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PROMETHEE Method for Prioritization of Electrical Energy Audit In Industry

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Abstract

The problem of electricity in industry is the increasing consumption of electrical energy which results in increasing electricity consumption costs. The solution is how to reduce electrical energy consumption in the factory. The first step is to conduct an electrical energy audit. This research discusses electrical energy audits in industry with the aim of providing recommendations for electrical energy efficiency. The model is determined as an industrial electrical system complete with an electrical loading system. Parameters determined: production machinery, lighting systems, office support equipment, clean water pumps and air conditioners. The PROMETHEE method was used for prioritization in selecting from several alternative energy-saving opportunities. The research stages began with an initial energy audit, calculation of energy consumption intensity (IKE), recapitulation of electrical energy consumption, determination of energy saving opportunities, and PROMETHEE calculation. The PROMETHEE method used with 3 (three) alternatives, namely energy saving opportunities at no cost, low costs energy saving opportunities and high costs energy saving opportunities. As the research object, only the production building at PT Hop Lun Indonesia (HLI), Semarang, Indonesia was determined. The results show that PROMETHEE can be used for electrical energy audits in industry. This is evidenced by the prioritisation of the best recommendation results from the three alternatives, namely the first order in low-cost energy saving opportunities by replacing the type of LED lamp that has the potential to save energy by 2,723 KWH/day, the second order of energy saving opportunities at no cost by socializing to all employees regarding energy savings and conducting periodic maintenance.

Introduction

The garment industry has a high dependence on electrical energy to support its operational activities, including production processes, office administration, and building maintenance. Almost all garment industry equipment uses electricity as the primary energy source. As production scales increase, electricity consumption also rises in direct proportion to the industry's operational needs. Uncontrolled electricity usage can lead to a surge in operational costs, making it necessary to implement appropriate energy efficiency strategies to reduce wasteful energy consumption (Oró et al., 2015; Harvey, 2009; Hossain et al., 2023). HLI is a garment industry located in Semarang Regency, Indonesian, with a building area of 9,844 m² and an installed electrical capacity of 555 KVA. One of the main challenges faced by the company is the increasing electricity consumption, which impacts operational costs.

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The company's main electrical loads include production machines such as sewing, cutting, and molding areas, as well as lighting systems, office equipment, clean water pumps, and air conditioning units (Nord-Ågren, 2002; De Fonseka, 2023; Talampas, 2019). To address this issue, an energy-saving strategy is needed by conducting an electrical energy audit. The purpose of the energy audit is to evaluate energy consumption patterns, identify energy-saving opportunities, and provide efficiency recommendations to support energy conservation (Saputra, 2022; Moya et al., 2016; Jadhav et al., 2017; Annunziata et al., 2014). One of the methods used in the energy audit is the calculation of Energy Consumption Intensity (ECI) to determine the efficiency level of energy use in an industry. Poor energy management can lead to excessive electricity consumption, wastage, and uncontrolled increases in operational costs (Yuliantoro et al., 2019; Hossain et al., 2023; Bakare et al., 2023; Mohammadi et al., 2018). His study focuses on analyzing electricity consumption based on an energy audit in the garment industry. The PROMETHEE method is used to determine priorities in selecting energy-saving alternatives.

Several previous studies have examined energy audits using various approaches, including the use of the ECI method in initial energy audits (Choir & Irawan, 2023; Bruni et al., 2021; Thollander & Palm, 2012), audits and analysis of energy consumption intensity and energy-saving opportunities (Jamal et al., 2019), electrical energy audit based on fuzzy logic for hospital building (Pancarrani et al., 2023), and decision support system based on fuzzy logic for energy auditing in hospital building (Noor et al., 2024). In this study, the research object is HLI, which was selected due to its high electricity consumption ratio across various main electrical loads. The results of this study are expected to provide effective energy efficiency recommendations for the garment industry in optimizing electricity consumption and reducing operational costs.

Methods

Electricity Consumption Data

Founded in 2011, HLI is a leading manufacturer and exporter of women's lingerie and swimwear. The company operates on a 54,032 m² site, with a 9,982 m² production facility that includes a single floor and a mezzanine.

