

Establishment of Industrial Energy Benchmarking in Malaysian Downstream Palm Oil Industry

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The second largest energy demand in Malaysia comes from industrial sector (28 % of the total demand) and one of the main industries in Malaysia is palm oil industry. The energy consumption in Malaysian palm oil industry must be reduced in order to reduce the environmental impact (GHG emission). The main objective of this research is to establish energy benchmarking in Malaysian downstream palm oil industry using product-based energy benchmarking. The method for energy benchmarking consists of four main steps, which is data collection, data analysis, set-up baseline SEC and establishment of industrial energy benchmarking. The data used in this research was obtained from Malaysian Green Technology Corporation. An equation to estimate baseline SEC value has been obtained and energy benchmarking in this industry has been successfully established. Data analysis revealed that the average SEC for this industry is determine to be 2.59 GJ/t and the lowest SEC (0.04 GJ/t) was obtained by Company D while the highest SEC (5.99 GJ/t) is obtained by Company C. Apart from that, the recommendation of no cost, low cost, medium cost and high cost energy saving measures for this industry has been done. Finally, the best practice in this industry has been determined as maximizing the plant utilization rate and implementing ESMs.

1. Introduction

Great amount of energy has been produced to fulfill the industrial demand and most of the production of energy comes from non-renewable resources (Suruhanjaya Tenaga, 2020). Generation of energy through non-renewable sources can lead to various environmental problems such as air pollution, acid rain, greenhouse gas emission and global warming (UCS, 2019). These happened due to burning of fossil fuels which emit CO₂ and other greenhouse gases including carbon monoxide, methane gas, sulphur dioxide and nitrous oxide into the atmosphere (Kiss, 2019). Reducing industrial energy consumption, particularly the palm oil industry in Malaysia is very imperative to maximize profit for the country and minimize environmental issues (MPOC, 2013). Several steps can be taken to reduce energy consumption and one of them is through energy audit (Mahd Y., 2018). Energy audit measures the performance of energy usage of a building, company, institute or plant. Energy audit can identify the energy saving measures and the energy efficiency of a particular building and subsequently reduce the energy consumption without affecting the quality of the output (PCRA, 2019).

Another way to reduce energy consumption is by benchmarking (Mahamud et al., 2017). Energy benchmarking enables a company to compare their energy consumption with other companies or with a reference value (Andersson et al., 2018). By comparing the energy consumption, a company is able to determine the performance of energy usage and estimate the energy saving potential (Yang et al., 2016). Energy benchmarking in an industry can be divided into two types which is process-based energy benchmarking and product-based energy benchmarking (Wang et al., 2016). Energy benchmarking for industry has been applied in various countries such as China, India and UK as a way to reduce the energy consumption in industry (Tahouni and Panjeshahi, 2017). Unfortunately, such energy benchmarking has not been established for downstream palm oil industry in Malaysia. Downstream palm oil companies do not have a reference value to evaluate their performances and reduce their energy consumption. Energy benchmarking

in Malaysian downstream palm oil industry should be established in order to reduce the energy consumption in this industry. The main objective of this study is to establish energy benchmarking for Malaysian downstream palm oil industry. Other than that, this study also focuses on establishing best practices in this industry.

2. Methodology

The procedure of energy benchmarking includes four major steps which were data collection, data analysis, set-up baseline specific energy consumption (SEC) and establishment of energy benchmarking. SEC is the amount of energy consumed per product produced for a specific plant (Andersson, 2018). The data required for benchmarking process was obtained from Malaysian Green Technology Corporation (GreenTech Malaysia, 2017). GreenTech Malaysia had collected energy related data of several companies through energy audit report submitted by the companies under Energy Audit Conditional Grant (EACG) programme. The data used for energy benchmarking includes energy consumption data, production data, plant capacity, energy management matrix score and recommended energy saving measures.

