ENERGY AND ELECTRICITY CONSUMPTION ANALYSIS OF MALAYSIAN INDUSTRIAL SECTOR

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ABSTRACT

Malaysia has experienced strong economic growth in the last decade. Energy has been a key input to the development and growth of the country. The industrial sector is the second largest consumer of energy in Malaysia. In this project 64 factories in seven different manufacturing sectors were audited within the four regions of the east coast of Malaysia. In this audit, the most important parameters collected were; power rating and operation time of energy consuming equipment/machinery; fossil fuel and other sources of energy consumption; production figure; peak and off peak tariff usage behaviour; and power factor. This data was analysed to investigate the breakdown of end-use equipment/machinery, the peak and off peak usage behaviour, power factor trend, specific energy consumption and specific electricity consumption. The result of the audit shows the highest energy consuming equipment to be electric motors followed by liquid pumps and air compressors. The highest specific total energy (fossil fuel and electricity) consumption among industrial sub-sectors is found in rubber production, followed by fabricated metal industries. The highest specific electrical energy consumption was found in fabricated metal industries, followed by rubber industries. The specific energy and electricity consumption found in the study are compared with Indonesian industrial sectors and presented in this paper. The study also found 64% of electrical energy was consumed in peak hours by the industries; average power factor ranged from 0.88 to 0.91. The energy audit in this study can be an important tool and approach for policymakers to gain insight into energy and electricity use patterns in the Malaysian industrial sector.

Keywords: Energy consumption, Industrial sector, Specific energy consumption, Energy audit.

1. INTRODUCTION

There is a growing concern over energy consumption and its adverse impact on the environment. Most developing countries shifted from agricultural towards industrialisation and urbanisation during economic growth in the last decades. Growth in the industrial sector promising a healthy growing of gross domestic product (GDP), severely affected an ability to maintain fuel supplies or reserves. Introducing the concept of rational use of energy aims to reduce energy consumption and also corresponds to the optimum use of all limited economic resources [1]. This definition indicates the measures leading to a more rational use of energy showing advantages over the actual situation. Energy losses exist in many industries and their reduction can improve conservation significantly [2]. Among the various sectors contributing to greenhouse gas (GHG) emissions, the industrial sector was significant. Thus, mitigating GHG emissions from the industrial sector offers the best means of reducing overall GHG emissions. Therefore, energy conservation means less reliance on energy imports and, thus, less GHG emissions. Previous studies suggest implementing a few options with little or no cost to the industrial sector could reduce 10-30% of GHG emissions [3-4].

Malaysia is made up of Peninsular Malaysia and the states of Sabah and Sarawak on the island of Borneo. Today about 80% of the total 23.3 million people live in Peninsular Malaysia, the hub of the country’s economic activities. Like many other developing countries, energy has been the prime contributor towards the rapid growth of Malaysia’s economy. The Malaysian economy grew at 5.3% in 2005. Rural–urban migration, higher living standards and increased income per capita have also spurred an ever-increasing demand for energy. The overall energy demand is expected to increase at an average rate of 6.3% annually between 2005 and 2010. The industrial sector, was noted as the second higher consumer of energy at 38.6% in 2005 [5]. Against the backdrop of a growing need for coal and piped natural gas imports and Malaysia becoming a net crude oil importer in 2008, greater challenges lie ahead for the energy sector making that Peninsular Malaysia may become a net importer of fossil fuels (oil, gas and coal) sooner than expected [6]. An increase in energy consumed raised serious concern by the government to overcome the phenomena by promoting end-use energy efficiency, this means using less energy, but maintaining the same level of service. It can be achieved either by decreasing total energy used or by increasing production rate per unit of energy consumed. On the other hand, improving energy efficiency is the key to reducing GHG emissions. Therefore, energy research organisations and governments are actively engaged in developing methods of assessing energy efficiency. This assessment can
provide a reference for establishing energy policy and simultaneously reduce GHG emissions. One way to attain more efficient use of final energy in industry is determined by energy consumed and energy losses in a plant. Various equipment and devices that consume energy at varying levels of efficiency depend on characteristics and working conditions. Energy audit is one method that can identify and quantify how energy is being used. Numerous studies have been published on energy audit and energy analysis results for different industries [7-11]. Energy use performances and energy efficiencies in industry have also been studied in different surveys [12-13] in different countries. But in exiting literature, no study has identified and quantified estimates of energy usage breakdown in the industrial sector. This study presents the results and analysis of walkthrough energy audit on 91 factories in 11 industrial sectors located in Peninsula Malaysia. Emphasis given to electrical and fossil fuel energy consumption patterns of end-use equipments/machineries, specific energy consumption, peak and off-peak hour electricity consumption, and power factor at production processes. The authors hope this study will be useful in benchmarking and other policy measures for Association of Southeast Asian Nations (ASEAN) and other countries of industrial energy consumption. This study may be useful for utility companies to expand their plans. The results of the study can be considered as an insight into the energy and electricity use pattern of the Malaysian industrial sector for the policy maker. Furthermore, the results could provide important guidelines and insights for research, development allocations and energy projects.

