Jurnal Teknik Indonesia

Volume 5 Nomor 3 August 2026
https://jti.publicascientificsolution.com/index.php/rp

Case Study on Energy Consumption and Electrical Systems at an Integrated Industrial Oil and Gas Terminal

Luqvi Rizki Syahputra*, Agus Yulianto
Human Resource Development Center for Electricity, New and Renewable Energy, and Energy Conservation – Ministry of Energy and Mineral Resources, Indonesia
Email: luqitra@gmail.com*, joant818@gmail.com

Keywords:
Energy Consumption; Electrical Systems; Integrated Terminals; Industrial Oil and Gas

Abstract
The integrated oil and gas terminal is one of the facilities that has a considerable consumption of electrical energy because it supports the process of receiving, storing, and distributing fuel oil (BBM). Most of the energy consumption in the terminals comes from production equipment, specifically distribution pumps that operate continuously. However, there are still terminals that do not have a separation of energy use between production facilities and supporting facilities, making it difficult to evaluate energy efficiency. This study aims to analyze energy consumption patterns and electrical systems in integrated oil and gas terminals. This study uses a case study method with a quantitative descriptive approach. Research data was collected through observation, energy consumption measurement, documentation of operational data and electricity usage, and review of company documents. The results showed that energy consumption in integrated terminals was dominated by production facilities (67%), with production pumps as the main Significant Energy Use (SEU). The electricity system is supplied by PLN and supported by two generator units as a backup resource. The Energy Consumption Intensity (IKE) value of production facilities of 0.0019 GJ/KL/year is in the top 25% category, while supporting facilities of 1.05 GJ/m²/year are in the bottom 25% category. The basic analysis yielded a regression equation of $y = -19.59x + 927861$ with $R^2 = 0.7535$, and identified potential energy savings of 33.90% or 117,148 kWh per year through improved production pump efficiency and the implementation of rooftop solar photovoltaic (PV) panels. These findings show that energy audits are effective in identifying conservation opportunities and improving energy efficiency at integrated oil and gas terminals.

INTRODUCTION

In accordance with Government Regulation through Government Regulation No. 33 of 2023 where Energy Source Users and/or Industrial Sector Energy Users who use Energy greater than or equal to 4,000 (four thousand) equivalent tons of oil per year, are required to carry out energy conservation activities through energy management (Imtikhani et al., 2025). Energy Conservation is a systematic, planned, and integrated effort to conserve domestic energy resources and improve the efficiency of their utilization. Energy conservation programs or activities as intended can be carried out by one of them conducting an energy audit (Habib et al. 2026; Krarti 2020; Lawal et al. 2024). Energy audit activities are a process of evaluating energy utilization and identifying opportunities for energy savings as well as recommendations to improve efficiency for energy source users and energy users in the context of energy conservation (Teruna, 2019). The government targets potential savings in the industrial sector of 10-30%. Most of the energy sources used come from the supply of electricity (Santoso & Salim, 2019).

The government's energy use savings program against energy use inefficiency in the industrial sector is the main stream that encourages the need to implement energy saving and conservation (Sundaramoorthy et al., 2023). In addition, globally the biggest driving factor is the increase in greenhouse gas emissions arising from the burning of fossil fuels in industries and power sector plants, which requires oil and gas companies to reduce the rate of exhaust gas emissions to a minimum (Jarboui, 2021). PT ABC as one of the oil and gas companies in the country strives to manage energy consumption and minimize exhaust gases into the atmosphere in the context of energy conservation activities (Awow et al., 2025).

From this background, PT ABC views the need for an energy conservation program at the Integrated Terminal facility by carrying out energy audit activities. Energy audits are conducted based on observations and measurements that are appropriate and appropriate to energy performance with the aim of identifying, quantifying and reporting opportunities for energy performance savings. Through this energy audit activity, it is hoped that energy saving opportunities can be known and become an energy conservation program at PT. ABC Integrated Terminal (Anggriawan et al. 2025; Denis et al. 2022; Simsek et al. 2020; Wardhana et al. 2023; Zublie 2023).

The novelty of this study lies in its comprehensive energy audit approach using the ISO 50002 framework for an integrated oil and gas terminal. This study not only calculates the Energy Consumption Intensity (IKE) for production and supporting facilities, but also conducts an energy baseline analysis using regression, a CUSUM analysis to identify the best performance period, an evaluation of production pump performance as Significant Energy Use (SEU), and identification of potential energy savings through various scenarios including the implementation of rooftop solar power plants. This integrated approach differs from previous studies that generally only perform IKE calculations or analyze the electrical system separately (Fu et al. 2017; He et al. 2018; Mensah et al. 2016; Moslehi et al. 2018; Su et al. 2020).

In addition, the fulfillment of the Regulation of the Minister of Environment Number 01 of 2021 concerning the Company Performance Rating Assessment Program in Environmental Management is one of the government's efforts to encourage company compliance in environmental management (Aragòn-Correa et al. 2020; Bennett et al. 2017; Chang et al. 2015; Wu et al. 2018).

