SOHAR UNIVERSITY

INDUSTRIAL APPLICATIONS OF ENERGY SYSTEMS (IAES2008)

Faculty of Engineering

Sohar University

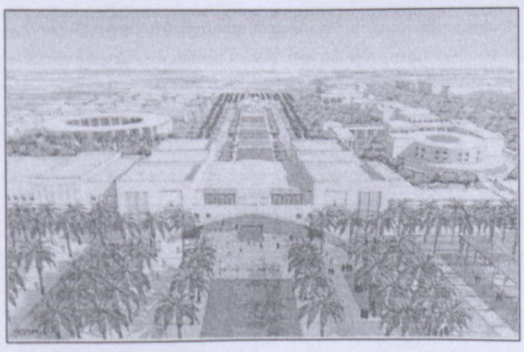
Sohar, Sultanate of Oman

April 1-2, 2008

Majan Electricity Company (SAOC)

Sohar Operations and Maintenance Company LLC

Oman Mobile Telecommunications Company, LLC



Sohar University, 2010

ENERGY AUDIT AND CONSUMPTION STUDY OF MALAYSIAN INDUSTRIAL SECTOR

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Abstract

Malaysia has been experiencing strong economic growth through the last decade. Energy has been a key input in the development and growth of the country. The industrial sector is the second largest consumers of energy in Malaysia. In the present work ninety-one (91) industries in eleven different manufacturing sectors were audited within the four regions of east-coast of Malaysia. In this audit, the most important parameters that have been collected are; 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 behavior; and power factor. These data were analyzed to investigate the breakdown of end-use equipment/machinery, the peak and off peak usage behavior, power factor trend, specific energy consumption and specific electricity consumption. The result of the energy audit shows that the highest energy consuming equipment is electric motor followed by liquid pumps and air compressor. The highest specific fossil fuel energy consumption among the industrial sub-sectors is found in the rubber producing industries followed by fabricated metal and basic iron steel producing industries, while the highest specific electrical energy consumption was found in the fabricated metal industries followed by iron and steel, and rubber producing industries. The study also found that the 64% electrical energy was consumed in peak hours by the industries and average power factor ranged from 0.88 to 0.92.

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

Introduction

Recently, there has been a growing concern about energy consumption and its adverse impact on the environment. Most of the developing countries shifted from agricultural towards industrialization and urbanizations due to the economic growth since last few decades. The growth in the industrial sector, promising a healthy growing of gross domestic products (GDP), severely affected the ability to maintain the fuel supply or reserve. Introducing the concept of rational use of energy aims at reduction of the energy consumption and also corresponding to the optimum use of all limited economic resources [1]. This definition indicates that the measures leading to a more rational use of energy have to show advantages over the actual current situation. Energy losses in a large number of industries exist, and the reduction of such losses can improve energy conservation significantly [2]. Among the various sectors contributing to greenhouse gas (GHG) emissions, the contribution of 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 are reported that implementing a few options with little or no cost in 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. Malaysian economic grew at 5.3 percent 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% per annum between 2005 and 2010. Industrial sector 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 implies that Peninsular Malaysia may become a

net importer of fossil fuels (oil, gas and coal) sooner than expected [6]. The increasing of energy consumed raised serious concern by the government of Malaysia to overcome the phenomena by promoting the end-use energy efficiency which means using less energy while maintaining the same level of service. It can be achieved either by decreasing total energy use or by increasing the production rate per unit of energy consumed. On the other hand, improving energy efficiency is the key to reducing green house gas (GHG) emissions. Therefore, energy research organizations and governments are actively engaged in developing methods of assessing energy efficiency. This assessment can provide a reference for establishing energy policy and can simultaneously reduce GHG emissions. One of the ways to attain the more efficient use of final energy in industry is determined by the energy consumed and energy losses in a plant. Various types of equipment and devices that consume energy at varying levels of efficiency depend on the characteristics and working conditions. Energy audit is one of the methods that can be used to identify and quantify how energy is being used in a plant. Numerous studies have been published on energy audit and energy analysis results for different industries [7-11]. Energy use performances and energy efficiencies of the industrial have also been studied in different surveys [12-14] in different countries. But in the exiting literature, no study has identified and quantified estimates of energy usage breakdown in industrial sector.

