ENERGY EFFICIENCY ANALYSIS FOR THE LABORATORY COMPLEX

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A report is submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering (with Honours).

Faculty of Mechanical Engineering

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DECLARATION

I declare that this project report entitled "Energy Efficiency Analysis for the Laboratory Complex" is the result of my own research except as cited in the references. This project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Author : LEE JIA YI

Date : ....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the Bachelor of Mechanical Engineering (With Honours).

Signature : ....

Supervisor : DR. TEE BOON TUAN

Date : ....

DEDICATION

To my beloved father and mother.

ABSTRACT

Building energy audit is widely used in the world energy policies to determine the respective energy usage and minimize the wastage of energy as buildings have hold the greatest potential in implementation of energy audit. It is important to understand the utilities' real operating conditions in the building and understand the building behavior before the energy audit is being undergone. In this thesis, energy audit has been implemented in UTeM Mechanical Engineering Laboratory Complex and some energy efficiency programs have been proposed. The two laboratories that have been focused in this project are Machine Workshop and Welding Workshop to compare the energy usage of heavily power consumed machine and the energy usage of air conditioning system. The steps of energy audit have included reviewing the historical data of the laboratory, visit to the laboratory, listing all the available equipment, estimation of power consumption, data collection using Chauvin Arnoux C.A 8435 energy meter and digital clamp meter as well as undergoing data analysis by comparing the estimated data and measured data. Besides from the energy consumption, the carbon footprint and energy usage intensity also have been taken into account in this thesis. At the last phase, energy conservation measures proposal and implementation of retrofit analysis have been performed based on the data obtained. From the measured data, it is found that Machine Workshop which consumes 4997.06kW per month has a higher monthly power consumption than the Welding Workshop which consumes 1454.42kW per month due to existence of heavy power machines and split unit of air conditioning system as well as most of the exact power consumption for equipment are at least 30% lower than their respective power rating. Therefore, it is important to undergo real measurement in energy audit besides from the estimation on calculations.

ABSTRAK

Audit tenaga telah luas digunakan dalam polisi tenaga sedunia untuk mendapatkan informasi tentang kegunaan tenaga dan mengurangkan pembaziran tenaga sedangkan potensi untuk melaksanakan audit tenaga dalam sektor bangunan adalah lebih tinggi berbanding dengan sektor lain. Pemahaman tentang keadaan operasi utiliti dalam bangunan yang benar dan struktur bangunan adalah sangat penting sebelum melaksanakan audit tenaga, Dalam tesis ini, audit tenaga telah dilaksanakan dalam Makmal Kejuruteraan Mekanikal Universiti Teknikal Malaysia Melaka dan beberapa program yang dapat meningkatkan kecekapan tenaga telah dicadangkan. Projek ini telah menfokuskan dua makmal dalam Makmal UTeM, iaitu Makmal Mesin dan Makmal Kimpalan demi mendapat perbandingan tenaga bagi kegunaan mesin yang bertenaga tinggi dan kegunaan sistem penyaman udara. Beberapa langkah telah dilaksanakan dalam audit tenaga seperti mengaji data makmal yang lama, melawat ke makmal, menyenaraikan mesin atau utiliti yang ada dalam makmal tersebut, menganggarkan kegunaan tenaga, mengumpul data menggunakan meter tenaga Chauvin Arnoux C.A 8435 dan Meter Amprobe serta menjalankan analisi data berdasarkan data yang dikutip dan anggaran. Selain daripada kegunaan tenaga, jejak karbon dan intensiti tenaga juga diambil kira dalam tesis ini. Dalam fasa yang terakhir, langkah-langkah untuk menjimatkan tenaga telah dicadangkan dan analisi retrofit telah dijalankan berdasarkan data yang dikumpul. Data kajian telah menunjukkan kegunaan tenaga bulanan Makmal Mesin adalah lebih tinggi daripada kegunaan tenaga bulanan Makmal Kimpalan sedangkan kegunaan tenaga bulanan bagi Makmal Mesin dan Makmal Kimpalan ialah 4997.06kW dan 1454.42kW disebabkan oleh mesin yang bertenaga tinggi dan sistem penyaman udara dalam makmal tersebut. Selain daripada itu, data kajian juga menunjukkan kegunaan tenaga kebanyakan utiliti atau mesin yang benar adalah 30% rendah daripada kadar tenaga. Secara ringkasnya, kajian ini telah menunjukkan kepentingan pengumpulan data yang benar dalam audit tenaga selain daripada menjalankan kiraan berdasarkan anggaran.

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ABBREVIATION	DESCRIPTION
ACMV	Air Conditioning and Mechanical Ventilation
AHU	Air Handling Unit
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
AUD	Australia Dollar
C1	medium voltage category
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CAM	Computer-Aided Manufacturing
CFL	Compact Fluorescent Lamp
CNC	Computer Numerical Control
CO_2	Carbon Dioxide
CRT	Cathode Ray tube
ECM	Energy Conservation Measures
EFFECTS	Efficient Energy & Thermal Management Systems Research Group
ENCON	Energy Conservation Opportunities
HVAC	Heating, ventilation and air conditioning
HP	Horsepower

IE2	High Efficiency
IE3	Premium Efficiency
IGA	Energy diagnosis and investment grade audit
ISO	International Organization of Standardization
KeTTHA	Ministry Of Energy, Green Technology and Water
LCD	Liquid Crystal Display
LED	Light-emitting diode
MEPS	Minimum Energy Performance Standards
MIG	Metal Inert Gas
PF	Power Factor
RM	Ringgit Malaysia
ROI	Return of investment
RPM	Rotation per minute
SESB	Sabah Electricity Supply Berhad
SESCO	Sarawak Electricity Supply Corporation
TNB	Tenaga Nasional Berhad
UTeM	Universiti Teknikal Malaysia Melaka
VSD	Variable Speed Drive
WTA	Walk-Through Audit

LIST OF SYMBOLS

SYMBOLS	DESCRIPTION
%	Percentage
^0C	Degrees Celsius
V	Volt
A	Ampere
h	Hour
kg CO_2/kWh	kilogram of carbon dioxide per kilo-Watt-hour
kW	kilo-Watt
kWh	kilo-Watt-hour
kW/day	kilo-Watt per day
kW/month	kilo-Watt per month
kWh/year	kilo-Watt-hour per year
kVA	kilo-Volt-Ampere
kVAR	kilo-Volt-Ampere Reactive
m/s	meter per second
s	second

CHAPTER 1

INTRODUCTION

1.1 Background

Energy efficiency is getting to be core in the world's energy policies since the attainability of all the energy policy's imperatives – reducing energy bills, decarbonisation, air pollution, energy security, and energy access are closely related to strong energy efficiency policy. Therefore, energy audit which is used to check the energy usage and minimize the wastage of energy is getting popular. (IEA, 2011) The process of energy audit has been divided into few steps which are analysis of the building and its utility data including study of the installed equipment and analysis of energy bills, survey on the utilities' real operating conditions, understand the building behaviour, evaluate the energy conservation measures and estimate the energy saving potential. (Stefano et al., 2013) Normally the energy performance indicator of school building will be operational profile, physical characteristics and total energy consumption which have included energy efficiency to compare energy levels between supply and demand, energy used for lighting (W/m^2), energy used for air conditioning(TR/100 m^2), annual energy consumption and total energy per unit area (kWh/m^2/year).