METHOD

This study used a case study method with a quantitative descriptive approach. The research data was collected through observation, energy consumption measurement, documentation of operational data and electricity use, and review of company documents. XYZ Integrated Terminal (IT) is one part of the Sub Holding Commercial and Trading Regional of Southern Sumatra - PT. ABC. Located on Jl. Province X. IT conducts business in the form of receiving, stockpiling and distributing fuel. The products managed for distribution are: Pertamax, Pertalite, Biosolar, Pertamina Dex, Dexlite and Avtur. IT distributes products to retail, industry, PT. PLN, DPPU and Ro-Ro Ships.

In the energy audit work at the Integrated Terminal, the energy audit team uses ISO 50002 guidelines and Standards, "Energy audits Requirements with guidance for use", which is a standard that defines minimum requirements that lead to the identification of opportunities for energy performance improvement. The ISO 50002 standard is a holistic approach to energy auditing that outlines a framework for organizational engagement, facility assessments, energy analysis, and plans to reduce energy consumption. Based on ISO 50002: 2014, energy audit is defined as a systematic analysis of energy use and energy consumption within the scope of the audit determined earlier.

An energy audit consists of a detailed analysis of the energy performance of an organization, equipment, system or process. Meanwhile, energy performance is a measurable result related to energy consumption, energy use, and energy efficiency. The results of the energy audit include current consumption and performance information, as well as providing recommendations on ranking improvement opportunities. The rating should be attributed to the impact on improved energy performance and the reduction of energy costs. In addition, energy audits can be used as an ingredient in energy reviews and can facilitate monitoring, measurement and analysis as described in ISO 50001, or they can be used separately.

RESULTS AND DISCUSSION

Energy Consumption Intensity / IKE

Energy Consumption Intensity / IKE is one of the indicators of energy performance. Energy performance indicators are a tool to determine the level of energy utilization performance in an industry/building. The energy use of a process/building can vary as a result of the type of process, type of product, area of the building, climate, number of inhabitants, hours of operation, and a number of other features.

Integrated Terminal Production Facility

Energy Consumption Intensity (IKE) is an overview of the total energy use of the unit of products produced, in this case the output of Throughput products distributed from various fuel products such as Pertamax, Pertalite, Biosolar, Dex, Dexlite and Avtur. Because product distribution activities in IT are only limited to distribution from storage tanks to filling sheds, tank cars and roro ships. The reference value of the IKE benchmark for IT refers to the energy intensity benchmarking from the regulation of the Director General of Pollution Control and Environmental Damage Number: P.11/PPKL/SET/KUM.1/9/2019 concerning benchmarking of the oil and gas distribution industry sector.

The following is a table of energy consumption, production and intensity in production activities in IT from 2022, 2023 and 2024 assuming 67% of energy in Production Facilities

Table 1. IKE Data of IT Production Facilities

Moon	Energy		Throughput	IKE
	kWh	GJ	KL	GJ/KL
Jan-22	25.342,75	91,23	52.998,01	0,00172
Feb-22	25.041,25	90,15	55.985,50	0,00161
Mar-22	20.185,76	72,67	58.854,60	0,00123
Apr-22	18.094,69	65,14	60.360,19	0,00108
May-22	20.190,45	72,69	51.761,29	0,00140
Jun-22	19.543,90	70,36	53.746,82	0,00131
Jul-22	18.989,14	68,36	52.535,28	0,00130
Aug-22	18.559,00	66,81	55.192,41	0,00121
Sep-22	17.807,26	64,11	43.228,24	0,00148
Oct-22	18.528,18	66,70	44.041,13	0,00151
Nov-22	17.280,64	62,21	44.198,62	0,00141
Dec-22	17.280,64	62,21	44.307,58	0,00140
Jan-23	17.456,85	62,84	43.268,92	0,00145
Feb-23	16.844,47	60,64	47.120,60	0,00129
Mar-23	16.592,55	59,73	46.560,74	0,00128
Apr-23	18.160,35	65,38	40.633,24	0,00161
May-23	17.820,66	64,15	45.621,96	0,00141
Jun-23	19.437,37	69,97	41.097,75	0,00170
Jul-23	19.057,48	68,61	44.307,11	0,00155
Aug-23	20.272,19	72,98	44.817,20	0,00163
Sep-23	21.005,17	75,62	43.271,39	0,00175
Oct-23	20.180,40	72,65	52.970,26	0,00137
Nov-23	20.877,87	75,16	44.747,85	0,00168
Dec-23	19.092,32	68,73	43.609,46	0,00158
Jan-24	19.235,03	69,25	40.902,67	0,00169
Feb-24	18.128,19	65,26	37.162,99	0,00176
Mar-24	18.353,98	66,07	39.032,77	0,00169
May-24	18.680,94	67,25	39.750,53	0,00169
Jun-24	20.028,31	72,10	37.188,10	0,00194
Jul-24	18.640,74	67,11	37.725,74	0,00178
Aug-24	18.463,86	66,47	33.302,59	0,00200
Sep-24	20.319,09	73,15	34.054,64	0,00215
Oct-24	20.372,02	73,34	34.759,47	0,00211
Nov-24	21.616,88	77,82	33.882,76	0,00230
Dec-24	18.724,49	67,41	36.325,94	0,00186

