Optimization and design of energy monitoring system in fuel terminal: a case study in North Sumatera province of Indonesia

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Abstract. Optimization of energy use in the PERTAMINA’s fuel terminal (TBBM) was carried out by the Energy Audit method. The data obtained during energy audit activities then processed to carry out the Energy Performance Indicators (EnPis) which produces Specific Energy Consumption (SEC) and energy baselines. The energy cost center that creates a web-based energy monitoring system is carried out to facilitate monitoring and control and will become supporting tools. The information provided from the energy monitoring system displays the profile of total energy consumption, distribution of energy consumption, the energy consumption of equipment in production facilities in the form of daily, monthly, and annual data. Energy intensity and baseline values obtained from energy consumption and production data for the past several years will be the target and warning system to maintain energy usage that exceeds reasonable limits. The results obtained by the value of energy intensity of 0.0023 GJ / KL, while the total emissions generated from energy consumption amounted to 1,144.4 tons-CO2 / year. 51% of energy is used for production facilities and the rest is used for supporting facilities. The use of electricity as well as thermal energy does not have a strong correlation with the level of fuel sales throughout the year and the use of NGS (New Gantry System) technology does not show a significant decrease in energy intensity, where IKE values fluctuate throughout the year. This reinforces the need for continuous and real time energy monitoring. By implementing the potential for energy savings, an energy use optimization is obtained by reducing energy consumption by an average of 10% - 15% per month or as much as 18,057 - 27,086 kWh per month, equivalent to 25 - 38 million rupiah per month.

1. Introduction
The Indonesian government through the national energy policy (KEN) sets the main policies and supporting policies as guidelines for implementing energy conservation, implementing energy diversification, fixing energy prices, energy infrastructure, environmental preservation and research, development, and application of energy technology [1]. The Government of Indonesia through the National Energy General Plan sets a potential efficiency target in the user sector of 52.3 MTOE in 2025, which is equivalent to 17.5% efficiency over the BAU scenario [2].

Improving the performance in the industrial sector, such as PERTAMINA’s fuel terminal (TBBM), can be realized by efficiency, both in the form of energy usage efficiency and cost-effectiveness. In terms of energy efficiency, the fuel usage in TBBM can be optimized by using the unit operational which has high efficiency to avoid high losses and waste in energy consumption. At the same time, real-time monitoring system to record and to report energy consumption at the facility can be implemented. The later one will produce a real-time amount of energy consumption during daily activities in the field. To
be able to achieve the efficient use of energy in the fuel distribution process, the implementation of energy audit activities is vital to be done first to be able to find the pattern of daily energy use and obtain energy-savings opportunities. From these results, optimization steps and real-time monitoring system can be designed.

In term of optimization processes, R.P Wibowo [3] conducted an optimization study on the delivery of fuel to gas stations in Bandung, wherein his research the system of route planning and scheduling the delivery of fuel to gas stations obtained to determine optimal routes and scheduling of fuel delivery to gas stations. R. Khusniah [4] studied the optimization of Pertamina's fuel distribution patterns using heuristic algorithms and proposed a modification of the vehicle routing model for planning Pertamina's fuel delivery routes. Route planning is constructed using the heuristic method includes two stages, namely (i) formation of the initial route, and (ii) the improvement of the initial route using the Tabu search algorithm. This model resulted in an improvement in distribution costs by 2.6%. Then Mulyono [5] conducted a study on optimization of supply patterns and distribution of fuel oil (BBM) in the country, which was focusing on the selection of product delivery routes (fuels) from source to destination in the distribution network so that the total transportation costs can be minimized. To the author's knowledge, there are no report related to the optimization of energy use with energy audits and energy management patterns in the fuels terminal found in the literature.

This research is carried out more specifically on obtaining optimum energy efficiency by conducting energy audits, looking for energy savings opportunities, and designing energy usage monitoring system that can be implemented in the TBBM. The study also discusses on energy performance indicators in the form of Energy Consumption Intensity (ECI) or Specific Energy Consumption (SEC) of each equipment, and the ideal energy baseline value in operating a fuel terminal facility.