In these cases, buildings have hold the greatest potential in effective energy savings since 35% of the global energy has been consumed in buildings. The HVAC system and lighting system may contribute to the major energy usage in a building as about 56 % of the electrical energy is used in HVAC system of the building and 25% of electrical energy is used in the lighting system. (Karam et al., 2016) Most of the academic building in Asia country would have an older cooling system like split units which are controlled using thermostat by the staff daily. (Sofia et al., 2016) HVAC system which is a distribution system, equipment or terminal to provide air-conditioning to a building has included ventilation and space cooling. All the air conditioning system should be installed according to the Thermal Environmental Conditions for Human Occupancy, ASHRAE Standard. The comfort cooling has a recommended design dry bulb temperature in the range of 23℃ to 26℃, 0.15m/s to 0.50m/s of recommended air movement and 55% - 77% of recommended design relative humidity, while the lowest service illuminance for working interiors in a building is set to be 200 Lux. (STANDARD MALAYSIA, 2007) The common lights that used in a building are T5 and T8 fluorescent lights followings the Standard for Lighting Design of Buildings.(He Hua et.al, 2009) The power of lighting that used usually ranges from 50W to 80W. (Sofia et al., 2016)

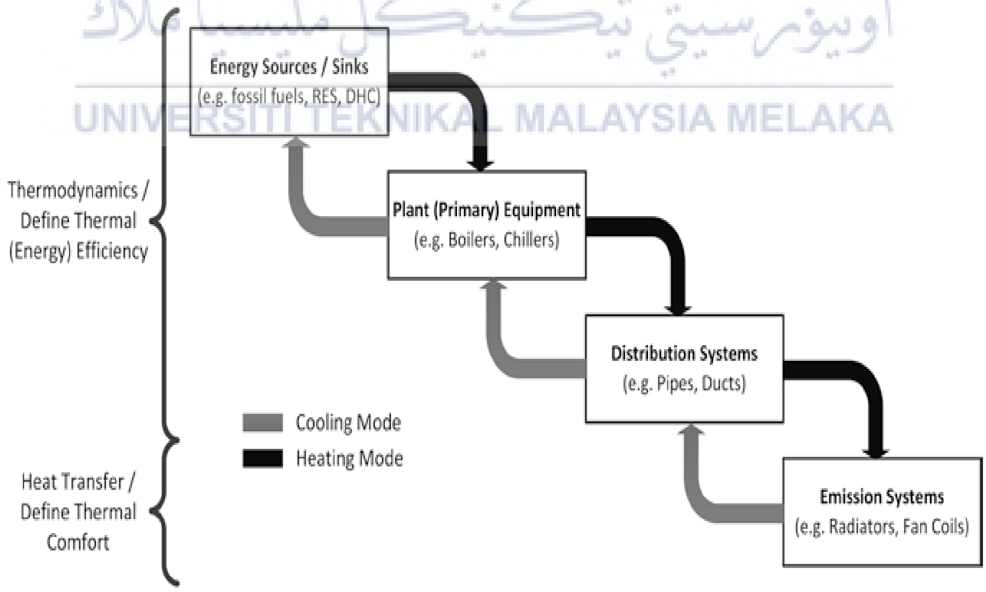


Figure 1.1: Rough Sketch of HVAC system (Sofia et al., 2016)

Besides that, energy audit is important to determine the energy usage during peak hours and non-peak hours in order to figure out the methods to reduce energy usage in an efficient way since Peninsular Malaysia the only one electric utility, Tenaga Nasional Berhad (TNB) has charged for the electricity usage according to peak period and non-peak period besides from the categories such as commercial category, industry category, mining category and specific agriculture. The peak period is from 8am to 10pm and the non-peak period is from 10pm to 8am.

In this case, UTeM Mechanical Engineering Laboratory Complex which is operating during weekdays has been selected to undergo energy audit. UTeM is a Malaysia public university which is established on 1 December 2000 with 7 faculties and variety of facilities such as sport complex, health centre, library, cafeteria and laboratories. It consists of UTeM Centre for Advanced Research on Energy to undergo research on energy and policy within the context of economic and environmental sustainability which supports the Energy Policy 1979. One of the research group, Efficient Energy & Thermal Management Systems (EFFECTS) Research Group is targeted to promote and conduct research in the areas of efficient energy and thermal management systems which pursue high energy efficiency and low carbon footprint in all the UTeM buildings.

UTeM Mechanical Engineering Laboratory Complex consists of six blocks which are Block A, Block B, Block C, Block D, Block E and Block F with total area of $8243.48m^2$. It consists of air conditioning laboratory, vibro-acoustics laboratory, CAD/CAM/CAE Studios, Combustion Laboratory, Conditional Based Maintenance laboratory, Engine Performance Testing Laboratory, Fluid Mechanics Laboratory, Prototype & Innovation Laboratory, Instrumentation Laboratory, Materials Science Laboratory, Mechanics of Machine Laboratory, Racing Vehicle Development workshop, Structural Health Monitoring

Laboratory, Structural Mechanics Laboratory, Tribology Laboratory and Vehicle Maintenance and Service Laboratory.

Figure 1. 2: UTeM Mechanical Engineering Laboratory Complex

1.2 Problem Statement

The purpose of this study is to determine the energy usage and energy efficiency in UTeM Mechanical Engineering Laboratory Complex which consists of air conditioning laboratory, instrumentation laboratory and CAD studios. Although the laboratory complex only operates during weekdays, its electricity bill is surprisingly high which cost more than RM12000 every month even with the government subsidise and burdens the UTeM management by referring to its past three years electricity bills. Therefore, the laboratory complex has a high potential in pursuing high energy efficiency and low carbon footprint. In order to eliminate the energy wastage, it’s necessary to understand the trend of the energy consumption. Therefore, this project is conducted to figure out the solutions to the following questions:

i) What is the trend of energy consumption and distribution in the lab buildings?

ii) What is the potential source of energy wastage based on the current lab operating conditions?

iii) What is the potential measures in implementing energy efficiency program for laboratory buildings?

1.3 Objective

(a) To conduct an energy audit and analysis for engineering laboratory buildings.

(b) To propose an energy efficiency program for the laboratory building.

1.4 Scope

The scopes of this study are outlined as follows:

i. Research is conducted in UTeM Mechanical Engineering Laboratory Complex.
ii. Determine and evaluate the current energy consumption.
iii. Identify the operation hours and conditions of the systems.
iv. Analyse the performance based on the data taken.
v. Determine the potential of energy saving plan.

1.5 Importance of the research

This research can provide an overview of energy consumption in laboratory as most of the current energy audit is focusing on the industry area and building area. It supports the Malaysia Government Energy Policy 1979 which promotes sustainable development, elimination of wasteful energy consumption and minimize the negative impacts of energy production on the environment. Besides that, it is important to determine the energy efficiency and carbon footprint of the laboratories which may help to reduce the energy consumption and electricity bill as well as decrease the negative impacts to the environment. It is possible to develop and energy efficiency program which can be used in all the UTeM laboratories and buildings.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the previous research and literature review on energy audit in the buildings have been discussed thoroughly. The calculation on HVAC system and lighting system have be done to examine the energy consumption of the building.

2.2 Energy Profile in Malaysia

There are three electricity utility in Malaysia, which are Tenaga Nasional Berhad (TNB) in Peninsular Malaysia, Sabah Electricity Supply Berhad (SESB) and Sarawak Electricity Supply Corporation (SESCO). Among the three providers, Tenaga Nasional Berhad (TNB) is the largest electric utility provider in Malaysia and the largest public-listed power company in Southeast Asia.

According to the data from Suruhanjaya Tenaga Malaysia, the energy demand increases annually and most of the energy has been used in the commercial and industrial area. As in 2015, the electricity consumed in industrial area and commercial area are 5218 ktoe (46%) and 3659 ktoe (32%) due to their big power machinery for daily operation.