Table 2. IKE IT Production

Year	Throughput (KL)	Energy (GJ)	IKE (GJ/KL)
2022	617.209,65	852,64	0,0014
2023	538.026,50	816,47	0,0015
2024	445.149,33	833,42	0,0019

In the data above, IKE IT has increased from 2022 to 2024, which means that energy consumption per production unit (KL) is getting bigger from year to year. In 2022-2023 there was an increase of 7%, and in 2023-2024 there was an increase of 26%. The higher the IKE value, the more energy is wasted in producing each product KL. This increase could indicate a **decline in energy efficiency** in IT from 2022 to 2024.

Supporting Facilities / Office IT

Supporting Facilities / Office IT consists of office buildings used for office activities, testing / labs and document storage. Regarding IKE in Supporting Facilities / Office, because it uses 33% of total energy and has an air-conditioned floor area of 391.06 m2, it can be explained in the following table.

Table 3. IKE Data on IT Supporting Facilities

Year/Month	kWh	Giga Joule	IKE (GJ/M2)
Jan-22	12.482,25	44,94	0,1149
Feb-22	12.333,75	44,40	0,1135
Mar-22	9.942,24	35,79	0,0915
Apr-22	8.912,31	32,08	0,0820
May-22	9.944,55	35,80	0,0915
Jun-22	9.626,10	34,65	0,0886
Jul-22	9.352,86	33,67	0,0861
Aug-22	9.141,00	32,91	0,0841
Sep-22	8.770,74	31,57	0,0807
Oct-22	9.125,82	32,85	0,0840
Nov-22	8.511,36	30,64	0,0784
Dec-22	8.511,36	30,64	0,0784
Jan-23	8.598,15	30,95	0,0792
Feb-23	8.296,53	29,87	0,0764
Mar-23	8.172,45	29,42	0,0752
Apr-23	8.944,65	32,20	0,0823
May-23	8.777,34	31,60	0,0808
Jun-23	9.573,63	34,47	0,0881
Jul-23	9.386,52	33,79	0,0864
Aug-23	9.984,81	35,95	0,0919
Sep-23	10.345,83	37,24	0,0952
Oct-23	9.939,60	35,78	0,0915
Nov-23	10.283,13	37,02	0,0947
Dec-23	9.403,68	33,85	0,0866
Jan-24	9.473,97	34,11	0,0872
Feb-24	8.928,81	32,14	0,0822
Mar-24	9.040,02	32,54	0,0832
Apr-24	9.330,09	33,59	0,0859
May-24	9.201,06	33,12	0,0847
Jun-24	9.864,69	35,51	0,0908
Jul-24	9.181,26	33,05	0,0845
Aug-24	9.094,14	32,74	0,0837
Oct-24	10.033,98	36,12	0,0924
Nov-24	10.647,12	38,33	0,0980
Dec-24	9.222,51	33,20	0,0849

Table 4. IKE IT Supporting Facilities

Year	Energy (GJ)	IKE (GJ/MT)
2022	419,96	1,07
2023	402,14	1,03
2024	410,49	1,05

The graph above shows that energy consumption per m² of supporting facilities decreased from 2022 – 2023. In 2022 – 2023 it decreased by 3.73%, while in 2023 – 2024 it increased by 1.94%, The higher the supporting IKE indicates the energy used for supporting facilities (e.g. offices, lighting, air conditioning, public facilities) per unit area of the building. This indicates a decrease in energy efficiency in supporting facilities. Although it is not a significant energy use, the Supporting IKE in the Integrated Terminal has experienced a consistent increase, indicating an increase in energy consumption per building area and a decrease in energy efficiency.

IKE Value Benchmark

The calculation of the IKE value of IT Production Facilities and IT Supporting Facilities as described above, provides an Intensity value that has relatively increased on average from 2022 to 2024. Production facilities have experienced a total increase of 45% from 2022-2024, while Supporting Facilities have experienced a total increase of 33% from 2022-2024. Based on the benchmark energy intensity value in accordance with the Regulation of the Director General of Environmental Control and Pollution Number: P.11/PPKL/SET/KUM.1/9/2019 concerning Benchmarking of the Oil and Gas Distribution Industry Sector.

The value of energy consumption intensity in production activities in IT is included in the top 25% of the energy consumption intensity of TBBM. This is a good achievement in the IT energy conservation and efficiency program. However, it needs to be used as an alert that even though IT benchmarking values are still in the top 25% or efficient, IT still needs to carry out consistent energy conservation/efficiency activities. Because the trend from 2022 to 2024 shows an increase in energy consumption per unit of product. As for IT Supporting Facilities, the IKE value of supporting the Integrated Terminal **is much greater** than the benchmark. Example of 2024:

1. FT = **1,05 GJ/m²**
2. Benchmark rate-rate = **0.0097 GJ/m²**
3. The difference = about **108 times greater**.

This shows that energy consumption for supporting facilities in IT **is inefficient compared** to standards.