The data obtained was analysed in order to determine the baseline for energy benchmarking in Malaysian downstream palm oil industry. Six downstream palm oil companies having at least three similar palm oil products were selected. It is imperative to note that although the product ranges are similar, the size and capacity differs. It is impossible to have companies with similar size and capacity as they are all privately and independently managed. Analysis of data includes calculating SEC and determining the factors contributing to the SEC value. Microsoft Excel was used throughout the analysis process. SEC of each company was calculated using Eq(1). In order to calculate the SEC value, the energy consumption data and production data of all companies were extracted from the energy audit report. The unit of the energy consumption and production of all companies were standardized to be in the same unit which is GJ for the energy consumption and t for the production.

$$SEC = \frac{\text{Energy consumed}}{\text{Amount of products produced}} \quad (1)$$

The factors that affect the SEC value of each company were then determined by linear regression of the SEC value with the potential variables. First, individual linear regression between SEC value and potential variables has been done in order to see the effect that each variable have towards the SEC value. The SEC value is strongly affected by a variable if the R² value obtained from the linear regression is 0.75 and above. Then, multiple linear regressions were used to determine the effect of multiple variables on SEC value. The result is significance when the range of R² is higher than 0.75, F-test less than 0.05, t-Stat more than 2 and P-value less than 0.05. After data analysis, baseline SEC value for each company was set-up. Baseline SEC is very important in energy benchmarking process. It serves as a reference value in comparing energy performance of companies, organizations or plants (Chan, 2014). The SEC of different companies is compared using bar chart in order to find the lowest SEC and the average SEC for the respective industry. An equation that relates SEC value and variables affecting SEC value is obtained from the multiple linear regression analysis. The equation is altered to give an equation that can be used to estimate the baseline SEC value. The baseline SEC value of each company is then calculated using the altered equation.

Finally, establishment of energy benchmarking was performed to compare and determine the performance of each company. The benchmarking process consists of evaluating energy performance and recommendation of energy saving measures. The purpose of evaluating the energy performance of specific company or plant is to show them how good are they in utilizing energy compared to other companies or plants in the same industry, as well as the reason behind it. The company can do some improvement when their energy performance is low. In order to evaluate the energy performance of each company, bar chart is used to compare actual SEC of a company with its baseline SEC calculated. If the actual SEC of a company is lower than its baseline SEC, the company is said to have a good performance. The energy saving measures can help a company or plant to improve their energy performance (Suruhanjaya Tenaga, 2016). The lists of recommended energy saving measures for the respective companies were obtained from the energy audit report. The recommendation of energy saving measures to be implemented by the companies has been made based on the company or plant performance and it can be no cost, low cost, medium cost and high cost. The most recommended type of energy saving measures by all companies was determined. Next, the data of the implemented energy saving measures and the electricity savings achieved from it has been obtained and from there, the energy saving measures that is implemented the most was determined.

Establishing the best practices in an industry is important so that the companies can practice it to save their energy. The procedure to establish best practices includes data collection, data analysis and establishment of best practices. To establish best practices, only electrical energy consumption data are used instead of the

whole energy consumption data. Data collected for the establishment of energy benchmarking will also be used in establishing the best practices. The additional data needed are current energy consumption data, current production data and list of energy saving measures implemented together with its savings. Data that has been collected was analyzed by comparing the SEC value for Year 2 (SEC calculated using current data) with the SEC value for Year 1 (actual SEC value during benchmarking period). The company had improvement if the current SEC value is lower than the previous SEC value. This is because the amount of energy consumed per product produced is lesser. The factors that affect the current SEC value and the changes that happened in the company were identified. Next, the best practices were determined based on the factors and changes that have been identified.

3. Results and discussion

3.1 Energy benchmarking

Energy benchmarking between those six companies is done by using the SEC value. The SEC value shows how much energy is consumed to produce 1 t of product. The SEC for each company and the average SEC for downstream palm oil industry is shown in Figure 1(a). Company C has the highest SEC (5.99 GJ/t) while the lowest SEC (0.04 GJ/t) is obtained by Company D. The average SEC for this sector is 2.59 GJ/t. Company B and Company C has higher value of SEC compared to the average SEC. The variation in SEC value can be due to several factors such as the plant capacity, plant utilization rate, design and layout of plants, age and condition of equipment, utilization of high technology equipment, and the extent to which management and employees emphasize energy conservation.