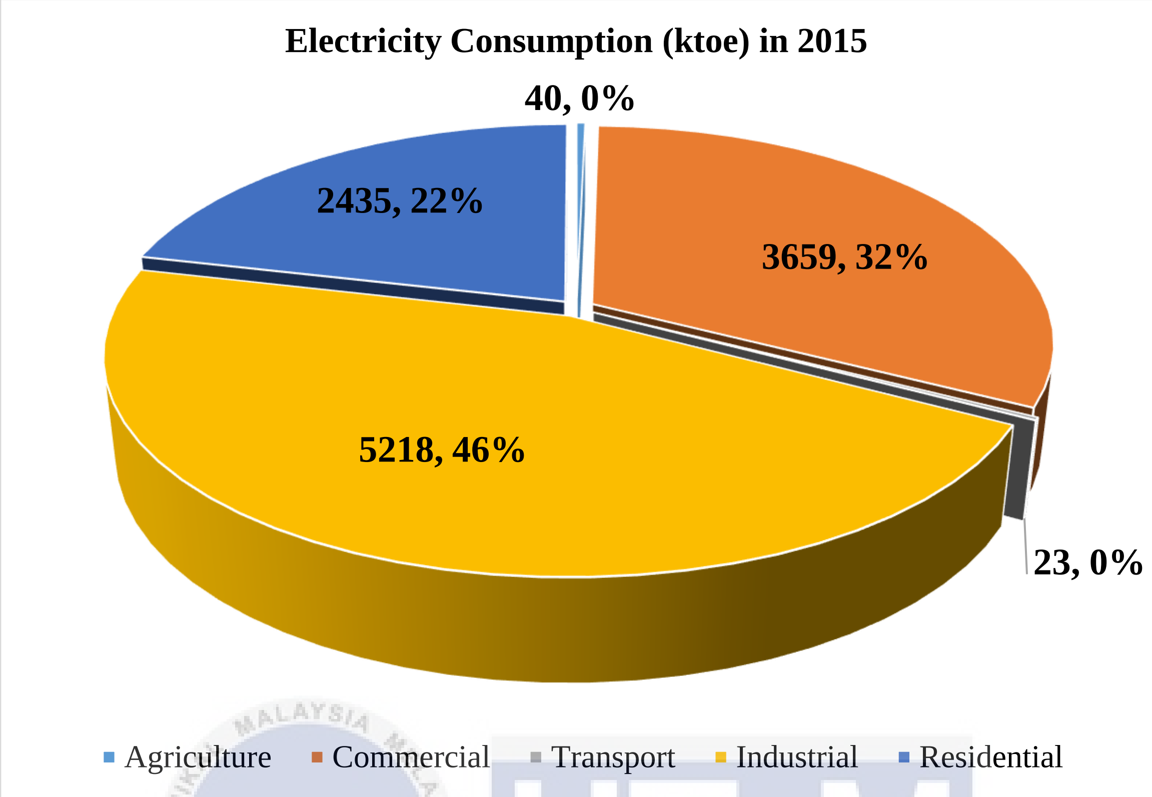


Figure 2.1: Electricity Consumption (ktoe) in Malaysia 2015 (Suruhanjaya Tenaga Malaysia, 2017)

2.3 Energy Policy in Malaysia

Throughout the years, Malaysia Government has generated some policies on the energy field to ensure a sustainable development of economy and energy.

a) National Energy Policy 1979

This policy was defined by Malaysia government in 1979 which focused on the nation's five-year development after dramatic drop in oil production due to the invasion of Iran by Iraq and the increase of oil price. There are three key objectives in this policy which are

i.) Supply Objective: To ensure the provision of adequate, secure and cost-effective energy supply through sustainable development of indigenous energy resources, both non- renewable and renewable sources.

ii.) Utilization Objective: To promote the efficient utilization of energy and the elimination of wasteful and non-productive patterns of energy consumption.

iii.) Environment Objective: To minimize the negative impacts of energy production, transportation, conversion, utilization and consumption on the environment.

b) The National Green Technology Green Technology Policy

This policy is established by Ministry Of Energy, Green Technology and Water (KeTTHA) at April 2009 which is aimed to minimize growth of energy consumption, facilitate the growth of green technology industry and ensure a sustainable development. This policy has covered the energy sector, building sector, water and waste management sector and transportation sector.

c) New Energy Policy & 10th Malaysia Plan, 2010

This policy addresses on the economic efficiency, security of supply & social and environmental objectives with 5 pillars:

i.) Energy pricing which looks more on the resource allocation, economic development path and energy up taking.

ii.) Energy Supply which is focusing on diversify supply, alternative sources and new entrants.

iii.) Energy Efficiency which focuses on market competency and low carbon economy.

iv.) Governance which is more on integrity, regulatory consistency and market disciplines.

v.) Change Management which concerns on integrity, sequenced, gradual and social assistance

2.4 Energy Saving Activities

There are many international organization or standards such as International Energy Agency, United States Department of Energy and Minimum Energy Performance Standards (MEPS) which have promoted the importance and method of saving electricity. However, the implementation rate and energy saving rate are always being questioned. Regarding this issue, Suruhanjaya Tenaga Malaysia who is responsible to audit and analyse the electrical energy consumption has undergone analysis on the implementation rate of electricity saving activity and the energy that has been conserved throughout the years. The activities that have undergone on lighting system are changing T8 bulb to T5 bulb to LED bulb, de-lamping on certain area which is over bright, installing transparent roof to replace the light during daylight and installing timer or sensor for auto off operation. While the related activities on HVAC system are replacing normal Air-Cond unit with inverter unit, replacing old chiller with high efficient chiller and install VSD for AHU or chiller pump. In 2013, there are 283 electricity saving activities, 36% on lighting system and 161 electricity activities, 20% on HVAC system as shown in Figure 2.2. Meanwhile, the activity that has saved up the most electricity is activity on HVAC system which has saved 6308431.15kWh of electricity, 30% as shown in Figure 2.3. The big data on the electricity saving activities has shown the hidden potential of reducing the energy consumption.

