Improving Energy Efficiency at Palm Oil Mill Industries

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Abstract. Palm oil production has become one of the essential economical in Malaysia, where it is one of the world's largest oil palm producer and exporter. The rapid growth of the palm oil mill as the primary product dominating Malaysian agriculture industries leads to the increasing of energy usage. However, the efficiency of electrical energy usage has been recognized as one of the significant factors to reduce the cost of electrical energy consumption. This research aims to determine the energy consumption of palm oil mill process and proposed improvement to its potential energy consumption. This research is limited to the energy efficiency improvement in one of Malaysia palm oil industry. The palm oil mill selection and the palm oil mill processes have been identifying in the early phases. Four main palm oil processes which are fruit bunch reception, sterilizing, threshing and pressing have been investigating to improve the energy efficiency. From the calculation of processing palm oil processes, the monthly electrical consumption was near to 127MWh. The result found that 31.49% of energy consumption can be reduced in a month by the selected palm oil mill processes by replacing the current motor to high-efficiency motor.

1. Introduction
Energy plays an important role nowadays. It is the main driving force behind all human activities. Energy is defined as the ability to produce change or do work [1]. Rapid population and industry growth increased energy consumption demand [2-3]. In Malaysia, power plants generate electricity by converting non-renewable energy such as coal, natural gas and fuel oil [4]. Electricity is the most widely used energy type for domestic, commercial and industrial purposes which are leads to the insufficient energy resources of non-renewable energy [5]. That has been the most demanding challenge need to face by industries to ensure their sustainable business development. Energy efficiency can reduce the use of primary energy resources and achieves significant savings [6]. This method is suitable for all industries, including palm oil mills. The purpose of carrying this study is to determine the energy consumption of each palm oil mill processes and discover its potential saving. However, this research is limited to the energy efficiency improvement in one of Malaysia palm oil industry. Solutions and recommendation discussed in the paper, which is support by the measurement of approximate saving cost per month in the selected palm oil mill.

Energy is the primary source for all activities. The demand for electrical power today has been increasing every day at an increasing rate. Since energy can not be to generated or destroyed, electricity requires energy sources to be generated and energy management to be understood; energy
resource studies are a must to estimate the energy consumption and proposes ways of energy-saving solutions. Electricity generation utilizes both renewable and non-renewable energies [7]. However, the trend of world energy consumption indicates that 82% is from non-renewable energy, while the remaining 18% is from renewable energy. There are currently several primary energy sources used worldwide for generating electricity. The sources include solar energy, hydrogen energy, wind energy, tidal energy, hydroelectric energy, wave energy, biomass energy, fossil fuels and nuclear power [8-9]. In Malaysia, natural gas and coal-generated nearly 80% of electricity. Fossil fuel, such as natural gas, are classified as non-renewable energy and can not be replenished. Continuous uncontrolled use of fossil fuel will finish up the resources in no time [10-15].

The palm oil mill consists of different processes from fresh fruit bunch until becoming crude oil, which is including sterilization, threshing, digestion, pressing and clarification. Its starts with receiving fresh fruit bunch from the plantation in bunch reception by sterilization process [16]. The fruit bunch are steam up to 3 bars or equal to 300 kPa in pressurized vessels to arrest the formation of free fatty acids and prepare the fruit for next sub-processes. After finishing the process, the sterilized straps are discarding in a rotating drum thresher. The stripped bundles or empty fruit bundles (EFB) are transported for mulching in the plantation while the fruits are then was transporting to the press digesters. The fruits in the digesters are heated with live steam and continuously stirred to loosen the oil-bearing mesocarp from the nuts and open the oil cells in the mesocarp. The digested mash is then was pressed. The oil is extracted through the screw presses. Then the press cake is transmitted to the kernel plant where the kernels are recovered. Press oil is diluted and pumped into vertical clarification tanks. The clarified oil is then fed to purifiers to remove dirt and humidity before further drying in the vacuum drier. The oil is ready for storage and delivery [17-20].

Further study is required to sustain the energy consumption at the palm oil mill. Besides, energy losses during the processing of palm oil will increase production costs and also have an adverse effect on the environment. The tendency to overcome these energy losses has drawn greater attention to issues related to industrial energy efficiency. A plant or a process’s energy efficiency is inversely proportional to the energy losses. Energy efficiency can, therefore, be improved when energy losses can be minimized. As a reduction in the energy losses will significantly increase the efficiency of the plants, possible causes of these losses must be identified in order to improve the energy efficiency of the plant.