Table 1. Composition of HLI

Area	Size (m^2)	Percentage
Ground Floor Production Area	8,213.00	82%
Ground Floor Production Admin & Office	1,125.00	11%
Mezzanine Office	644.00	7%
Total	**9,982.00**	**100%**

HLI's electricity needs are supplied by Indonesian Electric Company with an installed capacity of 555 KVA to power various facilities, including lighting, air conditioning, clean water pumps, office utilities, the production building, the canteen, and other support facilities. The company also operates a 1,000 KVA power transformer and a 600 KVA generator. Energy consumption in the production building for the productions area and office equipment.

Table 2. Electrical Loads of SDP in Production Building

Sub Distibution Panel	Electrical Loads (KW)
Ground Floor Production Area	969.025
Ground Floor Production Admin & Office	50.515
Mezzanine Office	32.930
Total	**1,052.470**

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Table 2 shows that total of electrical loads in building production at HLI is 1,052.470 KW. From January to December 2023, total electricity consumption reached approximately 4,000,000 KWH, averaging 348,984 KWH per month. The highest consumption occurred in October, reaching 374,800 KWH, as shown in Table 3.

Table 3. Energy Consumption Data (KWH) January–December 2023

Month	KWH 2023
January	313,607.68
February	334,644.84
March	344,204.32
April	221,817.76
Mey	359,502.64
Juni	328,906.00
July	353,763.80
August	336,563.04
September	353,764.60
October	384,360.77
November	374,800.96
December	353,763.80
Total Consumption	4,059,700.21
Average/ Year	348,984.06

Research Model

The research model is designed to provide a systematic guide for conducting the study. The research model is shown in Figure 1.

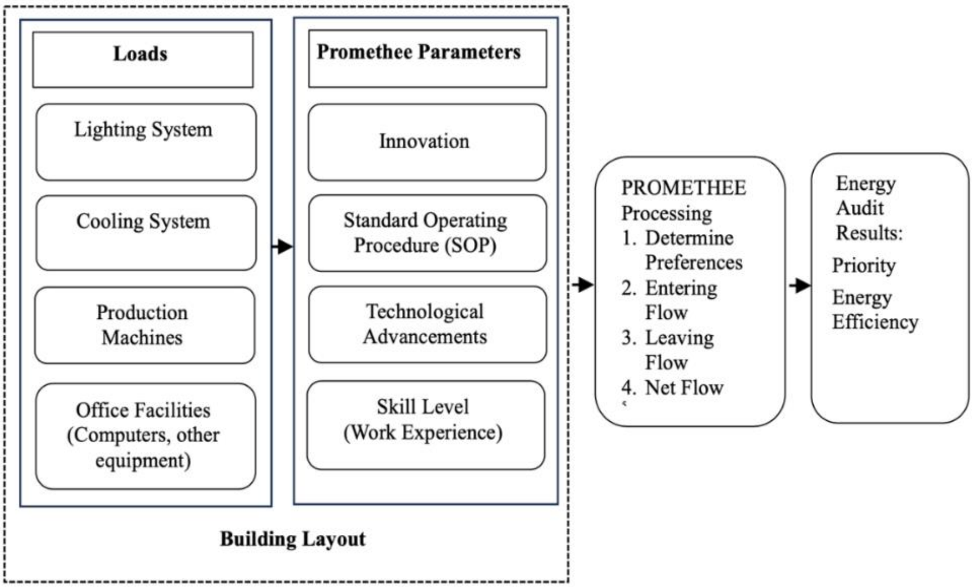

Figure 1. Research Model

Energy Consumption Intensity (ECI)

According to Indonesian National Standard (SNI 6196:2011) on energy audit procedures for buildings, Energy Consumption Intensity (ECI) is defined as the ratio between energy consumption and building area over a specific period (National Standardization Agency of Indonesia, 2011). The calculation of ECI aims to evaluate the efficiency of energy usage in a building. The ECI value of a building can be determined using equation (1).

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The determination of Electrical Energy Consumption Intensity values has been implemented in various countries (ASEAN, APEC) and is expressed in KWH/m² per year. To establish standard regulations, the ECI values are based on research conducted by ASEAN-USAID (US Agency for International Development), with a report published in 1992. These values were adopted in Indonesian National Standard (SNI 05-3052-1992), with details provided in Table 4 (Indonesian National Standard, 2000).