Energy Baseline

Baseline is a parameter that is used as an initial basis and then used as a control condition to measure the success of energy conservation implementation. Baseline is obtained by relating energy use to production levels or to other parameters that affect energy used during operation. The baseline is obtained by linking the energy consumption for the product distribution process with the expenditure of "Throughput" (Kiloliters of Fuel distributed). By using baseline regression analysis using driving variables in the form of Throughput (Kilo Liter) and Energy Variable (Giga Joule) and data taken for 3 years from 2022 – 2024, the following results were obtained:

Table 5. IT Regression Analysis

Measurable data		Variable	
Period of project	Date	Drive	Energy
Sunday		Throughput (KL)	GJ
1	Jan-22	52.998	91,2
2	Feb-22	55.985	90,1
3	Mar-22	58.855	72,7
4	Apr-22	60.360	65,1
5	May-22	51.761	72,7
6	Jun-22	53.747	70,4
7	Jul-22	52.535	68,4
8	Aug-22	55.192	66,8
9	Sep-22	43.228	64,1
10	Oct-22	44.041	66,7
11	Nov-22	44.199	62,2
12	Dec-22	44.308	62,2
13	Jan-23	43.269	62,8
14	Feb-23	47.121	60,6
15	Mar-23	46.561	59,7
16	Apr-23	40.633	65,4
17	May-23	45.622	64,2
18	Jun-23	41.098	70,0
19	Jul-23	44.307	68,6
20	Aug-23	44.817	73,0
21	Sep-23	43.271	75,6
22	Oct-23	52.970	72,6
23	Nov-23	44.748	75,2
25	Jan-24	40.903	69,2
26	Feb-24	37.163	65,3
27	Mar-24	39.033	66,1
28	Apr-24	41.061	68,2
29	May-24	39.751	67,3
30	Jun-24	37.188	72,1
31	Jul-24	37.726	67,1
32	Aug-24	33.303	66,5
33	Sep-24	34.055	73,1
34	Oct-24	34.759	73,3
35	Nov-24	33.883	77,8
36	Dec-24	36.326	67,4

From the data from the regression analysis period conducted as presented above, there is no strong correlation between the amount of fuel distribution and energy consumption. This is shown by the small value of R2 or the relationship between fuel production/distribution and non-linear energy consumption value (the regression relationship is very weak).

In addition, deviation analysis can also be given using CUSUM (Cumulative Summary) from the baseline which serves to determine the best performance model of the existing baseline as follows:

Table 6. Results of Baseline Analysis

Period of project	Energy Actual GJ	Baseline Energy GJ	Variance Energy GJ	CUSUM Energy GJ
1	91	71	20	20
2	90	72	18	39
3	73	72	0	39
4	65	73	(7)	32
5	73	71	2	33
6	70	71	(1)	32
7	68	71	(3)	30
8	67	72	(5)	25
9	64	69	(5)	20
10	67	69	(3)	17
11	62	69	(7)	10
12	62	69	(7)	3
13	63	69	(6)	(4)
14	61	70	(9)	(13)
15	60	70	(10)	(23)
16	65	69	(3)	(27)
17	64	70	(6)	(32)
19	69	69	(1)	(32)
20	73	70	3	(29)
21	76	69	6	(23)
22	73	71	2	(21)
23	75	70	6	(15)
24	69	69	(1)	(16)
25	69	69	0	(16)
26	65	68	(3)	(19)
27	66	68	(2)	(21)
28	68	69	(1)	(22)
29	67	69	(1)	(23)
30	72	68	4	(19)
31	67	68	(1)	(20)
32	66	67	(1)	(21)
33	73	68	6	(15)
34	73	68	6	(10)
35	78	68	10	1
36	67	68	(1)	0

CUSUM (Cumulative Sum Control Chart) analysis for energy variance from baseline to time (period). CUSUM is a statistical tool used to detect small changes or shifts in processes by accumulating deviations from baseline or expected average values.

Period 1 – 19: The CUSUM graph continues to decline to a low of around **–32 GJ,** meaning that energy consumption is more efficient than baseline (there are energy efficiency efforts). **Period 20 – 36**: The chart starts to rise again, close to 0. This indicates that there is an increase in energy overconsumption in the final period. The endpoint (**Final**) is at **1 GJ.** So the best period is in the period 1-19 due to the downward trend of CUSUM.

Current Energy

a. Electrical Power Quality

Power quality is important in electrical power systems in industry. With good power quality, it has an impact on maintaining the continuity of electric power services. On the other hand, if the power quality is not good, it will interfere with the performance of the electric power system such as frequent disruptions of service continuity, short circuits, potential fires, waste of electricity account payments, damage to electronic equipment and so on. The electrical power supply from the generator to the load is operated within the tolerance limits of electrical parameters such as voltage, current, frequency and waveform.

b. Mechanical Systems

Distribution pumps are the main energy user equipment (SEU = Significant Energy Users) in IT facilities. This energy user equipment operates to distribute fuel oil / fuel from the stockpile tank into the fuel product distribution transportation trucks. Each type of fuel product distributed has its own distribution pump. In the Energy Audit activity, the Auditor conducts measurements and evaluations of the performance of the distribution pumps where the output of the measurement results at the pump is the efficiency of the pump. There are 10 distribution pumps in IT, but in this case only 6 pumps are measured and evaluated pump performance.

c. Air Conditioning System

Based on the results of data collection and information during the audit, the activation of the air conditioning system/air conditioning system in the building was carried out by the Building Operations Team but there are no SOPs or rules set for the time of starting or extinguishing the air conditioner.