2. Methodology
The methods flow for this study divided into three phases, which is Phase 1, Phase 2, and Phase 3, respectively. In Figure 1, the first phase shows some literature review conducted are focused on palm oil mill process, location of the palm oil mill plants, operation hour and energy tariff by TNB. The palm oil mill was selected, and it is located in Banting, Selangor Darul Ehsan. It is approximately 15 kilometres (17 minutes) from Jenjarom and 14 kilometres (15 minutes) to Telok Panglima Garang. The palm oil mill has operated for 40 years until now. Full processes of palm oil are processing at this mill from fresh fruit bunch until becoming crude palm oil. In phase 2, data has been collected by using several methods. The data are focus on machine list, machine usage and make some energy analysis. After the data is collected, the study to find total energy consumption and energy efficiency are calculated. In the final phase, data were analyzed to make some conclusion. The result has been discussed, and some recommendation to improve energy efficiency for palm oil mill process is proposed.
3. Results and Discussion
The data are collected and presented in the table form for ease of reading and calculation. Table 1 shows the machine year usage, while Table 2 shows the operation hour of machines. The palm oil mill operates for 26 days a month. The power consumption of each machine shown in Table 3.

| No. | Processes     | Machines                                      | Year Usage |
|-----|---------------|-----------------------------------------------|------------|
| 1   | Fruit reception| Loading hydraulic ramp system                  | 10         |
|     |               | FFB conveyor                                  | 10         |
| 2   | Sterilizing   | Inclined scraper conveyor                     | 10         |
|     |               | Distributing conveyor                         | 10         |
| 3   | Threshing     | Rotary thresher drum                          | 10         |
|     |               | Bunch crusher                                 | 10         |
|     |               | Recycling empty bunch conveyor                | 10         |
|     |               | Bottom cross conveyor                         | 10         |
|     |               | Inclined scraper conveyor                     | 10         |
| 4   | Pressing      | Digester                                      | 10         |
|     |               | Screw press                                   | 10         |
|     |               | Fruit distributing conveyor                   | 10         |
|     |               | Top cross conveyor                            | 10         |
|     |               | Fruit elevator                                | 10         |
Table 2: Operation hour of machines

| No. | Processes              | Machines                        | Operation (hours/days) |
|-----|------------------------|---------------------------------|------------------------|
| 1   | Fruit reception        | Loading hydraulic ramp system   | 16                     |
|     |                        | FFB conveyor                    | 16                     |
| 2   | Sterilizing            | Inclined scraper conveyor       | 16                     |
|     |                        | Distributing conveyor           | 16                     |
| 3   | Threshing              | Rotary thresher drum            | 16                     |
|     |                        | Bunch crusher                   | 16                     |
|     |                        | Recycling empty bunch conveyor  | 16                     |
|     |                        | Bottom cross conveyor           | 16                     |
|     |                        | Inclined scraper conveyor       | 16                     |
| 4   | Pressing               | Digester                        | 16                     |
|     |                        | Screw press                     | 16                     |
|     |                        | Fruit distributing conveyor     | 16                     |
|     |                        | Top cross conveyor              | 16                     |
|     |                        | Fruit elevator                  | 16                     |

Table 3: Power consumption of each machine

| No. | Processes              | Machines                        | Power Rate (kW) | Quantity | Total Power Consumption (kWh) |
|-----|------------------------|---------------------------------|-----------------|----------|------------------------------|
| 1   | Bunch reception        | Loading ramp hydraulic system   | 5.0             | 1        | 5.0                          |
|     |                        | FFB conveyor                    | 4.0             | 1        | 4.0                          |
| 2   | Sterilizing            | Inclined scraper conveyor       | 7.5             | 1        | 7.5                          |
|     |                        | Distributing conveyor           | 4.0             | 1        | 4.0                          |
| 3   | Threshing              | Rotary thresher drum            | 18.5            | 2        | 37.0                         |
|     |                        | Bunch crusher                   | 11.0            | 1        | 11.0                         |
|     |                        | Recycling empty bunch conveyor  | 7.5             | 1        | 7.5                          |
|     |                        | Bottom cross conveyor           | 5.5             | 1        | 5.5                          |
|     |                        | Inclined scraper conveyor       | 7.5             | 1        | 7.5                          |
| 4   | Pressing               | Digester                        | 40.0            | 3        | 120.0                        |
|     |                        | Screw press                     | 30.0            | 3        | 90.0                         |
|     |                        | Fruit distributing conveyor     | 4.0             | 1        | 4.0                          |
|     |                        | Top cross conveyor              | 2.2             | 1        | 2.2                          |
|     |                        | Fruit elevator                  | 7.5             | 2        | 15.0                         |
Base on the data from Table 1, Table 2 and Table 3, the energy consumption is calculated from Eq. (1) and summarized in Table 4.

\[
\text{Energy consumption} = \text{Total operation (h)} \times \text{Total Power (W)}
\]