Table 4. Standard Criteria for Energy Consumption Intensity

No	Building Type	Standard ECI (KWH/m2/year)
1	Commercial (Company)	240
2	Hypermarket/Supermarket	330
3	Apartemen/ Hotel	300
4	Hospital	380

Meanwhile, the standard values for monthly and annual electricity consumption intensity are presented in Table 5 (Suharto, 2016).

Table 5. Electrical Energy Consumption Intensity (ECI) Values

(KWH/m²/month)	(KWH/m²year)	Criteria
4.17 – 7.92	50.04 – 93.04	Very Efficient
7.92 – 12.08	93.04 – 144.96	Efficient
12.08 – 14.58	144.96 – 174.96	Fairly Efficient
14.58 – 19.17	174.96 – 230.04	Slightly Wasteful
19.17 – 23.75	230.04 – 285.00	Wasteful
23.75 – 37.50	285.00 – 450.00	Very Wasteful

As a guideline, standard energy consumption intensity values for buildings in Indonesia have been established by the Ministry of National Education of the Republic of Indonesia in 2004, as shown in Table 6 (Iriantoro, 2016).

Table 6. Standard ECI for Buildings in Indonesia

Criteria	Air-Conditioned Room (KWH/m²/month)	Non-Air-Conditioned Room (KWH/m²/month)
Very Efficient	4.17 – 7.92	0.84 – 1.67
Efficient	7.92 – 12.08	1.67 – 2.50
Fairly Efficient	12.08 – 14.58	–
Slightly Wasteful	14.58 – 19.17	–
Wasteful	19.17 – 23.75	2.50 – 3.34
Very Wasteful	23.75 – 37.75	3.34 – 4.17

PROMETHEE (Preference Ranking Organization for Enrichment Evaluation)

PROMETHEE is one of the methods used in Multi-Criteria Decision Making (MCDM) analysis to determine or rank a multi-criteria analysis (Imandasari et al., 2018). In the first phase, the outranking relationship values are established based on the dominance of each criterion. The preference index is determined, and the outranking values are graphically presented according to the decision-maker's preferences. The basic data for evaluation using the PROMETHEE method is presented in Table 7.

Table 7. Basic Data for PROMETHEE

	f1(.)	f2(.)	……….	Fj(.)	………..	fk(.)
a1	f1(a1)	f2(a1)	……….	Fj(a1)	……….	Fk(a1)
a2	f1(a2)	f2(a2)	……….	Fj(a2)	……….	Fk(a2)

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Ai	f1(ai)	f2(ai)	……….	Fj(ai)	……….	Fk(ai)
An	f1(an)	f2(an)	……….	Fj(an)	……….	Fk(an)

The preference structure is built based on the criteria in equation (2).

The PROMETHEE method can be implemented through several stages (Imandasari et al., 2018): 1) Determine the criteria to be used along with the weight for each criterion; 2) Identify all available alternatives; 3) Accurately determine the preference type for each criterion. There are six commonly used preference types, as shown in equations (3) until (8).

Usual Criterian

H (d) = (3)

Quasi Criterian/ U-Shape

H (d) = (4)

Linier Criterian/ V-Shape

H (d) = (5)

Level Criterian

H (d) = (6)

Criteria with linear preference and no distinct area

H (d) = (7)

Gaussian Criteria

H (d) = 1 – exp (8)

Calculating the preference for each criterion. The preference for each criterion is determined by comparing each pair of alternatives, which is the difference between the evaluation values of two alternatives for a specific criterion. The multi-criteria preference index is determined based on the weighted average of the preference function, as shown in equation (9).

(a,b) = Pi (a,b): (9)

Calculating the preference direction based on the leaving flow and entering flow index values, which can be determined using an equation, while the entering flow value is calculated using another equation (10) and (11).

Φ^+ (a) = (a,b) (10)

Φ^- (a) = (a,b) (11)

Net Flow is calculated using an equation (12)

Φ (a) = Φ^+ (a) – Φ^- (a) (12)

Rank the alternatives based on net flow (ranking).

The net flow results of all alternatives are ranked from the highest to the lowest value. The best alternative is the one with the highest net flow value

Research Steps

The research flowchart for electrical energy audits using the PROMETHEE method is shown in Figure 2.