Figure 1. Temperature settings in the room

The results of measuring the temperature and humidity of the air in the room using thermometer and humidity meter measuring equipment in each room are shown in the following table:

Table 7. Measurement of Room Temperature and Humidity of Integrated Terminal Office Building

No	Room Name	Temperature (°C)			RH (%)		
		Actual	SNI	Conditions	Actual	SNI	Conditions
1	Lobby	24,8	25,5±1,5	Standards	58,7	60±10	Standards
2	R. Meeting	25,1	25,5±1,5	Standards	67,2	60±10	Standards
3	Marine	26,5	25,5±1,5	Standards	57,7	60±10	Standards
4	Staff	26,9	25,5±1,5	Standards	55,4	60±10	Standards
5	R. Control	25,7	25,5±1,5	Standards	58,6	60±10	Standards
6	Rear Waiting Sofa	26,0	25,5±1,5	Standards	63,4	60±10	Standards
7	Spv QQ	25,8	25,5±1,5	Standards	68,0	60±10	Standards
8	Spv MPS	26,0	25,5±1,5	Standards	59,3	60±10	Standards
9	Spv RSD	25,1	25,5±1,5	Standards	55,9	60±10	Standards
10	Server	26,4	25,5±1,5	Standards	57,3	60±10	Standards
11	Spv HSSE	26,8	25,5±1,5	Standards	62,4	60±10	Standards
12	Spv SS GA	26,4	25,5±1,5	Standards	59,6	60±10	Standards
13	Clinic	22,3	25,5±1,5	Standards	57,3	60±10	Standards
14	R. ITM	25,1	25.5±1.5	Standards	60,6	60±10	Standards

From the measurement results in the table above, it is concluded that the distribution of temperature and humidity in several rooms of the Integrated Terminal Office Building is quite diverse, and overall meets the SNI 6390:2020 value standard, especially at a temperature of 25.5±1.5 'C and for the RH value of 60±10 in accordance with SNI 6390:2020.

d. Lighting System

The principles of structuring and managing lighting systems in office buildings need to prioritize effective and efficient lighting to meet these four objectives. With the implementation of a good lighting control system and technology, the energy use for lighting systems can be saved up to 50% of the common conditions encountered in the majority of offices in Indonesia today.

In general, lighting systems are divided into two systems, namely natural lighting systems and artificial lighting systems. The natural lighting system in the Integrated Terminal Office Building is designed well enough to produce enough lighting for the room near the side of the building. Even so, there are still some areas that keep the lights on even though they are quite close to the window.

Artificial lighting is the lighting produced by light other than natural (sunlight). In general, light comes from lamps that use electrical energy. Based on observations and surveys, the lighting system in the building. The Integrated Terminal office has all used LED lights.

The lighting in the building is carried out by the Building Operations Team and there are SOPs or rules set for the time to turn on or off the lights. Technically, the pattern of turning lights on and off is in a good operating pattern.

Some of the findings related to the lack of effectiveness in the use of lights include:

1. The number of lights that light up at a point that has received natural lighting.
2. The lights are on even though the room is not in use/there is no activity for a long time.
3. Less strict supervision of lighting operations, where the majority of the lights

e. Energy Management

The Energy Auditor team conducted an energy management interview with IT. A portrait of the implementation of energy management in IT obtained from the results of interviews conducted with the Energy Management Team can be seen in the Table below.

The results of filling the energy management matrix based on interviews showed that the matrix pattern formed like a High Balanced Form. It can be seen that IT has become aware of energy management which has energy saving programs such as using energy efficiency technology, replacing conventional equipment with efficient equipment. Energy management is carried out with full support from the top leadership through the established energy policy and the formation of an energy team that implements the savings action plan and also monitors. However, these efforts still have the potential to improve energy efficiency and can improve motivation, information system and promotion criteria. Another thing that needs to be considered is the speed of employee rotation, especially those in the Energy Team so that they change quickly.

Energy Efficiency Potential

a. Energy Saving Potential in Product Pumps

1. Pump Performance Improvement 01 – Pertalite

In distributing Pertalite Products, IT uses Pump 01 and Pump 05, which are operated alternately. At the time of the energy audit, Pump 01 was used to distribute Pertalite Products. Pertalite's output in 1 year is more than half of the total overall IT Throughput output. From the results of the pump performance evaluation, Pump 01 has an efficiency value of 36.5%. The potential energy savings for Pump-01 are as follows:

1. Improved pump performance by improving pump efficiency.
2. Re-optimize the use of VSD.

From the results of the simulation, it was found that the potential energy and cost savings in Pump-01 were:

67.0 h/year or IDR 96,794,900, -/year.