2. Method
2.1. Data collecting
The data collection technique used is the Energy Audit method can be implemented as follows.

a. Energy Survey
   Energy survey in the field to find real data about the condition of energy use in the fuel terminal, and the equipment used, as primary data.

b. Obtaining the secondary data from location related to daily activities in the field.

2.2. Processing and analysis of data
From the results of secondary and primary data collection through field research, and combined with existing theories, then the data processed and analyzed to find the following below:

a. The Pattern of Energy Utilization and Production explains the following matters:
   - Percentage of primary and secondary energy utilization.
   - Distribution of energy use.
   - Production profile.
   - Energy Performance Indicators (EnPis) include: Specific Energy Consumption (SEC), Normalization (Regression), Energy Baseline, Energy Cost, and Benchmark.
   - Potential for GHG emissions or CO2 emissions.

b. Evaluation of main energy user facilities and supporting energy, including evaluating the electrical load distribution system and evaluating the main equipment in the distribution system in the form of distribution pump equipment.

c. Potential Energy Savings.

d. The Design of an Energy Monitoring System covers the following matters:
   - Designing an energy cost center.
   - Creating an energy reporting system (Energy reporting).
3. Results and discussions

This research was conducted at the Medan Labuhan Deli Fuel Oil Terminal (TBBM) Group as one of the busiest TBBMs and a high level of complexity among existing fuel terminals in Sumatra. The electricity supplied by the national grid (PLN) through the transformer has a capacity of 1385 kVA with the help of backups from 3 electrical generator units with a total capacity of 1737 kVA.

3.1. Energy utilization and production

The utilization of thermal energy and electrical energy in 2018 is 7.4% (own use) and 92.6%, respectively. The electricity consumed is used for the operation of fuel and utility distribution machines (except generators) and office buildings. Based on the energy survey conducted, the percentage of electrical energy consumption load is obtained as shown in table 1 below.

| Facility               | % Cons |
|------------------------|--------|
| NGS                    | 51 %   |
| Building (Office, Workshop, etc.) | 39 %   |
| Lighting Outdoor       | 8 %    |
| Etc.                   | 2 %    |

Table 1. Composition of energy use.

Production or distribution of fuel production consists of premium, pertamax, diesel oil, and pentalite. The total production and distribution of each product reach 226 thousand kiloliters (KL) per month on average [6].

3.2. Energy performance indicators (EnPIs)

Energy Performance Indicators (EnPIs) are a tool to determine the level of performance of energy utilization in industry and building. Table 2 and figure 1 show the specific energy consumption (SEC) values for main daily activities, which is the average EEC is around 0.0023 GJ/KL during 2018.

|          | 2018 Electrical GJ | Own Use GJ | Production (KL) | SEC (GJ/KL) |
|----------|---------------------|------------|-----------------|-------------|
| Jan      | 455.04              | 29.05      | 222,078.40      | 0.0022      |
| Feb      | 452.16              | 58.09      | 194,973.03      | 0.0026      |
| Mar      | 447.84              | 19.36      | 200,652.63      | 0.0023      |
| Apr      | 444.96              | 32.92      | 208,810.56      | 0.0023      |
| May      | 511.20              | 34.86      | 196,471.74      | 0.0028      |
| Jun      | 511.20              | 40.66      | 190,168.29      | 0.0029      |
| Jul      | 444.96              | -          | 192,649.73      | 0.0023      |
| Aug      | 436.32              | 34.86      | 191,071.10      | 0.0025      |
| Sep      | 447.84              | 23.24      | 196,141.91      | 0.0024      |
| Oct      | 311.04              | 19.36      | 202,799.85      | 0.0016      |
| Nov      | 328.32              | 54.22      | 186,554.50      | 0.0021      |
| Dec      | 351.36              | 54.22      | 195,834.70      | 0.0021      |
The energy consumption baseline for production was used as a basis for evaluating and targeting energy management throughout the production process. The regression analysis obtained is of $R^2 = 0.2657$, as shown in figure 2, meaning that 26.6% of energy consumption was influenced by the production or distribution of fuels. It can be said that 73.4% of energy consumption was influenced by other variables outside this regression model.