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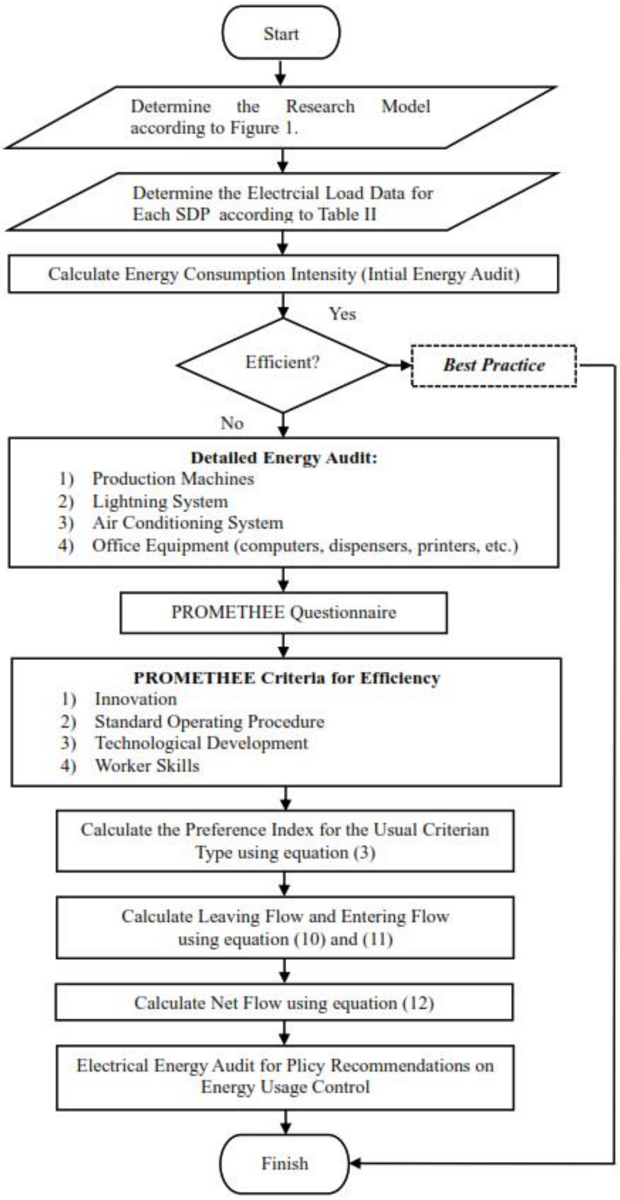

Figure 2. Flowchart Research Steps

Results and Discussion

Calculation of Energy Consumption Intensity (ECI)

Referring to the research model in Figure 1 and the electrical load data in Table II, the next step is to calculate the energy consumption in the production building of HLI based on the initial energy audit. The first step in calculating ECI (Energy Consumption Intensity) in this study is determining the ECI of electrical power from January to December 2023, as shown in Table 8.

Table 8. Calculation of Monthly Electrical Power ECI for the Year 2023

Month	KWH 2023	ECI/ Month	Result
January	313,607.68	31.42	Very Wasteful
February	334,644.84	33.52	Very Wasteful
March	344,204.32	34.48	Very Wasteful
April	221,817.76	22.22	Very Wasteful
Mey	359,502.64	36.02	Very Wasteful
Juni	328,906.00	32.95	Very Wasteful

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July	353,763.80	35.44	Very Wasteful
August	336,563.04	33.72	Very Wasteful
September	353,764.60	35.44	Very Wasteful
October	384,360.77	38.51	Very Wasteful
November	374,800.96	37.55	Very Wasteful
December	353,763.80	37.54	Very Wasteful
Total Consumption	**4,059,700.21**		
Average/ Year	**348,984.06**		

The electricity consumption of the production building at HLI over one year amounted to 4,059,700.21 KWH, with a building area of 9,982 m². The following is the ECI calculation for the year 2023 in the production building of HLI by reffering to equation (1).

= 406,70 KWH/ m^2/ year

The ECI calculation results for the production building at HLI do not comply with the standard in Table 7 and fall into the 'Very Wasteful' category. Therefore, a detailed energy audit is the next step

Detailed Energy Audit

Electrical Energy Consumption of the Lighting System

The total electrical energy consumption from the lighting system across all areas and rooms in the production building is presented in Table 9.

