2, is a policy system that will be chosen by the management in order of priority to make savings including there are 3 which is:
    a. Arrangements for utilization of electrical equipment by employee, this can be done by conducting socialization about the use of lights, air conditioners and all forms of office facilities that are sourced from electricity. And supported by the SOP policy on the use of facilities during business hours or while in the office. Another thing that can be done by conducting environmental management offices and facilities work properly in order to maximize performance and streamline employee time and energy on employees .
    b. Maintenance of existing equipment, these actions are actions that do not need to spend a large investment. To keep that old equipment is saving energy is to maintain the function of the equipment as it is in the condition they are new, namely the holding of maintenance or checking facilities offices as well as cleaning of lamps, air

conditioning maintenance periodically and checking the equipment of electricity there.

c. Utilization of new energy-saving technologies, this policy is need for huge investment to buy equipment new energy efficient as well as infringing entire illumination with LED lights, replacement of air-conditioning systems (AC) by the inverter system with a value of COP and EER high and the replacement of the entire new office equipment that is not yet energy efficient with more energy efficient.

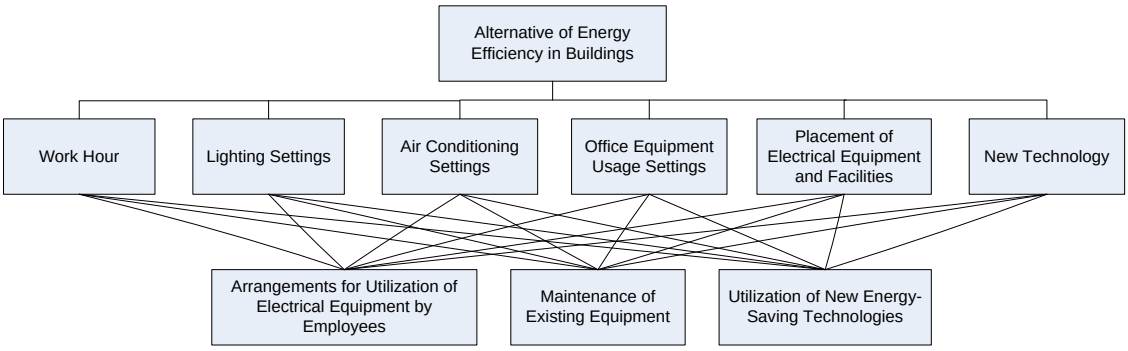

Figure 1. Energy Efficiency Hierarchy Structure of the MC Building

b. Processing AHP Assessment Weight

The calculation of priorities and consistency tests are carried out by weighting each criterion, weighting is carried out based on the results of audits carried out and also based on considerations from building management.

Table 1. Weighting of *Level* 1 Hierarchy Criteria

Criteria	Working hours	Lighting	AC	Equipment	Placement	Technology
Working hours	1	2	2	0.5	7	7
Lightning	0.5	1	0.5	0.2	3	3
AC	0.5	2	1	0.5	3	5
Equipment	2	5	2	1	5	7
Placement	0.143	0.333	0.333	0.2	1	2
Technology	0.143	0.2	0.2	0.143	2	1

Table 2. Normalization Matriks

Criteria	Vector Eigen						Total
Working hours	0.233	0.190	0.331	0.197	0.333	0.280	1.565
Lighting	0.117	0.095	0.083	0.079	0.143	0.120	0.636
AC	0.117	0.190	0.166	0.197	0.143	0.200	1.012
Equipment	0.467	0.475	0.331	0.393	0.238	0.280	2.184
Placement	0.033	0.032	0.055	0.079	0.048	0.080	0.326
Technology	0.033	0.019	0.033	0.056	0.095	0.040	0.277

c. Calculation of Consistency Value

Table 3. Consistency Testing

Criteria	Number of Row	Weight	Vector Eigen	λ Max
Working hours	4.286	0.261	1.565	1.118
Lightning	10.533	0.106	0.636	1.117
AC	6.033	0.169	1.012	1.017
Equipment	2.543	0.364	2.184	0.926
Placement	21	0.054	0.326	1.143
Technology	25	0.046	0.277	1.154

n = 6
λ Max = 6,474

$$CI = \frac{\lambda Max - n}{n-1} = \frac{6{,}4736411-6}{6-1} = 0.095$$

$$CR = \frac{CI}{RI} = \frac{0.094728}{1{,}24} = 0.0766$$

Based on the data processing, priority weighting results obtained on the MC building energy efficiency factor of 0.095 or 9.5% with a consistency ratio of 0.0766 or 7.66% where 7.66% ≤ 10% which means it can be said that the consistency assessment the weight between energy efficiency factors in the MC building is acceptable.

The next step is to calculate the weight of the savings system with a pair wise comparison of each savings system at level 2 with the same calculation steps as the previous processing. Based on the results of weight processing for the assessment of savings system solutions, then a comparison between the weights of each factor and the savings system is calculated as follows:

Table 4. Processing results weights between electric energy efficiency

Criteria	Arrangements for utilization of electrical equipment by employee	Maintenance of existing equipment	Utilization of new energy-saving technologies	Value
Arrangement of working hours	0.309	0.581	0.11	0.261
Lamp settings	0.309	0.581	0.11	0.106
AC settings	0.164	0.297	0.539	0.169
Office equipment usage settings	0.633	0.26	0.106	0.364
Placement of electrical equipment and facilities	0.669	0.243	0.088	0.054
New technology	0.122	0.23	0.648	0.046

Table 5. Final results

Criteria	Results	%	Rank
Arrangements for utilization of electrical equipment by employee	0.485	48,5	1
Maintenance of existing equipment	0.311	31,1	2
Utilization of new energy saving technologies	0.204	20,4	3

Based on data processing using the AHP method, obtained priority order of energy efficiency that can be selected as a recommendation for Management Center Building are:

1. Arrangements for utilization of electrical equipment by employee is 48.5%
2. Maintenance of existing equipment is 31.1%
3. Utilization of new energy saving technologies is 20.4%

d. Validation Using *Expert Choice Software 11*

Validation of calculation of pair wise comparison of criteria with alternatives and criteria with goals *(goals)* using the AHP method is done using the *Expert Choice 11* assistive program.