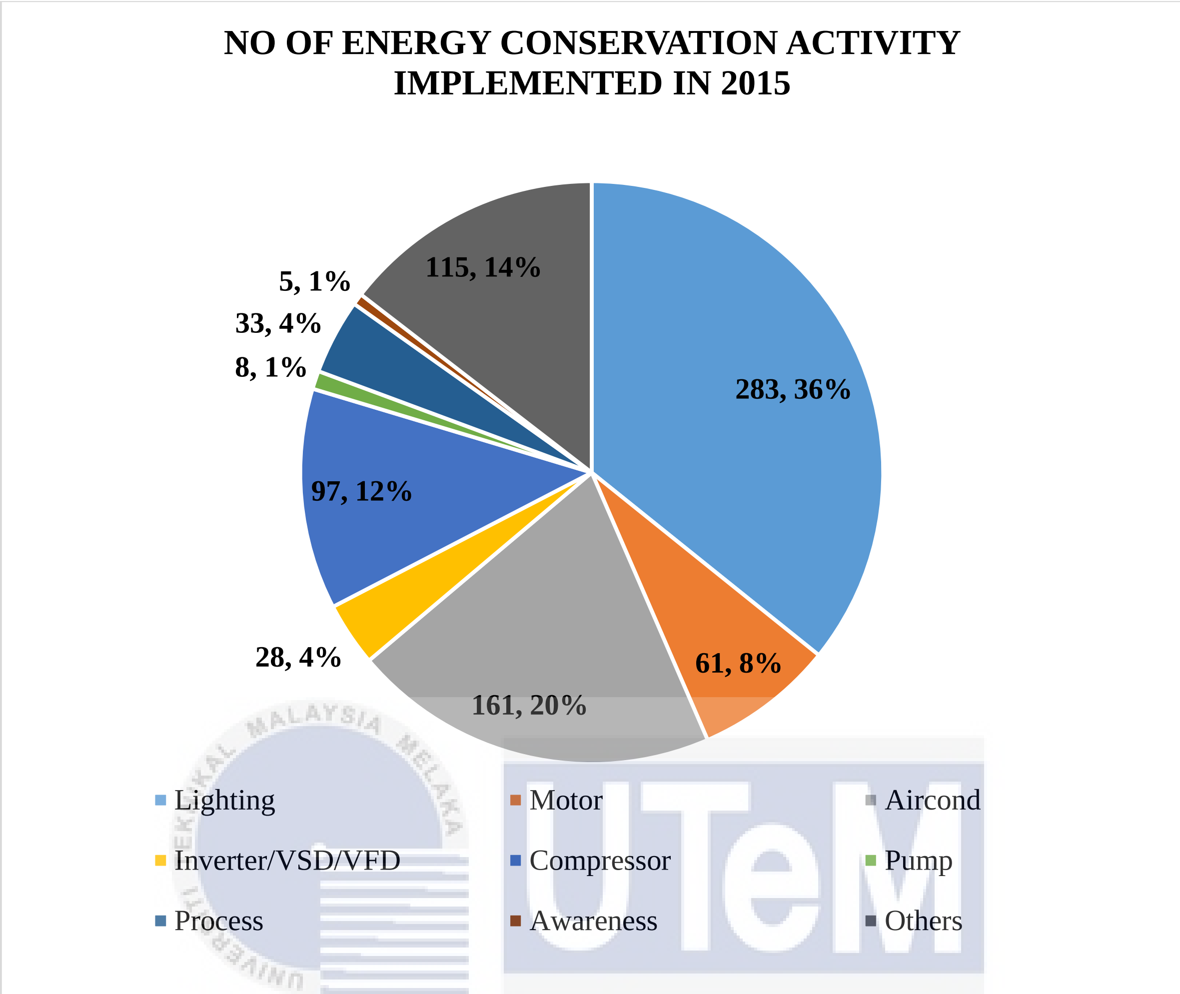


Figure 2.2: No of Energy Conservation Activity Implemented In 2015 (Suruhanjaya Tenaga Malaysia, 2017)

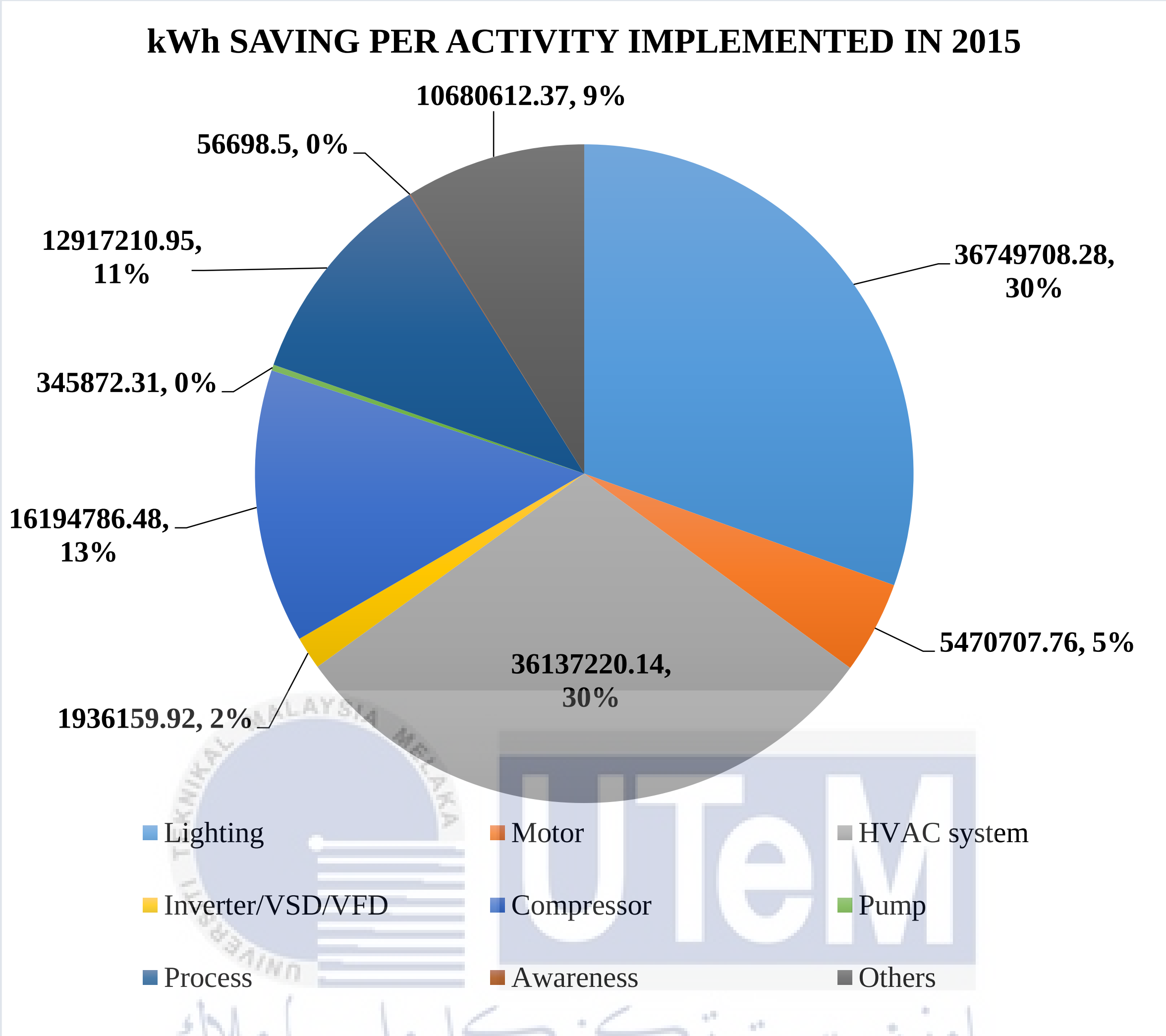


Figure 2.3: kWh Saving Per Activity Implemented In 2015 (Suruhanjaya Tenaga Malaysia, 2017)

2.5 Energy Audit

Energy audit is a systematic analysis of energy use and energy consumption within a defined energy audit scope, in order to identify, quantify and report on the opportunities for improved energy performance. (ISO 50002:2014, 2014) All of the energy audits in Malaysia should be undergone following to ISO 50001: 2011 Energy Management Systems which is an international standard published in August 2011 that has included industrial plants, commercial, institutional and governmental association. The energy audit has been divided into three phases which are investigation phase, monitoring phase as well as analysis and reporting phase. Besides that, the level of detail on evaluation of energy flow, energy input, human comfort, health and safety will determine the type of audit. There are three types of energy audit which are walk-through audit (WTA), energy diagnosis and investment grade audit (IGA).

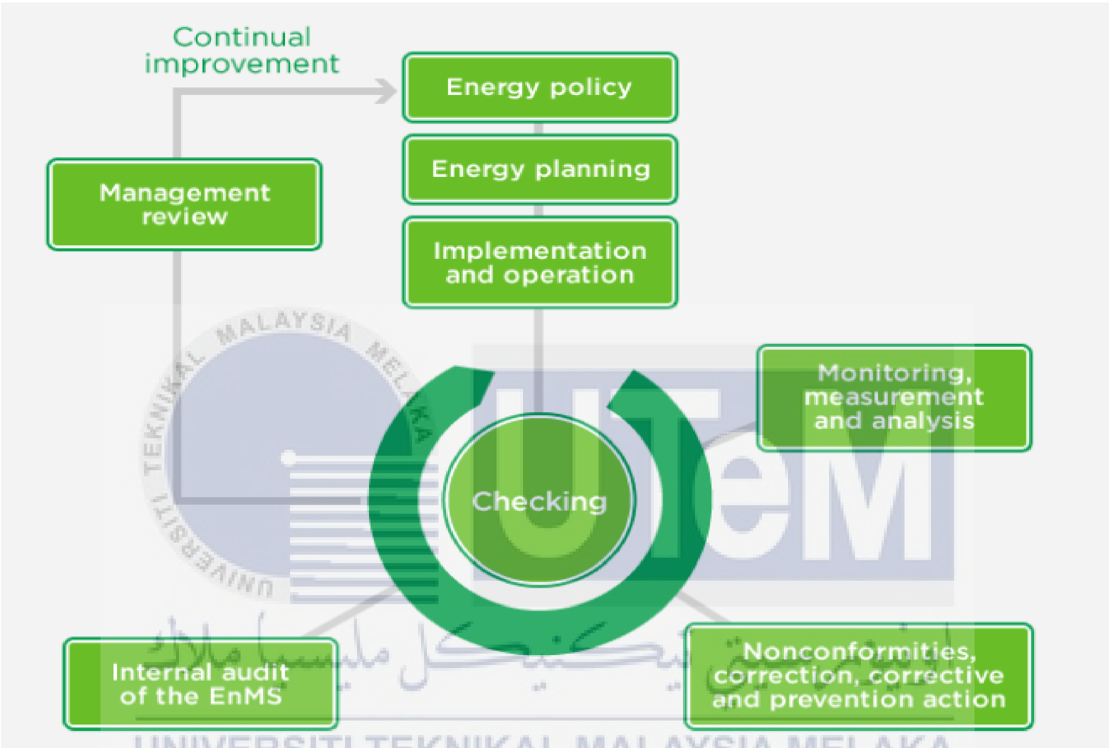


Figure 2.4: Summation of the energy management process (ISO 50001, 2011)