The SEC target value formula that must be achieved every month can be determined by the following equation:

$$y = 2000000x^{1.688}$$

where $y$ is the SEC target and $x$ is the current month production/distribution of fuels. The SEC targets find for monthly during 2018 shown in table 3.
The target SEC value obtained can be a reference to determine plant performance at that time, and is a value that can be monitored at any time. Greenhouse gas emissions resulting from the use of electricity and fuel oil (diesel fuel) reached 1,144.35 t-CO$_2$e, with details, as shown in table 4.

Table 4. Greenhouse gas emissions.

| Energy Consumption | Value   | t-CO2e  |
|--------------------|---------|---------|
| Electric (PLN)     | 1,428 MWh | 1,117   |
| Fuel (Own Use)     | 10,350 Liter | 27.3   |
| Total              |         | 1,144.35 |

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Table 3. Comparison of the actual SEC value against the target SEC.

| SEC (actual) GJ/KL | SEC (average) GJ/KL | SEC (target) GJ/KL | Remark   |
|-------------------|---------------------|-------------------|----------|
| 0.0020            | 0.0023              | 0.0018            | Not efficient |
| 0.0022            | 0.0023              | 0.0022            | Efficient |
| 0.0020            | 0.0023              | 0.0018            | Not efficient |
| 0.0022            | 0.0023              | 0.0021            | Not efficient |
| 0.0021            | 0.0023              | 0.0019            | Not efficient |
| 0.0021            | 0.0023              | 0.0020            | Not efficient |
| 0.0021            | 0.0023              | 0.0019            | Not efficient |
| 0.0021            | 0.0023              | 0.0020            | Not efficient |
| 0.0021            | 0.0023              | 0.0022            | Not efficient |
| 0.0021            | 0.0023              | 0.0019            | Not efficient |
| 0.0021            | 0.0023              | 0.0023            | Not efficient |
| 0.0021            | 0.0023              | 0.0025            | Not efficient |
| 0.0023            | 0.0023              | 0.0024            | Efficient |
| 0.0025            | 0.0023              | 0.0024            | Not efficient |
| 0.0024            | 0.0023              | 0.0023            | Not efficient |
| 0.0016            | 0.0023              | 0.0022            | Efficient |
| 0.0021            | 0.0023              | 0.0025            | Efficient |
| 0.0021            | 0.0023              | 0.0023            | Efficient |
| 0.0039            | 0.0023              | 0.0018            | Not efficient |
| 0.0026            | 0.0023              | 0.0020            | Not efficient |
| 0.0011            | 0.0023              | 0.0016            | Efficient |
| 0.0011            | 0.0023              | 0.0017            | Efficient |
| 0.0023            | 0.0023              | 0.0022            | Not efficient |
| 0.0029            | 0.0023              | 0.0024            | Not efficient |
3.3. Evaluation of main energy user facilities and support facilities

Assessment of main energy user facilities includes evaluating the electrical load distribution system, evaluating the main equipment in the distribution system in the form of distribution pump equipment, and evaluating the Diesel Engine Generator. Meanwhile, the evaluation of support facilities includes the calculation of Energy Consumption Intensity (ECI) in office buildings and the distribution of electrical loads in office buildings. The results of measurements in the electrical system obtained that the total energy consumed reached 6,019 kWh with good electrical quality in accordance with applicable standards.

All distribution pumping equipment uses an electric-motor energy source and is equipped with VSD (Variable Speed Drive) installation. Means that, almost all pump efficiencies are above 60% and the pump operates efficiently. As for the generator set equipment, it is only used as a backup of electricity when the electricity supply from PLN is interrupted.

ECI on building offices is obtained at 12.6 kWh / m² / month, whereas the value obtained is still in the category of an efficient building according to the Minister of Energy and Mineral Resources RI No. 13 of 2012 [7].

3.4. Identification of energy saving opportunities and energy use optimization recommendations

Based on the results of energy surveys, observations, measurements in the field, as well as analysis and evaluation, it can be identified several improvements and potential energy savings in the context of optimizing energy use in TBBM. Among others are improvements to the electrical system, lighting system, air system, use energy saving technology in electrical equipment, electricity metering, the addition of new renewable energy sources, installation of automatic sensors and implementation of energy monitoring systems in real time. The potential energy savings that can be achieved and the percentage of savings obtained are shown in Table 5.