Table 9. Total of Lamp (KWH/ day)

No.	Entire Area & Rooms	Ground Floor Production (KWH)	Ground Floor Office (KWH)	Mezzanine Floor Office (KWH)	Energy (KWH/ day)
1.	Total	5,189.440	139.360	36.720	5,365.520
2.	Percentage	96.71%	2.60%	0.69%	100%

Table 9 shows the total electrical energy consumption of the lighting system in the production area on the ground floor, amounting to 5,189.440 KWH/day, accounting for 96.71%. The ground floor office consumes 139.360 KWH/day, representing 2.60%, while the mezzanine office consumes 36.720 KWH/day, making up 0.69%. There are three types of lamps used: TL-D, Highbay, and LED Bulb, as shown in Table 10.

Table 10. Percentage and Number of Lamp Usage

No.	Lamp Type	Lamp Specification	Quantity (pcs)	Percentage
1.	TL-D	TL-D 1 x 80	4,134	97.96%
2.	LED	High Bay LED	36	0.86%
		Bulb LED	50	1.18%
	Total		**4,220**	**100.00%**

Table 10 shows that the total number of lamps installed in the production building is 4,220 units, resulting in an electrical energy consumption of 5,365.520 KWH/day for the lighting system. The total percentage of TL-D lamp usage is 96.71%, Highbay LED lamps account for 0.86%, and Bulb LED lamps make up 1.18%.

Electrical Energy Consumption of the Air Conditioning System

Table 11. Electrical Energy Consumption of the Air Conditioning System

No.	Entire Rooms	Ground Floor (KWH)	Mezzanine Floor (KWH)	Energi (KWH/ day)
1.	Total	434.640	146.460	581.100

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2.	Percentage	74.80%	25.20%	100%

Table 11 shows that the total electrical energy consumption of the air conditioning system is 581.100 KWH/day. The energy consumption on the ground floor is 434.640 KWH/day, accounting for 74.80%, while the mezzanine floor consumes 146.460 KWH/day, representing 25.20%.

Electrical Energy Consumption of Production Machines

The total electrical energy consumption of production machines is determined by multiplying the power of each machine in the production area by the daily operational hours (16 hours). This is detailed in Table 12.

Table 12. Electrical Energy Consumption of Production Machines

No	Area Name	Number of Mechines	Total Energy (KWH/ days)
1.	Sewing Area	1,239	8,270.880
2.	Moulding Area	38	524.800
3.	Cutting Area	26	272.320
4.	Pakcing Area	3	24.000
5.	Quality Control Room	2	32.000
	Total	**1,308**	**9,124.000**

Table 12 shows that the total electrical energy consumption of production machines is 9,124.000 KWH/day. The power and number of machines in each production area vary according to operational needs.

Electrical Energy Consumption of Office Facilities

The operational hours of office facilities follow the working hours of each area or room during the production process. The calculation of electrical energy consumption for office facilities is detailed in Table 13.

Table 13. Electrical Energy Consumption of Office Facilities

No	Building	Total Power (watt)	Total Energy (KWH/ day)
1.	Production	7,455	227.700

Table 13 shows that the electrical energy consumption of office facilities in the Production Building is 7,455 Watts, with a total energy usage of 227.700 KWH/day. This includes computers, dispensers, printers, exhaust fans, monitors, projectors, electronic equipments, and refrigerators

Total of Electrical Energy Consumption

Referring to Tables 9 to 13, a recapitulation of the annual electrical energy consumption (KWH/year) from the lighting system, air conditioning system, production machines, and office facilities is presented in Table 14.

Table 14. Total of Electrical Energi Consumption

No	Month	Equipment Category (KWH/ month)			
		Lighting System (KWH)	AC System (KWH)	Production Machines (KWH)	Office Facilities (KWH)
1	January	109,976.00	11,906.16	187,042.00	4,683.52
2	February	117,357.88	12,706.77	199,587.50	4,992.69
3	March	120,707.04	13,068.36	205,920.00	5,138.92
4	April	77,782.88	8,419.56	132,398.00	3,317.32
5	Mey	126,072.56	13,649.46	214,414.00	5,366.62
6	Jue	115,341.52	12,487.26	196,166.00	4,911.22

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7	July	124,056.20	13,429.95	210,992.50	5,285.15
8	August	131,438.08	14,230.56	223,538.00	5,594.32
9	September	124,057.00	13,429.95	210,992.50	5,285.15
10	October	134,787.24	14,592.15	229,240.50	5,740.55
11	November	131,438.08	14,230.56	223,538.00	5,594.32
12	December	124,056.20	13,429.95	210,992.50	5,285.15
Total Consumption (KWH/ year)		**1,437,070.68**	**155,580.69**	**2,444,091.50**	**61,194.93**

Table 14 shows that the highest annual electrical energy consumption (KWH/year) among the four load aspects in the production building comes from production machines, totaling 1,437,070.68 KWH/year. Meanwhile, the lowest annual electrical energy consumption (KWH/year) is from office facilities, amounting to 61,194.93 KWH/year.