2.5.1 Walk-Through Audit

This is the basic and quickest energy audit which is suitable for lower energy expenditures site or act as scoping audit for larger sites. This method has included interviews with site-operating personnel, a brief review on facility utility bills and other operating data as well as consists of a walk-through inspection of a facility to identify maintenance, operational or glaring areas of energy waste or inefficiency. It will provide a quantitative overview of energy performance and identify low cost opportunities with payback periods of up to 2 years. Examples of maintenance measures include setting back heating set-point temperatures, replacing broken windows, insulating exposed hot water or steam pipes, and adjusting boiler fuel–air ratio.(Krarti, 2011)

2.5.2 Energy Diagnosis

This energy audit is a more detailed energy audit to perform economic calculations as well as include some metering devices to identify the actual energy consumption and losses. There will be financial analysis and energy efficiency analysis on the building referring to the utility data over past several months or years to evaluate its energy demand rates and energy usage profiles. These data will help in verifying the potential for energy savings. Meanwhile, it is possible to make an energy retrofit projects by analyzing the utility data. (Krarti, 2011)

2.5.3 Investment Grade Audit (IGA)

This audit is a more precise subsystem audit which is the combination of walk-through audit and energy diagnosis. It has included a detailed account of energy use, implementation with detailed investments and operational and maintenance costs and an analysis of the investment model. Normally, this audit will focus on process or subsystem level such as HVAC system, building management system, compressed air system or lighting system. It requires monitoring on energy data from time to time to determine the real energy demand and operating conditions with other relevant variable. Normally, the handheld and clamp-on instruments will be used to determine the variation of some building parameters such as the indoor air temperature, luminance level, and electrical energy use, while sensors will be used with a data-acquisition system for long term measurement project. (Krarti, 2011)

2.5.4 General Procedure for Energy Audit

The first step in energy audit is to gather information about the case study building and utility data analysis which will assist in evaluating the energy profile and energy trend of the building. All of the data will be collected from the architectural drawings, mechanical drawings, electrical drawings and the past utility bills. The utility bills will help to determine if there is any weather effects. For example, there will be standard condition of human comfort which is the calculation basis and design basis. When the temperature of the room is higher than the standard condition due to the hot weather, the HVAC system might need more energy to achieve the average level of comfort. If the weather is windy or cold, the HVAC system needs lesser amount of energy to achieve the comfort level. Meanwhile, the second step will be walk through survey which is aimed to identify the customer needs, current operating conditions and maintenance procedures. The third step will be baseline for building for energy use which will develop a base-case model to estimate the energy savings from some energy conservation measures. Lastly, the energy savings measures will be evaluated using energy saving analysis and economic analysis. The initial cost to implement the energy conservation measures and the simple payback or life-cycle cost analysis will be considered in this step. (Krarti, 2011)

Phase	Thermal Systems	Electric Systems
Utility analysis	• Thermal energy use profile (building signature) • Thermal energy use per unit of a product • Thermal energy use distribution (heating, process, etc.) • Fuel types used • Analysis of the thermal energy input for specific processes used in the production line (such as drying) • Utility rate structure	• Electrical energy use profile (building signature) • Electrical energy use per unit of a product • Electrical energy use distribution (cooling, lighting, equipment, process, etc.) • Analysis of the electrical energy input for specific processes used in the production line (such as drying) • Utility rate structure (energy charges, demand charges, power factor penalty, etc.)
On-site survey	• List of equipment that uses thermal energy • Perform heat balance of the thermal energy • Monitor of thermal energy use of all or part of the equipment • Determine the by-products of thermal energy use (such as emissions and solid waste)	• List of equipment that uses electrical energy • Perform heat balance of the electrical energy • Monitor electrical energy use of all or part of the equipment • Determine the by-products of electrical energy use (such as pollutants)
Energy use baseline	• Review mechanical drawings and production flow charts • Develop a base-case model using (any baselining method) • Calibrate the base-case model (using utility data or metered data)	• Review electrical drawings and production flow charts • Develop a base-case model (using any baselining method) • Calibrate the base-case model (using utility data or metered data)
Energy conservation measures	• Heat recovery system • Efficient heating and drying system • EMCS • HVAC system retrofit • Hot water and steam use reduction • Cogeneration (possibly with solid waste from the production line)	• Energy efficient motors • Variable speed drives • Air compressors • Energy efficient lighting • HVAC system retrofit • EMCS • Cogeneration (possibly with solid waste from the production line) • Peak demand shaving • Power factor improvement • Reduction of harmonics

Figure 2.5: Energy Audit Summary for Industrial Facilities (Krarti, 2011)

2.6 Lighting System

There are two types of light sources, incandescence and luminescence. Both of the light emission is the same in which the electronic transitions from higher to lower energy states, but they are different in case of the mode of electron excitation and resultant spectral distribution of radiation. (Judith et.al, 2000) There are many cost effective methods to improve the lighting systems efficiency such as use energy-efficient lighting lamps, addition of reflective devices, delamping if the luminance levels are higher than the recommended levels by the standards and apply daylighting controls. (Krarti, 2011) The new model of LED since 2011 have greater performance in both energy efficient and luminosity compare to other convectional lamps. (Ganadran, 2014). LED lamps are more expedient and environmental friendly, but it has higher initial cost due to its low wattage consumption and high performance. (Udin, 2011)

The example of incandescence light sources are incandescent filament which is widely used in the household and commercial lighting due to its portability, pyro luminescence (Flame Luminescence) which is a process of high-temperature energy exchange between highly excited molecules and atoms, Cando luminescence (Gas Mantle) which is the light given off by the heated body which its intensity at some wavelengths can be higher than the blackbody emission expected from incandescence at the same temperature and Carbon Arc Radiation which occurs due to the incandescence of the electrodes and luminescence of vaporized electrode material or any other constituents of the surrounding gaseous atmosphere. (Judith Block et.al, 2000) Meanwhile, the examples of luminescence light source are photoluminescence which consists of gaseous discharges which is generated by sending electric discharge through noble gas and some additional substances susch as mercury, sodium and metal halides, fluorescence due to the luminescence of the mercury vapour when a gas discharge is converted into light by a phosphor coating on the inside of the tube or outer jacket and phosphorescence which is activated by IR radiation. (Block et.al, 2000)

2.7 HVAC System

Heating, Ventilating and Air conditioning system (HVAC) is a system which provides fresh air, heating or cooling to room using refrigerants by transfer the indoor heat to outdoor and replace the indoor air with cooler and fresher air as well as alter the air properties such as temperature, humidity or general quality of air. Generally, all the building in Malaysia must install the HVAC following ASHRAE standard and Malaysia standard to ensure the air conditioning system is desirable to maintain the occupants' health and comfort. The major components inside the air conditioning system are compressor, condenser, expansion valve and evaporator.