2. Pump Performance Improvement 02 – Pertadex

The current condition of Pump 02 is used to distribute Pertadex products. Pertadex's output in 1 year is only 0.43% of the total IT Throughput output. This means that the utilization of pump 02 is not optimal. Based on the calculation results, the efficiency of pump 02 is quite good, which is 58%, which means that the cost intensity is also large with a value of 481.56 Rp/m3. It is not very economical if the pump efficiency performance is improved because the demand/need for Pertadex is not large and results in a very high payback period. Therefore, one of the recommendations given is to increase the working hours of Pump 02 to at least above 3000 working hours in 1 year. It may not have an impact on energy savings, but in terms of utilization and maintenance costs, its use can be optimized.

3. Pump Performance Improvement 03 – Biosolar

Based on the results of the energy audit, Pump 03, which is used as one of the main pumps in the distribution of Biosolar products in IT, has an operating efficiency of 55.5%, so there is still an opportunity to improve performance. Considering that around 80% of Biosolar's annual throughput of 172,462 KL is distributed using Pump 03 and Pump 05 alternately, optimizing the operation of Variable Speed Drive (VSD) at Pump 03 is the main recommendation to improve energy efficiency. Based on the results of simulations using MEASUR software, the implementation of the recommendations is projected to be able to produce energy savings of 28,900 kWh per year or equivalent to electricity cost savings of around IDR 41,751,830 per year, so that it is one of the energy conservation opportunities that is feasible to be implemented.

4. Pump Performance Improvement 04 – Avtur

The current condition of Pump 04 is used to distribute Avtur products. Avtur's output in 1 year is only 3.15% of the total IT Throughput output. This means that the utilization of pump 04 is not optimal. Based on the calculation results, the efficiency of pump 02 is quite good, which is 59.5%, which means that the cost intensity is also large with a value of 90.29 Rp/m3. It is not very economical if the pump efficiency performance is improved because the demand for Avtur is not large and results in a very high payback period. Therefore, one of the recommendations given is to increase the working hours of Pump 04 to at least above 3000 working hours in 1 year. It may not have an impact on energy savings, but in terms of utilization and maintenance costs, its use can be optimized.

5. Pump Performance Improvement 06 – Pertamax

The current condition of Pump 06 is used to distribute Pertamax products. Pertamax's output in 1 year is only 4.9% of the total output of IT Throughput. This means that the utilization of pump 6 is not optimal. Based on the calculation results, the efficiency of pump 06 is quite good, which is 51.3%, which means that the cost intensity is also large with a value of 180 Rp/m3. It is not very economical to improve pump efficiency performance because the demand/need for Pertamax is not large and results in a very high payback period. Therefore, one of the recommendations given is to increase the working hours of Pump 06 to at least above 3000 working hours in 1 year. It may not have an impact on energy savings, but in terms of utilization and maintenance costs, its use can be optimized.

6. Pump Performance Improvement 09 – Industrial Biodiesel

The current condition of Pump 09 is used to distribute Biosolar Industry products. The output of the Biosolar Industry in 1 year is only ± 20% of the total output of Biosolar Throughput in IT. This means that the utilization of pump 8 is not optimal. Based on the calculation results, the efficiency of pump 09 is quite good, which is 52.4%, which means that the cost intensity is also large with a value of 90.29 Rp/m3. It is not very economical to improve pump efficiency performance because the demand/need for Pertamax is not large and results in a very high payback period. Therefore, one of the recommendations given is to increase the working hours of Pump 09 to at least above 3000 working hours in 1 year. It may not have an impact on energy savings, but in terms of utilization and maintenance costs, its use can be optimized.

b. Energy Saving Potential in Supporting Facilities / Office

Based on the results of the energy audit, the electrical system in IT in general has good power quality, but there are still several anomalies that have the potential to reduce the efficiency and reliability of the system, namely high harmonic values and load imbalances. High harmonics are mainly due to the use of Variable Speed Drives (VSDs) or inverters in production equipment such as pumps, which produce current distortion due to the semiconductor switching process. This condition can increase power losses, cause overheating of the motor, and interfere with the performance of the protection system and other electrical equipment. Therefore, it is recommended to install harmonic filters and load balancing through load redistribution or the use of active filter/phase balancer devices to improve power quality and extend the life of the equipment. In addition to the technical aspects of electricity, the audit also identified opportunities for energy savings through improving the management of lighting and air conditioning operations in office areas. The measurement results show that the load of lights and air conditioners is still quite high outside of operating hours, resulting in energy waste of around 90–100 kWh per working day. By optimizing the operating schedule of lights and air conditioners, for example operating facilities from 07.00 to 17.00 except for overtime needs, it is estimated that energy savings of 3,971 kWh per year or equivalent to cost savings of around IDR 5,737,605 per year can be obtained. This recommendation does not require additional investment and can be implemented through increasing the discipline and awareness of building users in managing energy consumption.