2. METHODOLOGY

This section examines targeted factories, walk-through audit, data collected, approaches used to estimate end-use electricity consumption, specific energy and electricity consumption, peak and off-peak hour electricity consumption and power factor.

2.1. TARGETED MANUFACTURING FACTORIES

The targeted industries in this study are electricity consumers of TNB (a utility industry in Malaysia), from industrial sectors in various regions within east-coast of Malaysia. Sixty-four manufacturing factories from four major industrial regions were targeted and audited. The locations of industrial regions along with number of audited factories in each region are shown in Table 1.

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of audited factories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central (Selangor, Kuala Lumpur)</td>
<td>29</td>
</tr>
<tr>
<td>North (Perak, Penang, Kedah, and Perlis)</td>
<td>18</td>
</tr>
<tr>
<td>South (Johor, Melaka and Negeri Sembilan)</td>
<td>10</td>
</tr>
<tr>
<td>East (Pahang and Terengganu)</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total (East-coast of Malaysia)</strong></td>
<td><strong>64</strong></td>
</tr>
</tbody>
</table>

Audited factories were divided into seven sectors according to the product that they manufactured. Table 2 lists the sectors with three digit International Standard Industrial Classification (ISIC) code and the number of factory audited from each sector.

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Sector/ISIC code</th>
<th>Number of audited factories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food products</td>
<td>311</td>
<td>9</td>
</tr>
<tr>
<td>Wood and wood products</td>
<td>331</td>
<td>8</td>
</tr>
<tr>
<td>Paper and paper products</td>
<td>341</td>
<td>13</td>
</tr>
<tr>
<td>Chemicals</td>
<td>352</td>
<td>4</td>
</tr>
<tr>
<td>Petroleum refineries</td>
<td>353</td>
<td>5</td>
</tr>
<tr>
<td>Rubber and rubber products</td>
<td>355</td>
<td>13</td>
</tr>
<tr>
<td>Fabricated metal products</td>
<td>381</td>
<td>12</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>64</strong></td>
<td></td>
</tr>
</tbody>
</table>

Before conducting a walk-through energy audit in the selected industrial facilities, following preparations were made. A meeting was held with appropriate plant personnel familiar with the physical conditions and day-to-day operation of the manufacturing equipment in the facility. The purpose was to identify areas where auditors’ attention should focus during the audit. A well prepared questionnaire and checklist was made for walkthrough energy audit and sent to an industrial facility at least a week prior to the audit to allow sufficient time for those relevant to obtain required data and inform staff. An audit team consists of qualified electrical and mechanical engineers was formed and trained in order to conduct a walkthrough energy audit:

(a) Initially, an energy audit meeting was held with a facility manager/maintenance engineer to introduce energy audit target and the members of the audit group. The facility manager then explained their manufacturing process and energy-consuming equipments/machinery providing operation and maintenance records for review by the auditors.
Following the meeting, the maintenance engineer took the audit team to the plant for an on-site audit. The auditors visited energy-consuming equipment with equipment operators.

Auditors reviewed operating manuals and equipment specifications for energy-consuming equipment.

In addition to the facility inspection, the auditors met again with staff to review preliminary findings and recommendations.

With this audit a checklist was given to investigate how industries emphasise energy conservation or awareness of energy conservation in their facilities. After the audit, data and recommendations were combined to produce an on-site energy audit report.

2.3 ENERGY AUDIT DATA

During a walkthrough audit, an audit team counted all equipment on the production floor, took notes on rated power from technical specifications on the equipment and daily operating hours. Teams also estimated total working days in a year in consultation with heads.

The most important data to have been collected during the walkthrough audit were; Power rating and operation time of energy consuming equipment/machinery; fossil fuel and other sources of energy consumption; production figures; peak and off peak tariff usage behaviour; and power factors. Using this data, an analysis investigated the breakdown of end-use equipment/machinery energy consumption, peak and off peak usage behaviour, power factor trends, specific fossil fuel energy and specific electricity consumption.