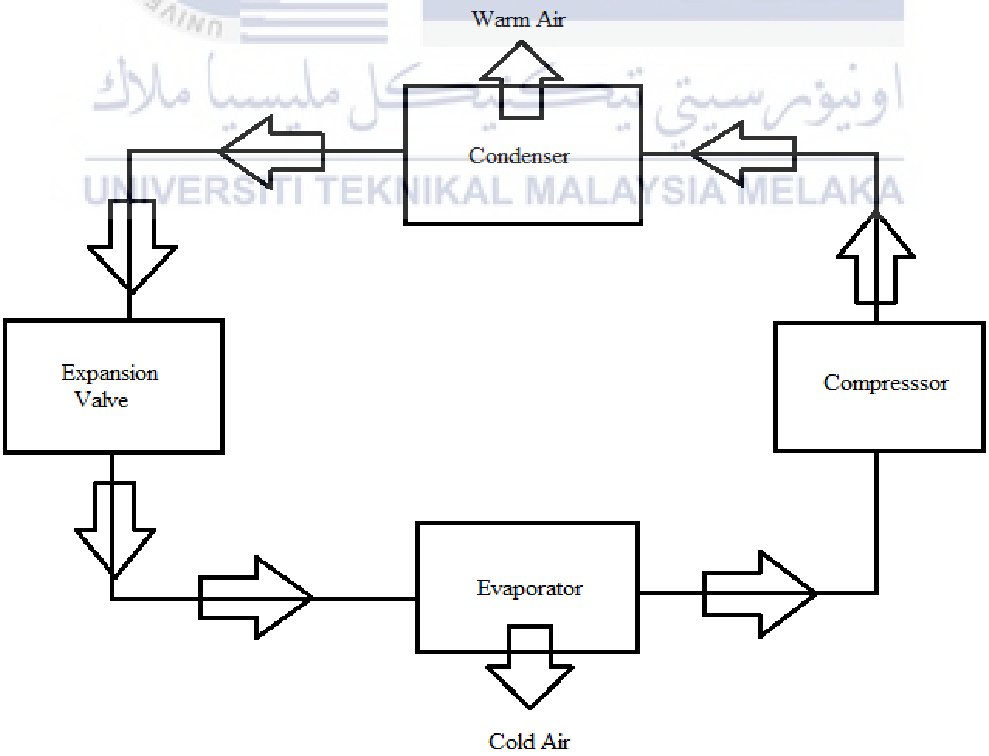


Figure 2.6: Principle of Air Conditioning System

Refrigerant enters the compressor which is playing a core role in the system by pumping the refrigerant through all the components as low pressure warm vapour. The hot refrigerant is then being moved to condenser and changes its state from hot vapour to hot liquid at high pressure. After that, the cooled refrigerant will be moved into expansion valve and the pressure of the refrigerant decreases. Lastly, the low pressure cool refrigerant will move into evaporator and the expanded refrigerant gas cools off the air blowing across the evaporator and back into a volume of space. The refrigerant will boil and change from cold air and evaporate as warm vapour once it heats up. The hot refrigerant will then move back to compressor and the cooling cycle continues. There are two general types of HVAC systems which are split unit and central air conditioning system. (Khemani, 2013)

2.7.1 Split Unit

Split Unit comprises of outdoor unit and indoor unit. Outdoor unit which is normally fitted outside the room consist of compressor, condenser and expansion valve, while indoor unit consists of evaporator and cooling fan which provides the cooling effect. A split unit type of air conditioner can be used to cool one to two rooms and there are few methods to install the split units such as wall mounted, ceiling mounted and floor mounted. Normally split unit air conditioners will be used small air conditioning capacities up to 5 tons. (Khemani, 2013)

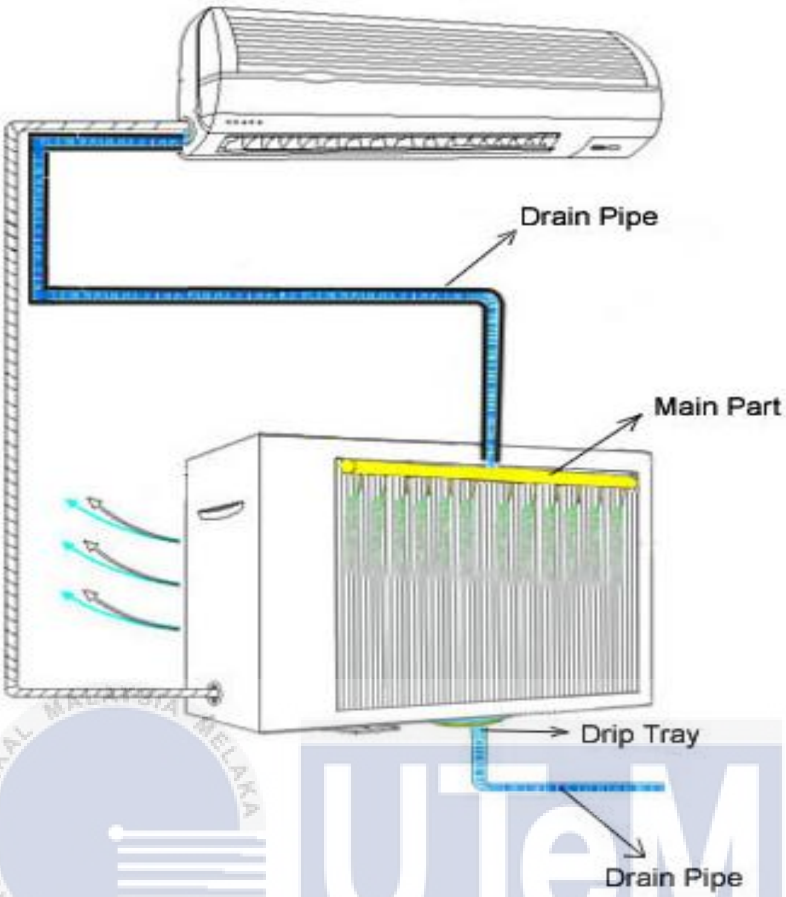


Figure 2.7: Split Unit (Source: Smart Clima Website: http://www.smartclima.com/air-conditioner-energy-saving.htm)

2.7.2 Centralised Air Conditioning System

A centralised air conditioning system will contribute the conditioned air through ducts to various space and is still operating based on principle of air conditioning system. The benefits of the centralised air conditioning system are consisting of sophisticated filter which can remove the airborne particles and microscopic particles and can help to reduce the electricity usage. Normally, this system will be used in large buildings such as hotels, theatres, airports and shopping mall and more economical compared to the usage of split unit. Centralised air conditioning system is usually used for the space where its cooling load extend beyond 20 tons. (Khemani, 2013)