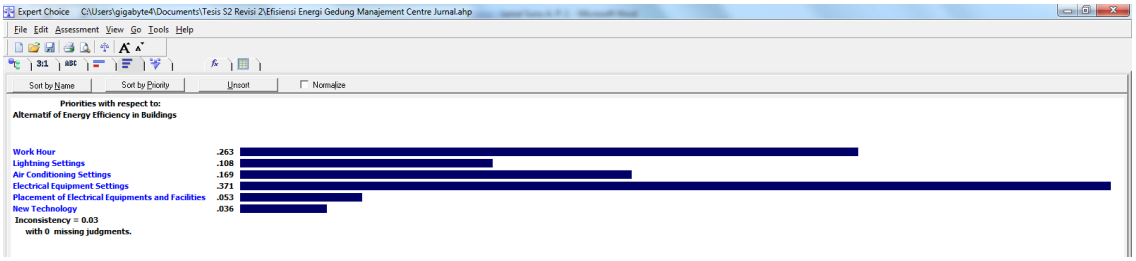

Figure 2. AHP Synthesis Results with *Expert Choice 11*

Dynamic Sensitivity for nodes below: Alternatif of Energy Efficiency in Buildings

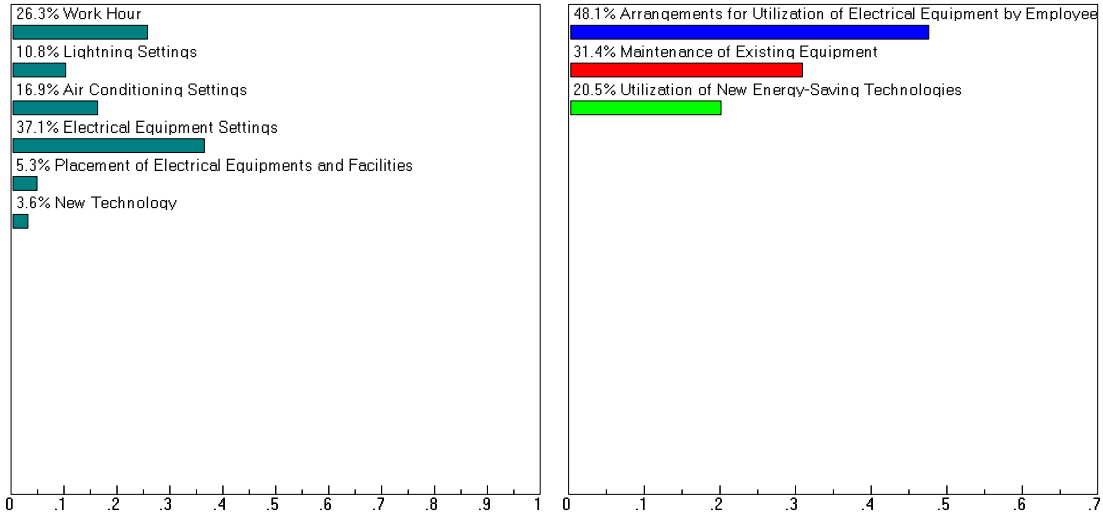

Figure 3. Percentage of Final Value from AHP Calculation

Based on the results obtained by comparison of manual calculation of criteria against goals with calculations using *Expert Choice 11 software,* a fairly small difference was found in the office equipment usage settings by 0.007, arrangement of working hours by 0.002, lamp settings by 0.002, Placement of electrical equipment and facilities by 0.001 and new technology by 0.010.

4. Conclusion

From the daily load measurements it is obtained that EUI MC building is 12,154 kWh / m², so based on ISO the air-conditioned building category of MC building is included in the efficient enough category so that through building maintenance and energy equipment energy efficiency can still be improved. The operation and maintenance of the building has not yet considered the principles of energy conservation. The forms of waste that occur in the MC building are not turning off the lighting when during recess, do not turn off the cooling device during recess, turning on lighting equipment in rooms that are rarely used, there are no regulations regarding the use of facilities in the MC building, there is no policy of electricity utilization in the MC building. The results of the AHP analysis and synthesis of the results obtained in the priority proposals for alternative electrical energy efficiency in the MC building with a sequence of weight values are: (1) Regulations on the utilization of office facilities by 48.5%, (2) Maintenance of equipment that has amounted to 31.1 %, Utilization of new energy saving technologies by 20.4%. The results of AHP analysis and synthesis with the help of the Expert Choice 11 program are: (1) Arrangement of office facility utilization by 48.1%, (2) Maintenance of equipment that has amounted to 31.4%, Utilization of new energy-saving technologies by 20.6% . The results obtained from manual calculations and calculations using Expert Choice 11 software are equivalent.

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