This study presents the results and analysis of walkthrough energy audit on ninety-one factories in eleven industrial sectors located in Peninsula Malaysia. Emphases was given on electrical and fossil fuel energy consumption pattern of end-use equipments/machineries, specific energy consumption, peak and off-peak hour electricity consumption, and power factor at production processes. Authors hope that this study will be useful for benchmarking and other policy measures for ASEAN and other countries of industrial energy consumption. This study may be useful for utility company to expand their future plan as well. The results of the study can be considered as an insight into the energy and electricity uses pattern of Malaysian industrial sector for the policy maker. Furthermore, the results could provide important guidelines and insights for future research and development allocations and energy projects.

Methodology

This section explains about targeted factories, walk-through audit, data collected, approaches used to estimate (SEC) and energy savings by high efficient motor and its payback period for using high efficient motors. These are elaborated below:

Targeted manufacturing factories

The targeted industries in the present study are electricity consumers of TNB (a utility industry in Malaysia) from industrial sector in various regions within east-coast of Malaysia. Ninety-one manufacturing factories from four major industrial regions have been targeted and audited. The locations of industrial regions along with number of audited factories in each region are shown in Table 1.

Table 1 Locations of audited factories

Location	Number of audited factories
Central (Selangor, Kuala Lumpur)	41
North (Perak, Penang, Kedah, and Perlis)	25
South (Johor, Melaka and Negeri Sembilan)	14
East (Pahang and Terengganu)	11
Total (East-coast of Malaysia)	**91**

Table 2 Number of audited industrial sector with ISIC code

Sectors	Sector/ISIC code	Number of audited factories
Food products	311	9
Wood and wood products	331	8
Paper and paper products	341	13
Chemicals	352	4
Petroleum refineries	353	5
Rubber and rubber products	355	13
Plastic and plastic products	356	7
Glass and glass products	362	4
Iron and steel	371	5
Fabricated metal products	381	12
Cement	390	6
Total		**91**

Audited factories are divided into 11 sectors according to the product that they manufactured. Table 2 listed the sectors with three digit International Standard Industrial Classification (ISIC) code and the number of factory audited from each sector.

Walkthrough energy audit

Before conducting a walk-through energy audit in the selected the industrial facilities, following preparations have been made. A meeting was held with the appropriate plant personnel who are familiar with the physical conditions and day-to-day operation of the manufacturing equipments in the facility. The purpose of the meeting was to identify areas where auditors' attention should be focused during the walk-through audit. The well prepared questionnaire and checklist has been made for walkthrough energy audit and sent to industrial facility at least one week prior to the walk-through audit in order to allow sufficient time for relevant person to obtain the required data and inform the concerned staff. An audit team consists of qualified electrical and mechanical engineers was formed and trained in order to conduct walkthrough energy audit. On-site walkthrough energy audit has been performed as follows:

(a) Initially, an energy audit meeting was held with the facility manager/maintenance engineer to introduce energy audit target and the members of the audit group. The facility manager then has explained their manufacturing process and energy-consuming equipments/machineries, and provided operation and maintenance records for review by the auditors.
(b) Following the meeting, the maintenance engineer took the audit team to the manufacturing plant for an on-site audit. The auditors have visited energy-consuming equipment with representatives of equipment operators.
(c) Auditors have reviewed the operating manual and equipment specifications for the energy-consuming equipment.
(d) In addition to the facility inspection, the auditors met again with the facility staff to review the preliminary findings and the recommendations being considered.
(e) Along with that an energy audit checklist have been filled to investigate industries emphasize on energy conservation or awareness of energy conservation in their industrial facilities. After the on-site walkthrough audit, the data and recommendations have been combined to produce the on-site energy audit report.

Energy audit data

During the walkthrough audit in a factory, audit team counted all the equipments on production floor, took notes on rated power from technical specifications on the equipments and operating hours per working day. Audit team has also estimated total working days in a year in consultation with responsible person of production process.