2.4 APPROACHES USED TO ESTIMATE SEC

Energy consumed per unit of physical product or specific energy consumption (SEC) was considered as a measure of energy efficiency. SEC can be expressed by the following equation:

\[
SEC = \sum_{i=1}^{N} \frac{J_i \cdot E_{it}}{P_t}
\]

where:
- \(J_i\) = number of unit associated with energy source \(i\)
- \(E_{it}\) = quantity of energy source \(i\) used during period \(t\)
- \(N\) = number of energy sources
- \(P_t\) = quantity of production during period \(t\)

3. ENERGY CONSUMPTION ANALYSIS

3.1 END-USE ELECTRICITY CONSUMPTION

In this study the maximum emphasis was given to discover end-use electricity consumption in the industrial production process during 2006. Based on the data, it was found that electrical motors consumed the highest amount of energy (47.05%) followed by pumps (13.75%), air-compressors (8.85%), air-conditioning systems (7.21%), workshop machines (6.00%), lighting (5.65%), overhead cranes (3.00%), ventilation (1.96%), furnace (1.26%), conveyor systems (1.00%), boilers (0.88%), refrigeration systems (0.49%), dust collecting equipment (0.30%), lift/escalators (0.20%), and other equipment (3.38%). Figure 1 shows the breakdown of end use energy consumption. As electric motors consume major part of industrial energy, several measures could be taken to reduce their consumption. The use of an energy efficient motor will reduce the financial cost of the industrial sector, such as the cost of motor maintenance. From the survey and data analysis it was found most factories still use standard motors even though some have knowledge of energy efficient motors.

3.2 SPECIFIC ENERGY CONSUMPTION (SEC)

The SEC of each sector is represented by average SEC from the audited industries of a particular sector. For each factory, the SEC has been calculated by considering total fossil fuel energy and the total electrical energy consumption data obtained during the audit. The SEC data of each factory was then compiled to estimate the sectoral SEC, and presented in Tables 4 and 5. The total specific energy (fossil fuel and electrical) of each sector are given as a range. It was found SEC varies significantly from one industry to another, even in the same industrial sector, depending on the production process, products, and raw materials used. The average SEC was given in terms of electrical energy consumption (MWh/100 ton) and total fossil fuel energy (GJ/100 ton) consumption in each sector. The highest total energy (fossil fuel and electricity) consumption among industrial sectors was found in the rubber and rubber producing industries (675 GJ/100ton) followed by fabricated metal producing industries (598 GJ/100 ton), while the highest total specific electrical energy consumption was found in the fabricated metal producing factories (166 MWh/100ton) followed by rubber and rubber producing industries (71.5 MWh/100 ton). A comparison of SEC with 6 Indonesian industrial sectors has been made and presented in Tables 3 and 4. From Table 4 it is observed that average SEC in Malaysian industry was lower than the Indonesian average industrial SEC. On the other hand, few Indonesian industrial sectors consumed less SEC than Malaysian industries. As SEC is dependent on total energy consumption and production figures, it is certainly influenced by type of fuel used, production process and energy consuming machinery (i.e. their efficiency).
From Tables 3 and 4, it was found that average SEC for electrical energy was quite similar for some industries in both countries.

![Figure 1: End-use average electricity consumption in audited Malaysian factories](image1.png)

**Table 3: Total Specific energy consumption of audited Malaysian and Indonesian factories**

<table>
<thead>
<tr>
<th>Sector/ ISIC code</th>
<th>Total SEC (electrical + fossil fuel) (GJ/100 ton of production)</th>
<th>Malaysian Audited factories</th>
<th>Indonesian factories</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Range</td>
<td>Average</td>
</tr>
<tr>
<td>311</td>
<td>15</td>
<td>3.89 - 52.6</td>
<td>590</td>
</tr>
<tr>
<td>331</td>
<td>506</td>
<td>49.3 - 1358</td>
<td>280</td>
</tr>
<tr>
<td>341</td>
<td>290</td>
<td>48.4 - 579.8</td>
<td>40</td>
</tr>
<tr>
<td>352</td>
<td>83</td>
<td>74.80 - 90.58</td>
<td>820</td>
</tr>
<tr>
<td>353</td>
<td>47</td>
<td>41.41 - 53.07</td>
<td>680</td>
</tr>
<tr>
<td>355</td>
<td>675</td>
<td>114 - 1152</td>
<td>-</td>
</tr>
<tr>
<td>381</td>
<td>598</td>
<td>489.6 - 802.8</td>
<td>1260</td>
</tr>
</tbody>
</table>