Energy consumption at bunch reception process

\[
= \left[ \frac{16 \text{ hrs}}{\text{days}} \times \frac{26 \text{ days}}{\text{month}} \right] \times 9,000 \text{ W} \\
= 3,744,000 \text{ Wh} \\
= 3,744 \text{ kWh per month}
\]

Energy consumption at sterilizing process

\[
= \left[ \frac{16 \text{ hrs}}{\text{days}} \times \frac{26 \text{ days}}{\text{month}} \right] \times 11,500 \text{ W} \\
= 4,784,000 \text{ Wh} \\
= 4,784 \text{ kWh per month}
\]

Energy consumption at threshing process

\[
= \left[ \frac{16 \text{ hrs}}{\text{days}} \times \frac{26 \text{ days}}{\text{month}} \right] \times 68,500 \text{ W} \\
= 28,496,000 \text{ Wh} \\
= 28,496 \text{ kWh per month}
\]

Energy consumption at pressing process

\[
= \left[ \frac{16 \text{ hrs}}{\text{days}} \times \frac{26 \text{ days}}{\text{month}} \right] \times 217,700 \text{ W} \\
= 90,653,200 \text{ Wh} \\
= 90,653.2 \text{ kWh per month}
\]

Total estimated energy consumption

\[
= \text{Energy consumption at bunch reception process} + \text{Energy consumption at sterilizing process} + \text{Energy consumption at threshing process} + \text{Energy consumption at pressing process}
\]

\[
= 3,744 + 4,784 + 28,496 + 90,653.2 \text{ kWh}
\]

\[
= 127,677.2 \text{ kWh per month}
\]

Table 4 shows a summary of data analysis. From this table, pressing is highest with 71%, threshing 22.32%, sterilizing with 3.75% while bunch reception 2.93% of energy consumption. Table 5 shows the comparison between current usage versus after replacement of IE4 motor class. The suggested potential saving is by replacing the current motor type to IE4 motor class type. The total of energy cost by using the current motor is 127,677.20kWh, while the IE4 motor is 87474.70kWh. There are significant energy saving by 40,202.50kWh that contributes to 31.49% of energy saving.

| Processes       | Total Energy Consumption (kWh) per month | Usage Percentage (%) |
|-----------------|------------------------------------------|----------------------|
| Bunch reception | 3,744.00                                  | 2.93                 |
| Sterilizing     | 4,784.00                                  | 3.75                 |
| Threshing       | 28,496.00                                 | 22.32                |
| Pressing        | 90,653.20                                 | 71.00                |
| Total           | 127,677.20                                | 100.00               |
Table 5: Comparison between current usage versus after replacement of IE4 motor class

| Type of Processes     | Power Consumption per Month (kWh) | Current motor | IE4 motor class |
|-----------------------|-----------------------------------|---------------|-----------------|
| Bunch Reception       | 3,744.00                          | 2808.00       |
| Steriliser            | 4,784.00                          | 4085.50       |
| Threshing             | 28,496.00                         | 19662.20      |
| Pressing              | 90,653.20                         | 60919.00      |
| Total                 | 127,677.20                        | 87474.70      |

Saving value: 40,202.50 kWh
Saving percentage: 31.49%

There are a few ways of solution and recommendations proposed in this study. The suggestion that would improve energy efficiency for the palm oil mill process has been made at the end of this study. The potential saving measures can be categorized into two categories, which are technical saving measures and manual saving measures, respectively. For technical saving measures, replacement of motor efficiency class was included. Meanwhile, preventive maintenance is proposed manual saving measures. Table 5 above shows the comparison between current motor usage and after replacement of IE4 motor class. Next suggestion for recommendation is development of programme for evaluate cost of electrical energy consumption by using MATLAB software which can leads to the trend of technology today.

4. Conclusion
This study investigated the energy consumption and the potential energy consumption improvement for oil palm mill process at Eng Hong Palm Oil Mill Sdn Bhd, which located in Banting, Selangor as a case study. This research has been focused only on four processes which are fresh fruit bunch reception, sterilizing process, threshing process and pressing process. The energy consumption for four processes was estimated at nearly 127,677.20kWh, costing around RM 37,026. From these figures, the pressing process was identified as the most significant contributor of electrical energy consumption with 71%, followed by the threshing process with 22.32%, sterilizing process with 3.75% and the bunch reception is the least energy consumer at 2.93%. The suggestion for potential saving measures proposed, which include the preventive maintenance of machines and motor efficiency classes. As proposed have been summarized, it estimated that the potential energy saving is about 40,202.50kWh per month or equivalent to RM 11,658. Therefore, by using this way, palm oil mill plant can save approximately 31.49% of energy consumption in a month.

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