The most important data that have been collected during walkthrough audit are; power rating and operation time of energy consuming equipments/machineries; fossil fuel and other sources of energy consumption; production figure; peak and off peak tariff usage behavior; and power factor. Using these data, an analysis has been carried out to investigate the breakdown of end-use equipments/machineries energy consumption, the peak and off peak usage behavior, power factor trend, specific fossil fuel energy and specific electricity consumption.

Approaches used to estimate SEC

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

$$SEC = \frac{\sum_{i}^{N} J_i E_{it}}{P_t} \quad (1)$$

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

An analysis of industrial energy consumption

End-use electricity Consumption

In this study the maximum emphasize was given to find out the end-use electricity consumption in the industrial production process for the year 2006. Based on the analyzed data, it has been found that electrical motors consumed the highest amount of energy (47.05%) followed by pumps (13.75%), air-compressors (8.85%), air-conditioning system (7.21%), workshop machines (6.00%,), lighting (5.65%), overhead cranes (3.00%), ventilation (1.96%), furnace (1.26%), conveyor system (1.00%), boiler (0.88%), refrigeration system (0.49%), dust collecting equipment (0.30%), lift/escalators (0.20%), and other equipments (3.38%). Figure 1 shows the breakdown of end use energy consumption. As electric motors consume major

fraction of industrial energy, several measures could be taken to reduce their energy consumption. The usage of energy efficient motor can reduce financial cost of industrial sector such as the cost of motor maintenance. From the survey and data analysis it has been found that the most of factories are still using the standard motors in their premises even though some of them have knowledge of energy efficient motors. This is due to several factors which are listed as follow:

- There is a tendency to follow the old trend of using standard efficiency motor
- the cost of efficient motor is very high
- lack of knowledge on efficient motor
- no enforcement from the government

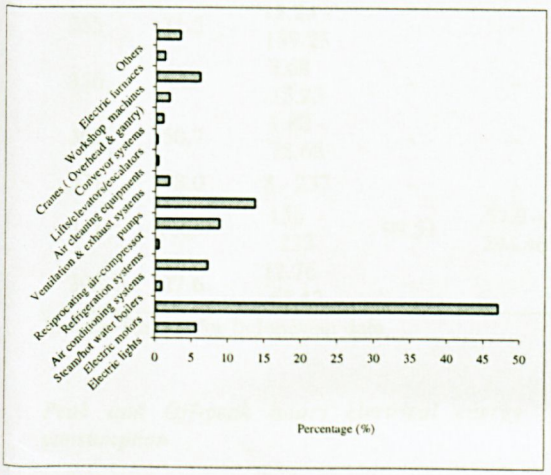

Figure 1 End-use average electricity consumption in audited Malaysian factories

3.1 Specific Energy Consumption (SEC)

In this study, the SEC of each sector is represented by average SEC from the audited industries of that particular sector. For each of the factory, the SEC has been calculated by considering the total fossil fuel energy and the total electrical energy consumption data that was obtained during the energy audit. The SEC data of each factory were then complied to estimate the sectoral SEC, and these are presented in Tables 4 and 5. The total specific energy (fossil fuel and electrical) of each sector have also been given as a range. It has been found that SEC varies significantly from one industry to another even in the same industrial sector due to the production process, products, and raw materials used in an industry. The average SEC was given in terms of total electrical energy consumption (MWh/100 ton) and total fossil fuel energy (GJ/100 ton) consumption in each sector. The highest total specific fossil fuel energy consumption among industrial sectors was found in the glass and glass producing industries (863 GJ/100 ton) followed by rubber and rubber producing industries (675 GJ/100ton) and 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 iron and steel producing factories (78 MWh/100 ton). A comparison of SEC with 6 Indonesian industrial sectors has been made and presented in Tables 3 and 4. From the Table 4 it has been observed that average SEC in Malaysian industry is lower than Indonesian average industrial SEC. On the other hand, few Indonesian industrial sectors consuming less SEC than Malaysian industries. As SEC is dependent on total energy consumption and production figure, it is certainly influenced by type of fuel used, production process, energy consuming machineries (i.e. their efficiency).