In terms of plant capacity and plant utilization rate, the SEC value should be lower as the plant capacity and plant utilization rate increases. The relationship between energy consumption with plant capacity and utilization rate is obtained by linear regression of the data in Table 1. Figure 1(b) and 1(c) shows that plant capacity and utilization rate has effect on SEC. However, the individual relationship between energy consumption and these two variables is not strong enough since the R^2 value is 0.45 for plant capacity and 0.49 for plant utilization rate. This shows that SEC value does not depend solely on plant capacity and plant utilization rate, but also depends on other factors such as the energy management level in a company. The energy management level or the extent to which management and employees emphasize energy conservation in a company can be seen through the Energy Management Matrix. Energy Management Matrix is a tool developed to evaluate the status of energy management system in an organization. There are six aspects that are evaluated in Energy Management Matrix, namely, Energy Policy, Energy Team, Motivation, Information System, Marketing, and Investment. The highest level in Energy Management Matrix is 4. Table 2 shows the score for Energy Management Matrix for all six companies.

Table 1: Plant Capacity, Plant Utilization Rate and SEC of All Companies

Comp	Plant Capacity (t)	Plant Utilization Rate (%)	SEC (GJ/t)
A	350,000	97.58	2.38
B	20,736	34.85	5.04
C	187,464	54.42	5.99
D	1,800,000	99.97	0.04
E	386,000	72.03	0.22
F	500,000	59.46	1.90

Table 2: Energy Management Matrix for all six companies

Criteria	Company					
	A	B	C	D	E	F
Energy Policy	4	1	1	4	4	4
Organization	3	1	1	4	4	4
Motivation	3	1	1	4	4	4
Information System	3	2	2	4	4	4
Marketing	3	1	1	4	4	4
Investment	3	2	3	4	4	4
Total	19	8	9	24	24	24

From the total score of Energy Management Matrix obtained, a linear regression between SEC and the total score of Energy Management Matrix has been done and it is shown in Figure 1(d). With the R^2 value of 0.9038, it shows that SEC of a company can be highly affected by the total score of Energy Management

Matrix of the company. Higher score means better energy management system which results in more efficient energy consumption. The SEC value obtained will be lower as the score increases. A multiple linear regression has been done in order to study the factors affecting SEC value of these companies. The variables that are chosen for this regression are total score of Energy Management Matrix (X1), plant capacity (X2), and plant utilization rate (X3). Based on the multiple linear regression result shown in Table 3, with the R² value of 0.96, it can be concluded that SEC is strongly affected by plant capacity, utilization rate and the energy management level in a company. Eq(2) relates the SEC and these three variables.