**Table 5. Opportunities for energy saving and energy use optimization recommendations.**

| Savings Recommendations | % Saving | Category |
|-------------------------|----------|----------|
| The use of LED type lights in office spaces that have not been installed. | 10% | Medium Cost |
| Reducing the electricity load at night by turning off lights and AC that are not used. | 10% | No Cost |
| Genset radiator repair and cleaning regularly. | 5% | Low cost |
| Lighting Retrofit Description Road / Lighting Area from HPL-N / Mercury to LED type | 15% | Medium Cost |
| Maintain the COP value (performance) of Split AC units with regular routine maintenance. | 5% | Low cost |
| Setting the AC unit temperature in the workspace. | 5% | No Cost |
| Building Performance Improvement. | 5% | Medium Cost |
| Central or Rooftop PLTS Installation (On-Grid). | 20% | High Cost |
| Installation of an energy monitoring system. | 15% | High Cost |

By implementing energy saving potentials as shown in table 4 above, a reduction in energy consumption is obtained by an average of 10% - 15% per month or as much as 18,057 - 27,086 kWh per month, equivalent to 25 - 38 million rupiah per month.
3.5. Design of energy monitoring system
The first step in the preparation of an energy monitoring system is to create an energy reference system, which is an energy flow chart starting from energy supply, distribution to the final energy user. Energy reference system or energy usage flow is then adjusted to the existing metering system which is then connected into an energy cost center system that is in accordance with the conditions of the energy use in each production process. Some of the equipment preparing and the energy monitoring scheme to be designed are as listed in table 6 and figure 3.

Table 6. Equipment used in energy monitoring systems.

| No | Material                          | Type  |
|----|-----------------------------------|-------|
| 1  | Arduino Mega                      | Hardware |
| 2  | Modul ESP32                       | Hardware |
| 3  | DC Converter                      | Hardware |
| 4  | Power Supply 12V/2A               | Hardware |
| 5  | RS485 Converter                   | Hardware |
| 6  | Terminated Resistor               | Hardware |
| 7  | USB Connector                     | Hardware |
| 8  | Spacer PCB                        | Hardware |
| 9  | Box Modul                         | Hardware |
| 10 | PCB Matrix                        | Hardware |
| 11 | Modul SIM800                      | Hardware |
| 12 | Wifi portable                     | Hardware |
| 13 | Power Meter PM5000 support RS485  | Hardware |
| 14 | CT Sensor 200A                    | Hardware |
| 15 | Web-based System Application      | Software |

Figure 3 Energy monitoring scheme.

4. Conclusions
From the results of research conducted using the energy audit method, the specific energy consumption (SEC) value obtained in TBBM is 0.0023 GJ / KL, and the IKE value of office buildings is 12.6 kWh /
m²/month. The value obtained is still in the range of efficient buildings according to ministry regulation of Indonesia (ESDM No. 13 of 2012). The energy baseline obtained for Medan Labuhan Deli Fuel Oil Terminal (TBBM) Group is accordance to $R^2 = 0.2657$, which mean that 26.6% of energy consumption influenced by the production or distribution of fuel activities. Therefore, 73.4% of energy consumption influenced by other variables outside the regression model. From the regression test conducted, it concluded that the relationship between fuel production or distribution with electricity consumption is not linear (the regression relationship is very weak), and therefore, the production or process of fuel distribution is not the main driver (main driving factor) in electrical energy consumption at this plant. This could be due to a large amount of energy (electricity) consumption for supporting facilities such as office buildings, warehouses, service houses, and street lighting or lighting areas. Therefore, it is necessary to monitor the use of energy (electricity) with energy management made in a cost center. By implementing the potential for energy savings, an energy use optimization is obtained by reducing energy consumption by an average of 10% - 15% per month or as much as 18,057 - 27,086 kWh per month, equivalent to 25 - 38 million rupiah per month.

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