From the Table 4 it has been found that average SEC for electrical energy is quite similar for some of the industries for both of the countries.

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

Sector/ISIC code	Total SEC (electrical + fossil fuel) (GJ/100 ton of production)			
	Malaysian Audited factories		Indonesian factories	
	Average	Range	Average	Range
311	15	3.89 - 52.6	590	8 - 2350
331	506	49.3 - 1358	280	150 - 600
341	290	48.4 - 579.8	40	4 - 180
352	83	74.80 - 90.58	820	10 – 233
353	47	41.41 - 53.07	680	150 – 15.7
355	675	114 - 1152	-	-
356	40	17.82 - 66.41	-	-
362	863	45 - 1884	-	-
371	503	127 - 2012	-	-
381	598	489.6 - 802.8	1260	20 - 4590
390	102	47.03 - 243.4	-	-

Source: Ref [9] for Indonesian data

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

Sector/ISIC code	Total specific electrical energy consumption (MWh/100 ton of production)			
	Audited factories		Indonesian factories	
	Average	Range	Average	Range
311	4.3	1.08 - 14.61	15.27	0.29 – 68.92
331	18.5	1.2 - 29.5	95.68	10.14 – 275.56
341	22.7	2.43 - 49.67	28.66	4.89 – 69.42
352	23.0	20.78 - 25.16	93.99	5.21 – 430.37
353	11.0	10.48 - 11.50	6.73	1.62 – 35.65
355	71.5	15.24 - 189.23	-	-
356	8.3	3.68 - 15.23	-	-
362	50.7	1.80 - 78.68	-	-
371	78.0	8 - 237	-	-
381	166.0	136 - 223	98.51	57.9 – 294.46
390	27.6	12.76 - 65.42	-	-

Source: Ref [9] for Indonesian data

Peak and Off-peak hours electrical energy consumption

From the data analysis it has been found that 64% of the total electrical energy consumption took place during the peak hours while 36% consumed during the off-peak hours as shown in Figure 2. Peak hours indicates the higher percentage due to the realization by the industries that amount of overtime payments to operate an industry during the off-peak hours will be higher than the savings obtained from operating during the off-peak period. It may be mentioned that minor equipments are also operated during the peak hours especially for regular production process and administrative purpose. It has been found that the most of the audited factories used off peak hours to run major equipments for production purpose and a few factories have an agreement with TNB to shift fully to the off-peak hour. It was also found that large and medium scale factories run their production plants during off-peak hours. Small scale industries are not wiling to run the production plants during off-peak hours due to the high employee cost.

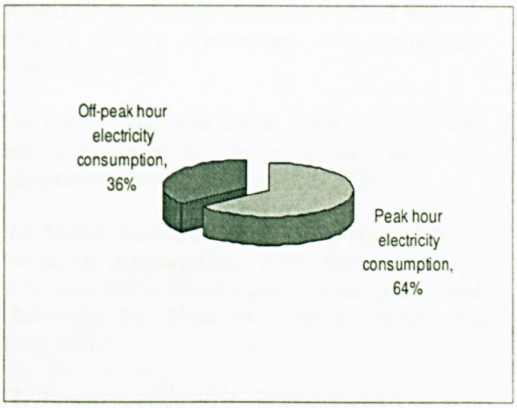

Figure 2 Percentage of Off-peak and Peak hours electricity consumption in Malaysian industries

Power Factor

From the data analysis it has been found that the average power factor ranged from 0.88 to 0.93 as shown in Table 5. It may be mentioned that improved power factor will reduce utility bill and increase the electrical systems capacity. TNB imposes a penalty to those 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 of the industries installed the capacitor bank for power factor correction. This will decrease the current through the facility power distribution system and will effectively increase the capacity of that line and reduce the line losses.