Energy Saving Opportunities

The calculation results of energy consumption intensity (ECI) at HLI's production building fall into the very wasteful category, making energy efficiency necessary through several proposed measures:

Zero-Cost Energy Saving Opportunities

This can be achieved by changing employee behavior patterns through the implementation of energy-saving actions, including: a) Posting stickers with energy-saving reminders on various components and equipment in both production and office areas; b) Socializing and providing training to employees to raise awareness about turning off equipment when not in use; c) Implementing Preventive Maintenance through regular visual inspections of electrical equipment; d) Low-Cost Energy Saving Opportunities

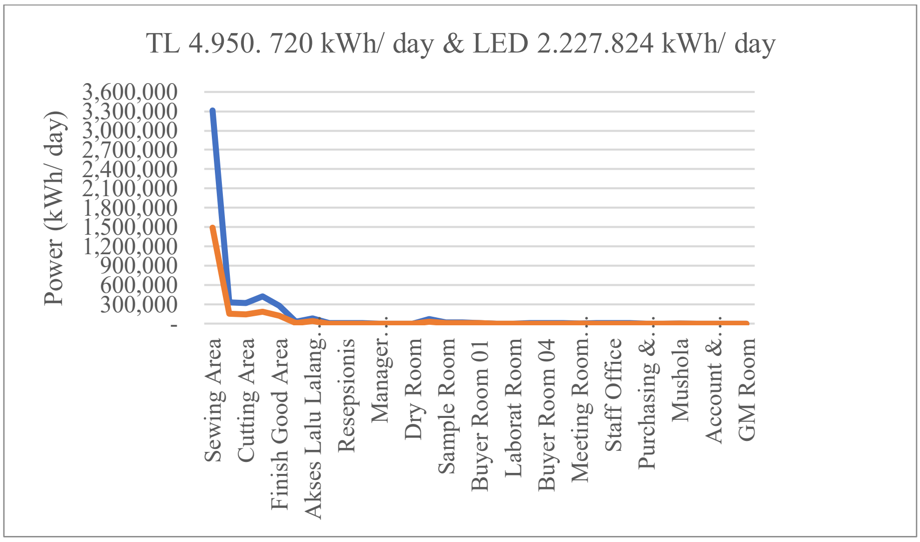

Figure 3. Comparison of KWH Consumption Between TL and LED TL Lamps

This energy-saving approach requires minimal costs and has the potential to reduce energy consumption by 5-15%. One of the efficiency efforts includes replacing TL-D lamps with LED lamps. Several areas in the production building have already adopted LED bulb lighting, including parts of the Reception Area, Conference Room, Pantry, Storage, and Mezzanine Floor Toilets. A comparative energy consumption graph for the lighting system before and after the LED lamp replacement is shown in Figure 3.

Figure 3 illustrates the efficiency of lighting after replacing conventional TL lamps with LED TL lamps, reducing energy consumption from 4,950 KWH/day to 2,227 KWH/day. After

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replacement = Σ energy consumption before replacement – Σ energy consumption after replacement = Σ 4.950 KWH/ day – 2.227 KWH/ day= 2.723 KWH/ day

High-Cost Energy Saving Opportunities

Although it requires a high investment cost, this efficiency measure can achieve 15-30% energy savings. One approach is upgrading the air conditioning system by replacing conventional AC units with inverter AC units. A comparison graph of electrical energy consumption between inverter and non-inverter air conditioning systems is shown in Figure 4.