Source: Ref [9] for Indonesian data

**Table 4: Specific electricial energy consumption of audited Malaysian and Indonesian factories**

<table>
<thead>
<tr>
<th>Sector/ ISIC code</th>
<th>Total specific electrical energy consumption (MWh/100 ton of production)</th>
<th>Audited factories</th>
<th>Indonesian factories</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Range</td>
<td>Average</td>
</tr>
<tr>
<td>311</td>
<td>4.3</td>
<td>1.08 - 14.61</td>
<td>15.27</td>
</tr>
<tr>
<td>331</td>
<td>18.5</td>
<td>1.2 - 29.5</td>
<td>95.68</td>
</tr>
<tr>
<td>341</td>
<td>22.7</td>
<td>2.43 - 49.67</td>
<td>28.66</td>
</tr>
<tr>
<td>352</td>
<td>23.0</td>
<td>20.78 - 25.16</td>
<td>93.99</td>
</tr>
<tr>
<td>353</td>
<td>11.0</td>
<td>10.48 - 11.50</td>
<td>6.73</td>
</tr>
<tr>
<td>355</td>
<td>71.5</td>
<td>15.24 - 189.23</td>
<td>-</td>
</tr>
<tr>
<td>381</td>
<td>166.0</td>
<td>136 - 223</td>
<td>98.51</td>
</tr>
</tbody>
</table>

Source: Ref [9] for Indonesian data

### 3.3 Peak and Off-peak Hours Electrical Energy Consumption

Data analysis showed 64% of total electrical energy consumption took place during peak hours, while 36% was consumed during off-peak hours, as shown in Figure 2. Peak hours indicate the higher percentage due to the realisation by the industries the amount of overtime payments to operate an industry during off-peak hours higher than the savings obtained from operating during off-peak period. It may be mentioned that minor equipment were also operated during peak hours, especially for regular production process and administrative purposes. It was found most audited factories used off peak hours to run major equipment for production purpose; a few factories had an agreement with TNB to shift fully to an off-peak hour. It was also found large and medium scale factories ran their production plants during off-peak hours. Small scale industries were not willing to run production plants during off-peak hours because of labour costs.

![Figure 2: Percentage of Off-peak and Peak hours electricity consumption in Malaysian industries](image2.png)

### 3.4 Power Factor

From the data analysis it was found the average power factor ranged from 0.88 to 0.91 as shown in Table 5. It may be mentioned that improved power factor will reduce the utility bill and increase electrical system capacity. TNB imposes a penalty on companies that have a power factor less than 0.85. In this study, the power factor has been found higher than the specified level as most industries installed capacitor bank for power factor correction. This decreases current through the facility power distribution system and will effectively increase the capacity of that line and reduce line losses.

![Diagram](image3.png)
Table 5: Average and range of power factor of audited factories

<table>
<thead>
<tr>
<th>Sector/ISIC code</th>
<th>Power factor</th>
<th>Average</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>311</td>
<td>0.88</td>
<td>0.75 – 0.94</td>
<td></td>
</tr>
<tr>
<td>331</td>
<td>0.87</td>
<td>0.85 – 0.92</td>
<td></td>
</tr>
<tr>
<td>341</td>
<td>0.88</td>
<td>0.85 – 0.92</td>
<td></td>
</tr>
<tr>
<td>352</td>
<td>0.91</td>
<td>0.89 – 0.95</td>
<td></td>
</tr>
<tr>
<td>353</td>
<td>0.89</td>
<td>0.86 – 0.90</td>
<td></td>
</tr>
<tr>
<td>355</td>
<td>0.91</td>
<td>0.90 – 0.93</td>
<td></td>
</tr>
<tr>
<td>381</td>
<td>0.90</td>
<td>0.85 – 0.90</td>
<td></td>
</tr>
</tbody>
</table>

4. CONCLUSION

In the present study energy audit has been completed in 11 industrial sectors comprising 91 factories of the east coast of Malaysia. From the analysis of energy audit data, it was concluded:

Among a wide variation of end-use electricity consuming equipment, electric motors were the major consumer of electrical energy followed by pumps and air-compressors. This study also found the majority of factories still used old equipment which were not efficient and wasted a huge amount of energy. There was a wide variation of specific energy consumption observed in the audited factories. This was due mainly to variety of products in a particular industrial sector, as well as the process involved in transforming raw materials to the final product. It found most audited factories had a lack of knowledge and awareness of energy conservation. It is recommended from this study that all factories should have an energy conservation department responsible for managing energy loss reducing specific energy consumption.

The study also found a huge amount of energy and costs could be saved if more efficient motors were used in place of standard efficiency motors with a short payback period particularly for larger motors. This study also found 64% electrical energy was consumed during peak hours by industry and the average power factor range from 0.88 to 0.91.

5. REFERENCES


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Presenter: The paper is presented by Prof Hassan.