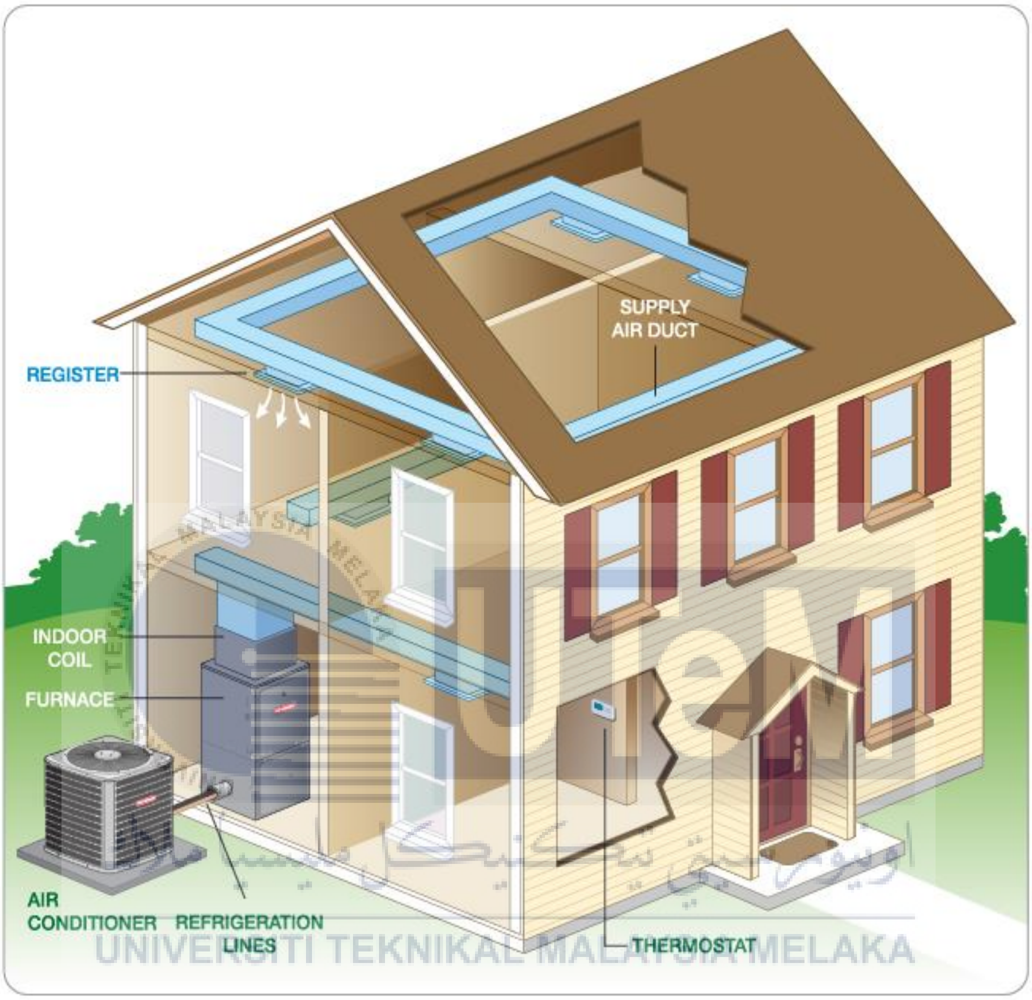


Figure 2.8: Centralised Air Conditioning System (Source: Goodman website: http://www.goodmanmfg.com/resources/heating-cooling-101/how-central-ac-systems-work)

2.7.3 Packaged Air Conditioning System

Packaged air conditioning system is usually used for cooling capacities between 5 to 20 tons and available in the market at a fixed rated capacities such as 3, 5, 7, 10 and 15 tons. It is normally used in at an area which is more than two rooms such as restaurants, telephone exchanges, home and small hall. There are two types of arrangement in the system in which the first system consists of evaporator, compressor and condenser and expansion valve in a single box and the cooled air will flow through the ducts in the rooms after being thrown by high capacity blower. Meanwhile, in the second system, the compressor and condenser are in the same casing and the expansion and evaporator will act as individual units which are located in the rooms. (Khemani, 2013)

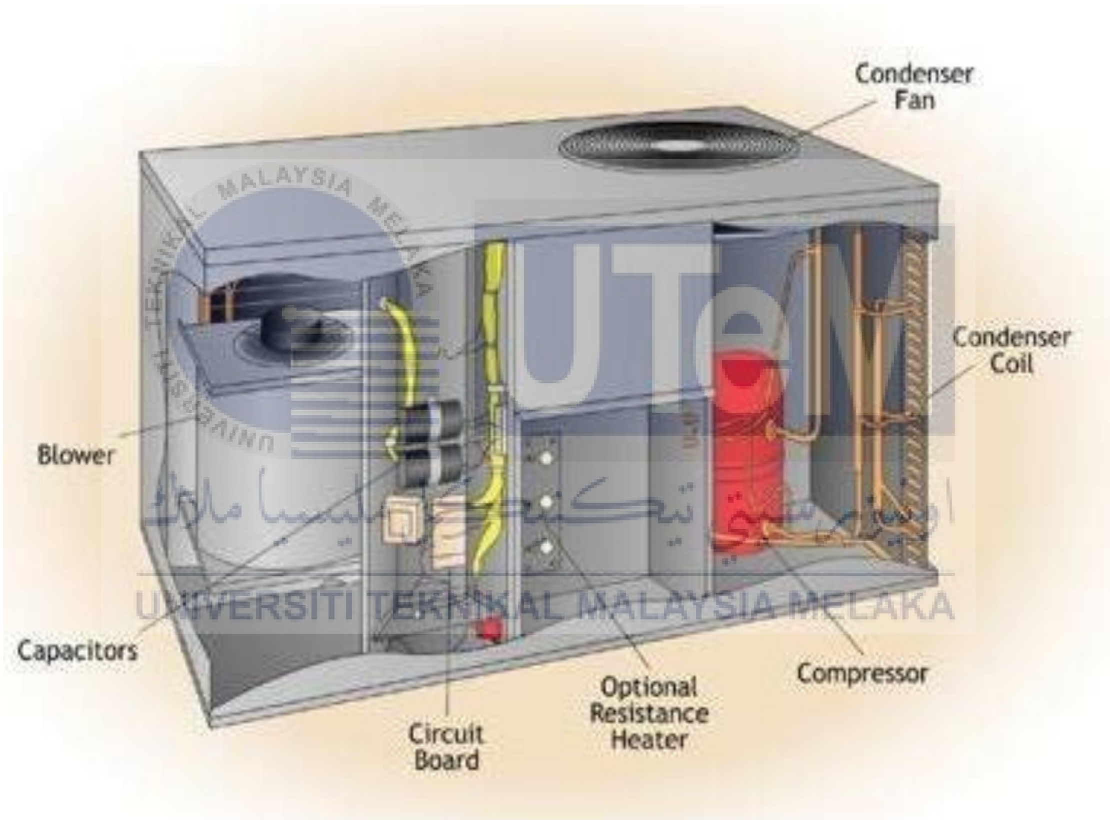


Figure 2.9: Packaged Air Conditioning System in second arrangement (Source: Bright Hub Engineering Website: http://www.brighthubengineering.com/hvac/61457-packaged-air-conditioners-types-of-packaged-ac/)

2.8 MS 1525:2014

MS 1525:2014 is a Malaysia code of practice on energy efficiency and use of renewable energy for non-residential buildings which has included the requirements on design of efficient lighting system, minimize losses in electrical power distribution equipment, design of efficient HVAC system and design of good energy management system. The requirements on the design of efficient lighting system have compliance to Lighting of work places - Part 3: Lighting requirements for safety and security of outdoor work places (MS ISO 8995) and Code Of Practice For The Design Of Road Lighting - Part 1: Lighting Of Roads And Public Amenity Areas (MS 825). This code has consisted of some recommendations on the average illuminance levels in certain area which has categorized the usage of lighting into three types: lighting for infrequently used area, lighting for working interiors and localised lighting for exacting task. (Standards Malaysia, 2014) The table of average luminance level and maximum allowable power intensity is shown in Table 2.1. This code also has some control accessibility on the lighting system to minimize the wastage of electricity on lighting system.

Table 2.1: Recommended average illuminance levels and maximum allowable power intensity (Source: STANDARDS MALAYSIA, 2014)

Task and Applications	Illuminance (Lux)	Minimum CRI	Max. lighting power intensity (W/m2)
a) Lighting for infrequently used area:			
- Minimum service illuminance	20	30	3

- Corridor, passageways, stairs	100	40	5
- Escalator, travellator	150	40	6
- Entrance and exit	100	60	5
- Cleaner room, stores	100	60	5
- Gate house	200	80	8
b) Lighting for working interiors			
- Infrequent reading and writing	200	80	8
- General offices, shops and stores,	300-400	80	14
- Drawing office	300-400	85	14
- Toilet	100	60	5
c) Localised lighting for exacting task			
- Proof reading	500	80	18
- Exacting drawing	1000	80	40
- Detailed and precise work	2000	80	60

Besides that, MS 1525:2014 has set the standard of the motor continuous rating at an acceptable range in which it should not exceed 30% of the estimated maximum load and has classified the motor according to their efficiency. The power factor for motor is also recommended to be corrected to above 0.85 when operating and is strictly disallowed to be below 0.85 to avoid utility tariff's penalty. (Standards Malaysia, 2014)