$$SEC = -0.27X1 - 5.19X2 - 0.43X3 \tag{2}$$

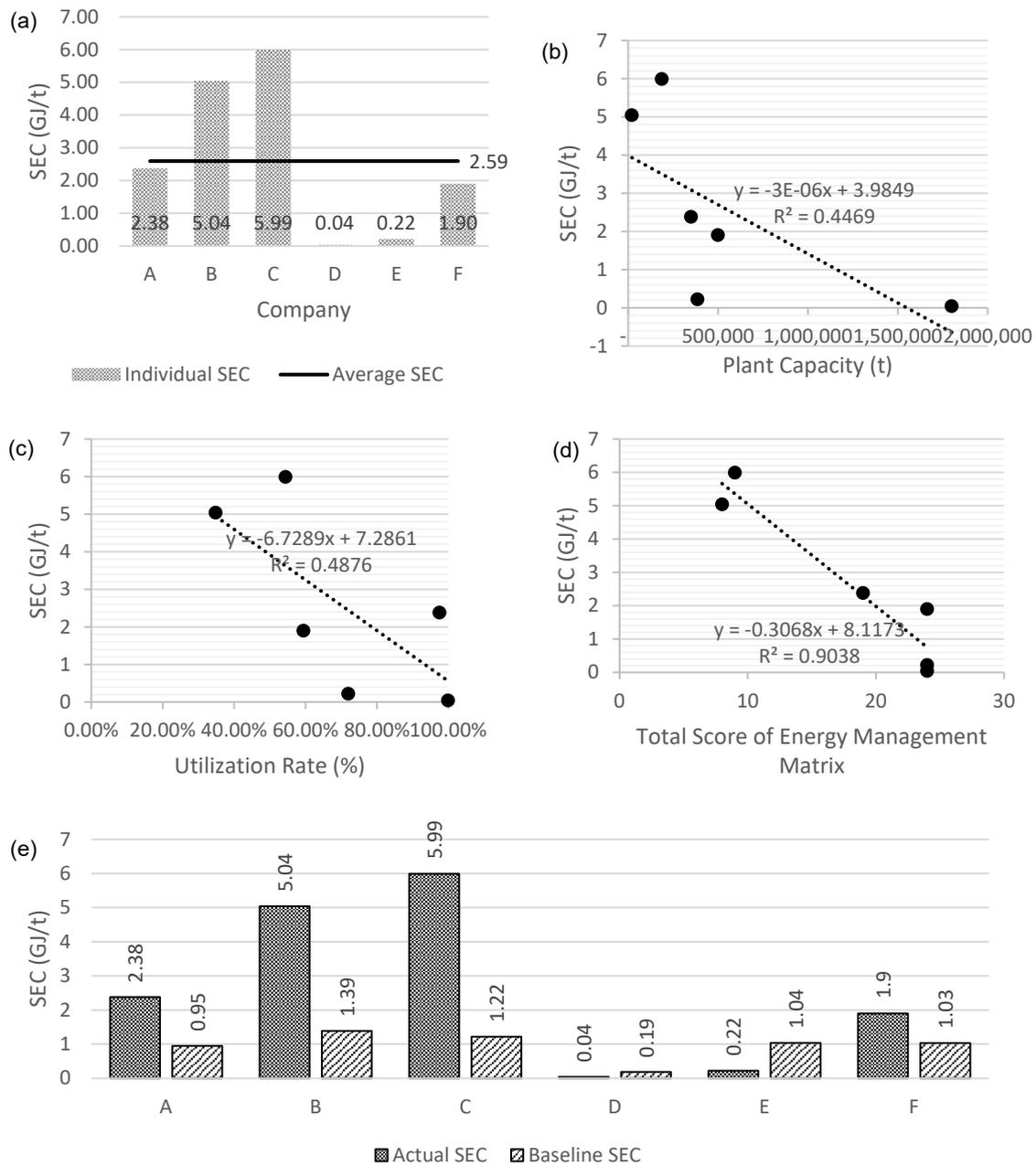


Figure 1: Illustration of (a) SEC for Downstream Palm Oil Industry (b) Relation between SEC and Plant Capacity (c) Relation between SEC and Plant Utilization Rate (d) Relation between SEC and Total Score of Energy Management Matrix (e) Actual and Baseline SEC of each company

Eq(3) can be used to calculate the SEC of a company from known value of plant capacity, plant utilization rate and total score of Energy Management Matrix. Every company should have a good energy management level. The total score of Energy Management Matrix should be at maximum which is 24. The baseline SEC for downstream palm oil industry can be estimated using Eq(3). The average SEC cannot be used as a baseline for this industry since the companies in this industry varies in capacity, products and operation. If the average SEC is used as a baseline, then it would not be a fair comparison.

$$SEC_{Baseline} = 1.5442 - 5.19(Capacity) - 0.43(Utilization Rate) \quad (3)$$

The performance of each company is determined by comparing the actual SEC value with the baseline SEC value. The baseline SEC value is calculated using Eq(3). The company has good performance if their actual SEC value is lower than the baseline SEC value. Figure 1(e) shows the actual and baseline SEC value of each company. It can be seen that company E and D has lower actual SEC value compared to the baseline SEC value. It can be concluded that company E and D has great performance and they should maintain their performance. Company A, B, C and F have low performance and they have a lot of room for improvement. They should do some improvement in order to increase their performance in consuming energy which will lead to more energy saving and increase the profits. One of the ways to reduce energy consumption is through implementation of energy saving measures. Table 3 and 4 tabulate the regression and ANOVA analysis between SEC that revealed the accuracy of the data statistically. The R square value which is beyond 91 % indicates that the result accuracy attained from the statistical analysis is acceptable.