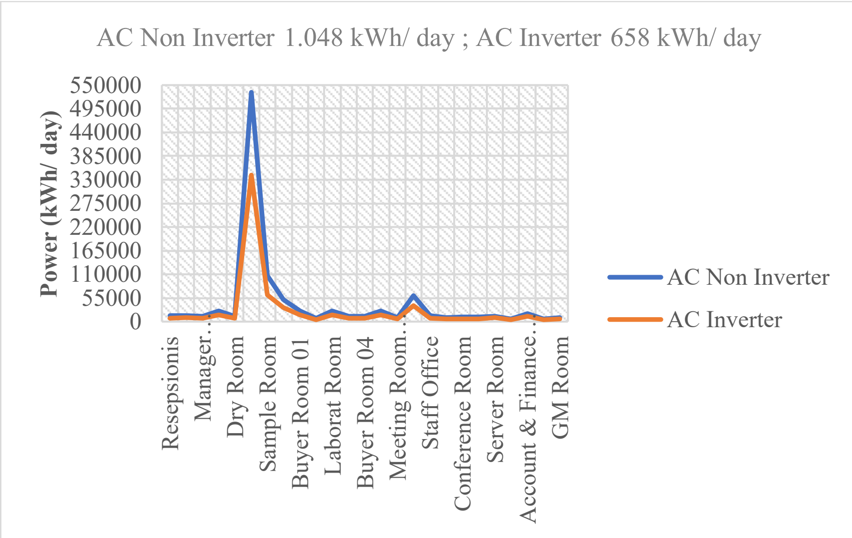

Figure 4. Comparison of KWH Consumption Between Non-Inverter and Inverter AC Units

Figure 4 explains that the efficiency of the air conditioning system improved after replacing conventional AC units with inverter AC units, reducing energy consumption from 1,048 KWH/day to 658 KWH/day.

After replacement= Σ energy consumption before replacement– Σ energy consumption after replacement = Σ 1,048 KWH/ day – 658 KWH/ day= 390 KWH/ day

The efficiency gained from replacing conventional AC units with inverter AC units amounts to 390 KWH/day. The highest level of electrical energy consumption occurs in production machines, many of which still use induction motors. The electrical energy consumption of the production machine is 570.25 kW / day which per day is 24 hours, the calculation is obtained. = 23,76 kW/ hour

The result of cos φ digital power factor with a total power factor value of 0.78, then the apparent power used:

= = 30,46 kW/ hour

The cos φ value can be improved by adding capacitor banks. Power improvements are able to achieve electrical energy efficiency which is due to being able to reduce energy losses in the electricity system, so as to save electrical energy. The amount of capacity value on the power capacitor needed for the electrical system in the garment industry.

Power capacitor capacity = apparent power used x 62% = 30,46 x 62% = 18,89 kVAR

The capacity value of power capacitors for power factor improvement in order to achieve the level of electrical energy efficiency according to the capacity available in the market is 20 kVAR, organized as follows 2 x (5+5) = 20 kVAR, dan dipasang secara paralel terhadap beban.

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PROMETHEE Calculation

Questionnaire Completion (Energy Saving Opportunity Facilities)

The questionnaire aims to gather suggestions on energy-saving opportunities, with responses collected from three respondents from the electrical and production departments at HLI. The questionnaire results from these three respondents are compiled using the geometric mean. The summary matrix of the energy-saving opportunity questionnaire from respondents 1 to 3 is shown in Table 15.

Table 15. Summary Matrix of the Energi-Saving Opportunity Questionnaire by Responden

No	Criteria	Unit	Energi-Saving Opportunity Sugestions (Geometri Mean)		
			No Cost (A1)	Low Cost (A2)	High Cost (A3)
1	Cost	Scale 1-5	2,8	4,2	2,0
2	Standard Operating Procedure	Scale 1-5	4,3	2,8	1,0
3	Technological Development	Scale 1-5	1,5	4,0	3,1
4	Workforce Skills	Scale 1-5	3,6	4,6	1,0

Preference Indeks Calculation and Multicriteria

The next step after obtaining the questionnaire results is to compare the alternatives by subtracting the values of alternatives A1 and A2, and so on. Then, the preference values are calculated according to the type of preference used. The calculation results for criteria K1 to K4, along with the preference value comparisons between alternatives shown in Table 16.