c. Installation of kWh Metering / Energy Monitoring in Production Facilities and Supporting Facilities / Office

The proposal to implement an Energy Monitoring System (SME) in IT is motivated by the unavailability of logging equipment to monitor electrical energy consumption in production and supporting facilities, so the implementation of this system is an important step in supporting energy conservation programs. The Energy Monitoring System allows real-time monitoring and recording of energy consumption, so that potential energy losses can be identified faster and become the basis for the implementation of various energy efficiency strategies. Based on a study published by Tehseen Akhtar et al. from the National University of Sciences and Technology (NUST), the implementation of an energy monitoring system can increase energy efficiency by up to about 8%, while the Center for Sustainable Systems, University of Michigan, reports that an Energy Management System can result in energy savings of 4–7%. Taking into account the results of the study, the potential for energy savings in the implementation of SMEs in IT is assumed to be 5%. Based on an analysis of annual energy consumption of 231,506.44 kWh at production facilities and 114,025.56 kWh at supporting facilities, the implementation of SME is estimated to save energy of 11,575.32 kWh/year and 5,701.28 kWh/year, respectively, or equivalent to electricity cost savings of IDR 16,722,867.69 per year at production facilities and IDR 8,236,636.33 per year at supporting facilities. With an estimated investment of IDR 50,000,000 for each system, the payback period is estimated to reach 2.99 years for production facilities and 6.07 years for supporting facilities, so that the implementation of the Energy Monitoring System is considered feasible as one of the efforts to improve energy efficiency in IT.

d. Potential Use of Solar Power Plants on IT Roofs

The proposed installation of Rooftop On-Grid Solar Power Plants in IT aims to reduce energy costs through the use of renewable energy while optimizing the use of available roof areas. The system is designed with the concept of zero export, so that all electrical energy produced is used for internal needs without distributing power to the PLN network. Based on an area analysis using Google Earth Pro, the most potential area for the installation of solar power plants is on the roof of the drum yard with an area of about 722.62 m², which is technically capable of accommodating a capacity of up to 115.65 kWp. However, taking into account the highest electrical load limit in IT of 100 kW, the proposed solar PV capacity is set at 100 kWp. Analysis of energy potential using the Global Solar Atlas shows that the system is projected to be able to produce electrical energy of 128,893 kWh per year, which is equivalent to a potential annual energy saving of 128,893 kWh and electricity cost savings of around IDR 186,211,711.10 per year. With an estimated investment of IDR 1,500,000,000, the implementation of this Rooftop Solar Power Plant has a Simple Payback Period (SPP) of around 8.06 years, so it is worth considering as an effort to improve energy efficiency and reduce operational costs in IT.

CONCLUSION

Based on the results of the implementation of the energy audit at the Integrated Terminal of PT. ABC, it is known that this terminal has the main facilities for receiving, storing, and distributing fuel oil (BBM). The distribution process is supported by 10 units of product pumps that function to distribute fuel from storage tanks to tank trucks and roll-on/roll-off (Ro-Ro) ships. The terminal's electricity system is supplied from the PLN network with an installed power of 164 kVA and is supported by two backup generator units (generators) with a capacity of 250 kVA and 200 kVA to ensure operational continuity. Based on the fuel throughput profile over the past three years, operational activities show energy consumption patterns that are the basis for evaluating terminal energy performance. The audit results also show that the distribution of electricity use in the Integrated Terminal has not been specifically separated between production facilities and supporting facilities. About 67% of electricity consumption is used to support production facilities, while the remaining 33% is used for supporting facilities. Energy flow analysis through Sankey diagrams identifies that production pumps constitute Significant Energy Use (SEU) or significant energy use that is the largest contributor to energy consumption at the terminal. Therefore, improving the efficiency of the pump system is a top priority in efforts to save energy. Based on the calculation of Energy Consumption Intensity (IKE), the production facility obtained a value of 0.0019 GJ/KL/year, which is included in the top 25% category, showing relatively good energy performance compared to the comparison group. Meanwhile, supporting facilities have an IKE value of 1.05 GJ/m²/year, which is in the bottom 25% category, so there is still a considerable opportunity to improve energy efficiency. In addition, the analysis yielded a proposed baseline of energy consumption with an equation of $y = -19.59x + 927861$ and a coefficient of determination $R^2 = 0.7535$, which shows that the model is able to explain about 75.35% of the variation in energy consumption based on the variables analyzed. The results of the audit further show that there is a potential energy saving of 33.90% or equivalent to 117,148 kWh per year. This potential is obtained through several improvement recommendations, including improving the performance of production pumps as the largest energy user and simulating the installation of the Rooftop Solar Power Plant (PLTS) system to support the use of renewable energy. These findings show that the implementation of the audit recommendations not only has the potential to reduce energy consumption and operational costs, but also supports the improvement of energy efficiency and the achievement of operational sustainability targets at the Integrated Terminal of PT. ABC.