Table 5 Average and range of power factor of audited factories

Sector/ISIC code	Power factor	
	Average	Range
311	0.88	0.75 – 0.94
331	0.87	0.85 – 0.92
341	0.88	0.85 – 0.92
352	0.91	0.89 – 0.95
353	0.89	0.86 – 0.90
355	0.91	0.90 – 0.93
356	0.92	0.90 – 0.95
362	0.89	0.85 – 0.90
371	0.92	0.90 – 0.94
381	0.90	0.85 – 0.90
390	0.88	0.85 – 0.92

Conclusion

In the present study energy audit has been done in eleven industrial sectors comprising 91 factories of east-coast of Malaysia. From the

analysis of energy audit data, it can be concluded that:

(a) Among wide variation of end-use electricity consuming equipments, the electric motors are the major consumer of electrical energy followed by pumps and air-compressors. This study also found that majority of the factories is still using old equipments which are not efficient and waste huge amount of energy. There is wide variation of specific energy consumption observed in the audited factories. This is mainly due to the variety of products in a particular industrial sector, as well as the process steps involved in transferring the raw material to the final product. It has been found that the most of audited factories have lack of knowledge and awareness about conservation of energy. It can be recommended from this study that all factories should have their own energy conservation department which may be responsible to manage energy losses and hence reduces specific energy consumptions.

(b) The study also found that huge amount of energy and bill can be saved if high efficient motors are used in place of standard efficiency motor with a short payback period particularly for larger motors.

(c) This study also found that the 64% electrical energy is consumed in peak hours by the industries and average power factor ranges from 0.88 to 0.93.

Reference

[1] Bilal A. Akash , Mousa S. Mohsen, 2003. Current situation of energy consumption in the Jordanian industry, *Energy Conversion and Management,* 44, 1501–1510.

[2] Mohsen, M.S., Akash, B.A., 1998. Energy analysis of the steel making industry. *International Journal of Energy Research,* 22, 1049–1054.

[3] Ghaddar N, Mezher T. 1999 Modeling of current and future energy intensity and greenhouse gas emissions of the Lebanese industrial sector: assessment of mitigation options. Applied Energy, 63, 53–74.

[4] Climate change 1995, 1996. Impacts, adaptation and mitigation of climate change: scientific-technical analysis. Contribution of working Group II to the Second Assessment Report of the Intergovernmental Panel Climate Change (IPCC), Cambridge, UK: Cambridge University Press.

[5] Ninth Malaysian Plane 2006 – 2010, The economic planning unite prime minister's department, Putrajaya, Malaysia, 2006.

[6]. Mohd. Zamzam Jaafar, Wong Hwee Kheng, Norhayati Kamaruddin, 2003 Greener energy solutions for a sustainable future: issues and challenges for Malaysia, *Energy Policy,* 31, 1061–1072

[7]. Fromme, J.W., 1996. Energy conservation in the Russian manufacturing industry. *Energy Policy,* 24, 245–252.

[8] Ibrik, I.H., Mahmoud, M.M., 2005. Energy efficiency improvement procedures and audit results of electrical, thermal and solar applications in Palestine. *Energy Policy,* 33, 651–658.

[9] Priambodo, A., Kumar, S., 2001. Energy use and carbon dioxide emission of Indonesian small and medium scale industries. *Energy Conversion and Management,* 42, 1335–1348.

[10] Thollander, P., Karlsson, M., Soderstrom,M., Creutz, D., 2005. Reducing industrial energy costs through energy-efficiency measures in a liberalized European electricity market: case study of a Swedish iron foundry. *Applied Energy* , 81, 115–126.

[11] David Yih-Liang Chan, Kuang-Han Yang, Chung-Hsuan Hsu, Min-Hsien Chien, Gui-Bing Hong, 2007 Current situation of energy conservation in high energy-consuming industries in Taiwan, *Energy Policy,* 35, 202–209

[12] Ozturk HK., 2005 Energy usage and cost in the textile industry: a case study for Turkey. *Energy,* 30:2424–46.

[13] Christoffersen LB, Larsen A, Togeby M., 2006 Empirical analysis of energy management in Danish industry. *Journal of Cleaner Production,* 14(5):516–26.

[14] Subrahmanya MHB., 2006. Labour productivity, energy intensity and economic performance in small enterprises: a study of brick enterprises cluster in India. *Energy Conversion and Management,* 47(6):763–77.