Table 3: Result of Multiple Regression between SEC and Plant Capacity, Plant Utilization Rate and Total Score of Energy Management Matrix

Regression Statistics	
Multiple R	0.959159857
R Square	0.919987631
Adjusted R Square	0.799969078
Standard Error	1.099210982
Observations	6

Table 4: Result of ANOVA between SEC and Plant Capacity, Plant Utilization Rate and Total Score of Energy Management Matrix

	df	SS	MS	F	Significance F
Regression	3	27.7854	9.2618	7.6653	0.11758479
Residual	2	2.4165	1.2082		
Total	5	30.2019			

3.2 Energy saving measures

Energy saving measures (ESMs) is important to reduce the energy consumption in a company. During energy audit, the potential energy savings were identified and energy saving measures were proposed accordingly. In summary, there are four types of ESMs which are no cost, low cost, medium cost and high cost. No cost ESMs include de-lamping of tube lights and optimization of compressed air system while installation of variable speed drive (VSD) for pump is one of the examples of low-cost ESMs. Next, medium cost ESMs can be integrating Sustainable Energy Management System, boiler heat loss reduction, improvement on chiller efficiency, condenser improvement with dedicated cooling tower and lead/lag air compressor control. Installation of high efficient lighting can be medium cost or high cost depending on the number of tube lights involved. Other than that, high cost ESMs include voltage optimization, compressed air demand management, waste heat steam generator, retrofit of hybrid chiller, installation of economizer as well as installation of micro turbine.

From the analysis done, most of the energy saving measures proposed are medium cost ESMs which accounts for 39 % of the total ESMs proposed by six companies, followed by high cost (33 %), no cost (18 %) and low cost (10 %). The priority of each ESMs can be determined by several factors such as its impacts, investment, payback period and also the execution time. There are 21 ESMs that has been implemented by the companies but only six of them is being specified. According to the analysis result obtained, 67 % from the ESMs being implemented focuses on lighting while others focuses on boiler (20 %) and pumps (20 %). Those ESMs are retrofitting of lighting, installation of high efficient lighting, and installation of transparent cladding on roof jack to reduce lighting.

4. Conclusion

Energy benchmarking in Malaysian downstream palm oil industry has been performed using the data of six companies which was extracted from energy audit report submitted to Malaysian Green Technology Corporation. From the data analysis, the average SEC for this industry is determined to be 2.59 GJ/t and the lowest SEC (0.04 GJ/t) was obtained by Company D while the highest SEC (5.99 GJ/t) is obtained by Company C. The factors that influence SEC value have been identified as plant capacity, plant utilization rate and the energy management level of a company. The performance of the companies involved has been evaluated and it shows that Company D and E have a good performance since their actual SEC is lower than their baseline SEC. The reasons why they have a good performance compared to other companies is because they have the best energy management, higher capacity and higher utilization rate compared to other companies involved in this study. The lists of energy saving measures that have been proposed for each company was obtained from the energy audit report. The energy saving measures for this industry has been summarized according to their specific categories which include no cost, low cost, medium cost and high cost. The example of no cost ESMs are de-lamping of tube lights and optimization of compressed air system. Installation of variable speed drive is one of the examples of low-cost ESMs. Some example of medium cost ESMs are improvement on chiller efficiency, set up a Sustainable Energy Management System as well as replacement of LED tube lights. Voltage optimization, installation of micro turbine, installation of economizer and retrofitting of hybrid chiller are the examples of high cost ESMs. An analysis has been done and the result shows that medium cost ESMs has the highest percentage of being proposed for the companies and most companies implemented ESMs that focuses on energy saving from lighting.

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