REFERENCES

Anggriawan, Akbar, Anita Susilawati, and Rahmat Iman Mainil. 2025. "Optimizing Steam to Electricity Ratio in Crude Palm Oil Refinery Captive Power Plant: A Six Sigma-DMAIC Capability Assessment." *Journal of Ocean, Mechanical and Aerospace-science and engineering-* 69(3): 240–52.

Anggriawan, A., Susilawati, A., & Mainil, R. I. (2025). Optimizing steam to electricity ratio in crude palm oil refinery captive power plant: A Six Sigma-DMAIC capability assessment. *Journal of Ocean, Mechanical and Aerospace-Science and Engineering, 69*(3), 240–252.

Aragón-Correa, J. A., Marcus, A. A., & Vogel, D. (2020). The effects of mandatory and voluntary regulatory pressures on firms' environmental strategies: A review and recommendations for future research. *Academy of Management Annals, 14*(1), 339–365.

Awow, C. D., Muguthu, J., & Njoka, F. (2025). Energy efficiency potentials in oil & gas operations: A case study of South Sudan's petroleum industry. *Energy Reports, 13*, 1673–1690. https://doi.org/10.1016/j.egyr.2025.01.017

Bennett, M., James, P., & Klinkers, L. (2017). *Sustainable measures: Evaluation and reporting of environmental and social performance*. Routledge.

Chang, L., Li, W., & Lu, X. (2015). Government engagement, environmental policy, and environmental performance: Evidence from the most polluting Chinese listed firms. *Business Strategy and the Environment, 24*(1), 1–19.

Denis, E. W. S., Sudjadi, & Utsman, F. (2022). Energy conservation and energy audit as an energy saving effort at MSTP UNDIP (Case study of MSTP Undip Jepara). *Journal of Physics: Conference Series*, 12014.

Fu, X., et al. (2017). Uncertainty analysis of an integrated energy system based on information theory. *Energy, 122*, 649–662.

Habib, S., et al. (2026). Comprehensive energy audit and conservation strategy for public buildings: Enhancing energy efficiency and grid sustainability. *Scientific Reports, 16*(1), 3889.

He, X., & Cha, E. J. (2018). Modeling the damage and recovery of interdependent critical infrastructure systems from natural hazards. *Reliability Engineering & System Safety, 177*, 162–175.

Imtikhani, N., Nugroho, A., & Farina, T. (2025). The influence of artificial intelligence in replacing the role of humans in the world of work reviewed from Government Regulation No. 33 of 2013 concerning the expansion of employment opportunities. *Journal of Social Technology, 5*(5), 1475–1496.

Jarboui, S. (2021). Renewable energies and operational and environmental efficiencies of the US oil and gas companies: A true fixed effect model. *Energy Reports, 7*, 8667–8676. https://doi.org/10.1016/j.egyr.2021.04.032

Krarti, M. (2020). *Energy audit of building systems: An engineering approach*. CRC Press.

Lawal, O. A., et al. (2024). Economic and environmental impact of energy audit and efficiency: A report from a Nigeria household. *Energy for Sustainable Development, 79*, 101387.

Mensah, A. F., & Dueñas-Osorio, L. (2016). Efficient resilience assessment framework for electric power systems affected by hurricane events. *Journal of Structural Engineering, 142*(8), C4015013.

Moslehi, S., & Reddy, T. A. (2018). Sustainability of integrated energy systems: A performance-based resilience assessment methodology. *Applied Energy, 228*, 487–498.

Santoso, A. D., & Salim, M. A. (2019). Penghematan listrik rumah tangga dalam menunjang kestabilan energi nasional dan kelestarian lingkungan [Household electricity savings to support national energy stability and environmental sustainability]. *Journal of Environmental Technology, 20*(2), 263–270.

Simsek, Y., & Urmee, T. (2020). Opportunities and challenges of energy service companies to promote energy efficiency programs in Indonesia. *Energy, 205*, 117603.

Su, H., et al. (2020). A systematic method for the analysis of energy supply reliability in complex integrated energy systems considering uncertainties of renewable energies, demands and operations. *Journal of Cleaner Production, 267*, 122117.

Sundaramoorthy, S., Kamath, D., Nimbalkar, S., Price, C., Wenning, T., & Cresko, J. (2023). Energy efficiency as a foundational technology pillar for industrial decarbonization. *Sustainability, 15*(12), Article 9487. https://doi.org/10.3390/su15129487

Teruna, J. C. (2019). Initial energy audit through electricity energy consumption intensity calculation (IKE): Case study on the Muara Teweh Polytechnic building. *Borneo Electricity, 5*(2), 27–30.

Wardhana, A. S. J., & Damarwan, E. S. (2023). Identification of energy saving potential through energy audit at PT. ABC. *Jurnal Edukasi Elektro, 7*(1), 63–74.

Wu, J., Xu, M., & Zhang, P. (2018). The impacts of governmental performance assessment policy and citizen participation on improving environmental performance across Chinese provinces. *Journal of Cleaner Production, 184*, 227–238.

Zublie, M. F. M. (2023). *Design and analysis of sustainable clean energy integration in a Malaysian higher educational institution*.