Table 16. Preference Comparison Between Alternatives

Criteria	A1, A2	A1, A3	A2, A1	A2, A3	A3, A1	A3, A2
K1	-1,4	0,8	1,4	2,2	-0,8	-2,2
K2	1,5	1,8	1	1,8	-3,3	-1,8
K3	-2,5	0,9	3,1	0,9	1,6	-0,9
K4	-1	3,6	1	3,6	-2,6	-3,6

Table 16 explains the preference comparison results between alternatives, which are presented in matrix form using PROMETHEE Usual Criterion according to equation (3). In this method, the decision-maker assigns absolute preference to alternatives with better values. The results of the calculation of preferences K1, K2, and K3 then calculate the multicriteria preference index, where the total number of criteria is multiplied by the preference values from the alternative comparison results. The results of the multicriteria preference index calculation are then placed into a matrix, as shown in Table 17.

Table 17. Multicriteria Selection Indicators

	A1	A2	A3
A1	0	0,25	0,75
A2	0,75	0	1,00
A3	0,25	0	0

Table 17 shows the calculation results of the multicriteria preference index, with the highest value at π(A2’, A3’) and the lowest multicriteria preference index value at π(A3’, A2’).

Leaving Flow and Entering Flow Calculation

The Entering Flow calculation is performed by summing the values of the alternatives vertically and then dividing the result by the total number of alternatives minus one. The Leaving Flow and Entering Flow values for each alternative are presented in Table 18.

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Table 18. Results of Leaving Flow and Entering Flow Values

Alternatives	A1 (No Cost)	A2 (Low Cost)	A3 (High Cost)	Leaving Flow	Ranking
A1 (No Cost)	0	0,25	0,75	0,50	2
A2 (Los Cost)	0,75	0	1,00	0,88	1
A3 (High Cost)	0,25	0	0	0,13	3
Entering Flow	0,50	0,13	0,88		
Ranking	2	1	3		

Table 18 presents the calculation results of leaving flow and entering flow, with the next step being the ranking of alternatives. For the leaving flow values, the ranking is arranged from the highest value. Meanwhile, for the entering flow values, the ranking is arranged from the lowest value. To further verify the ranking results, the next step involves calculating the net flow value.

Net Flow Calculation

The Net Flow calculation is obtained by subtracting the entering flow from the leaving flow. This calculation aims to determine the final ranking of the alternatives used, as presented in Table 19.

Table 19. Net Flow Result Calculation

Alternatives	Leaving Flow	Entering Flow	Net Flow	Ranking
A1 (No Cost)	0,50	0,50	0	2
A2 (Low Cost)	0,88	0,13	0,75	1
A3 (High Cost)	0,13	0,88	-0,75	3

Table 19 shows the ranking of the selected or prioritized alternatives. Alternative A2, with a net flow value of 0.75, representing Low-Cost Energy-Saving Opportunity, ranks first. The second rank is Zero-Cost Energy-Saving Opportunity (A1) with a net flow value of 0. Meanwhile, the lowest-ranked alternative is High-Cost Energy-Saving Opportunity (A3) with a net flow value of -0.75.

Based on the results of the initial audit that the production building at HLI is categorized as very wasteful as evidenced in Table 8, so the next step is to conduct a detailed energy audit including: lighting systems, air conditioning systems, production machinery and office equipment aimed at optimizing electrical energy. There are three concepts in energy efficiency, namely: zero cost saving opportunities, low cost saving opportunities and high cost saving opportunities. The three concepts are then calculated using the PROMETHEE method to get the first choice priority in reducing electrical energy.

Conclusion

The calculation and efficiency analysis using the PROMETHEE method identified the best solution among the three alternatives: First Place is Zero-Cost Energy Saving Opportunity. This involves efficiency measures without any financial investment, such as awareness campaigns, training, and reminders to cultivate self-awareness in energy conservation. Additionally, regular preventive maintenance is implemented to prevent equipment failures that could lead to costly repairs. The Second place is Low-Cost Energy Saving Opportunity. This involves minimal financial investment, such as replacing 36-watt TL lamps with LED TL lamps, which has the potential to improve energy efficiency by 2,723 KWH/day. The last place is High-Cost Energy Saving Opportunity. This requires a high financial investment, such as replacing conventional air conditioners with inverter AC units, which can improve energy efficiency by 390 KWH/day. additional power capacitor capacity of 2 x (5+5) = 20

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kVAR which aims to reduce energy loss in the electrical system, so as to save electrical energy.

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