Moreover, this code has recommended to size the ACMV system based on the ASHRAE handbook to meet the room comfort condition in which the recommended design dry bulb temperature is 24ºC to 26ºC, the minimum dry bulb temperature us 23º C, recommended design relative humidity is 50 % - 70 % and the recommended air movement is 0.15 m/s - 0.50 m/s. Meanwhile, chiller will be used only if the design load is more than 1000 kWhr and every system should be provided with at least one thermostat for the regulation of temperature. Each for adjustment. This code also consists of energy saving and comfort cooling steps on ACMV system such as control setback and shut off, reheat system, energy recovery, off-hour control and mechanical ventilation control. A fan system which is operating for more than 750 hours per years and with air flow rate exceeding 17 000 m3/h must consist of a motor which its required power doesn't exceed 0.42 W per m^3/h of air flow rate. (Standards Malaysia, 2014)

Besides that, there are two basic types of ACMV systems which are central system and unitary system. Central system consists of water distribution type and air distribution type. The water distribution central system which is a package of centrifugal, rotary, screw, scroll or reciprocating, compression refrigeration or absorption refrigeration type water-chilling will receive chilled water to perform cooling functions, while air distribution type which consists of terminal units will receive recirculated air from a central duct system to perform ventilating function. Meanwhile, the unitary system consists of evaporator, compressor and condenser to perform the cooling and dehumidification functions through duct or without duct. The standard rating temperature for cooling is shown in Table 2.2. (Standards Malaysia, 2014)

Table 2.2: Standard rating temperatures (Source: STANDARDS MALAYSIA, 2014)

Item	Air-cooled		Water-cooled (water-source)	
	Dry-Bulb	Wet Bulb	Inlet	Outlet
Room air entering equipment (°C)	27	19	-	-
Condenser ambient (air-cooled) (°C)	35	24	-	-
Refrigerant-water heat exchanger (°C)	-	-	30	35

Lastly, this code has a recommendation which is to use an intelligent building system, Energy Management System in building with more than 4000 m^2 air conditioned space. This system consist of three main parts which are control of equipment, monitoring of equipment and integration of equipment sub systems. Normally, this system will be used in energy consuming areas such air conditioning and mechanical ventilation system (ACMV system), lighting system, water pump system and gas heater system. The building will be equipped with data logger to determine the utility consumption and the historical energy usage or building activities will be observed to determine the energy profile. (Standards Malaysia, 2014)

2.9 British Standard 8207:1985

British Standard 8207: 1985 is a standard which is related to the energy conservation and environmental design. If the building is in design phase, the engineer should determine the performance of building before analysis the estimated energy demand using theoretical calculations. Meanwhile, the engineers should record the energy consumption, statically determine the performance indicator by compare the actual performance with theoretical performance as well as minimize the wastage of energy if the building is an existing building. Besides that, the engineers should consider the initiate cost, running costs, associated costs, notional costs, savings and return of investment (ROI) in the energy audit to get the best return of investment and achieve the best result. An efficient energy management should comprise of an energy management programme, owner’s manual, operating and maintenance procedures, commissioning and testing and monitoring in which its building occupants, existing system, operating and maintenance and energy consumptions should be known. (British Standard, 2007)

2.10 British Standard 15217:2007

British Standard 15217:2007 is a code on energy performance of buildings — Methods for expressing energy performance and for energy certification of buildings. The energy performance of a building is determined based on the primary energy of the building, its carbon dioxide emission and net delivered energy based on the parameter defined by national. Meanwhile the specific requirement of energy will be based on the energy usage, characteristics of building and the building systems component as well as the overall energy performance must be lesser than the overall energy requirement. Therefore, this code has listed some possible modification to minimize the overall energy performance and has suggested to use reference values to compare the energy performance of a given building to the energy performance of similar buildings. The list of possible modifications is shown in Table 2.3. (British Standard, 2007)

Table 2.3: Parameters with reduced or neutralized impacts (Source: British Standard, 2007)

Parameter	**Possible Reason**
Climate	To adapt the level of technologies requested to the climate
Building function	To adapt the requirements to the different designs, uses and feasible technologies
Energy carrier	For national energy policy regarding the possible use of different energy sources (e.g. gas/electricity), or to take into account the availability of specific energy sources in specific locations
Building size and/or shape	To avoid unduly onerous requirements on detached houses and too low requirements on large compact buildings. To adapt the requirements to buildings with different sizes and shapes.
Ventilation rate	To prevent too costly requirements for buildings or uses which require a high ventilation rate
Illumination level	To prevent too costly requirements for buildings or uses which require a high illumination level

2.11 Energy Audit by Previous Researchers

There are some energy audits that have been done by previous researchers on buildings and being reviewed.

2.11.1 An Approach to Energy Saving and Cost of Energy Reduction Using an Improved Efficient Technology by Abubakar, Abba, Jamilu (2015)

This study has focused on electricity consumption of the existing electrical appliances and high efficient electrical appliances in tutorial rooms. The electrical appliances used in the tutorial rooms are air conditioning system, projector and lightning. The electricity consumption has been obtained based on the theoretical calculations and the cost for the electricity consumption has been calculated based on the Tenaga National Berhad pricing and tariff. A comparison has been made based on the data to determine the efficiency of the application of high efficiency electrical appliances and the cost saved. From the results, the proposed high efficiency electrical appliances consume less power and less cost compared to the existing electrical appliances.

2.11.1.1 Methodology

This case study has been done in 5 selected tutorial rooms in level 4 of the Faculty of Electrical Engineering 19 A buildings, Universiti Teknologi Malaysia which are the lecture theatres for graduate studies. Five of the rooms are having the same electrical appliances, which are having 6 air conditioning systems, 1 projectors and 40 lightings, but the lecture time tables for them are different. Therefore, the electricity consumption for them are different. The existing air conditioning system is DAIKIN FCU-4-13-52A with 3730 Watt power consumption, while the existing projector is Hitachi CP-EX250 with 300 Watt power consumption. Meanwhile, the lightning lamp is Philips T8 with 32 Watt power consumption. During the case study, researchers have neglected small electrical load in which the students may bring along the handset chargers, laptop chargers and other electrical loads.

The first step in this case study is to determine the power consumption of the existing electrical appliances (Watt) and determine the lecture time table for respective tutorial room. The researchers have undergone calculations to determine the energy consumed by each electrical appliance per week (kW.hr/Week) and the total energy consumption per week (kW.hr/Week). The formula of calculation is shown as below:

$$Energy\ Consumed\ by\ electrical\ appliance\ per\ week$$

$$= Rating\ of\ electrical\ appliance\ x\ \frac{hour\ of\ class}{week}\ x\ \frac{6\ days}{week} \qquad \textbf{(2.1)}$$

The existing electrical appliances are then being replaced by high efficient electrical appliances. The Philips T5 lighting bulb with 3200 Lumens and 21 Watt power consumption has been selected to replace the existing T8 and the quantity of lighting lamps have been decreased from 40 lamps to 35 lamps. Meanwhile, the BEN Q BEMW853UST model projector with 80 Watt energy consumption has replaced the existing Hitachi projector and the Daikin 3hp (2.238 kW) Air Cond has been selected to replace the existing 3.73kW Air cond. The same analysis has been done on the proposed high efficiency electrical appliances.

After that, analysis has been done by determine the energy savings per week (kW.hr/Week) and energy savings per year (kW.hr/year) by using the formula as below:

$$Energy\ savings\ per\ week\ \left(kW.\frac{hr}{Week}\right)$$

$$= Energy\ consumed\ by\ existing\ electrical\ appliances\ per\ week\ \left(kW.\frac{hr}{Week}\right) -$$

$$Energy\ consumed\ by\ the\ proposed\ electrical\ appliances\ per\ week(kW.\frac{hr}{Week}) \quad \textbf{(2.2)}$$

$$Energy\ savings\ per\ year\ \left(kW.\frac{hr}{year}\right)$$

$$= energy\ savings\ per\ week(kW.hr/Week)\ x\ 52 \quad \textbf{(2.3)}$$

The total cost of energy for both cases have been calculated using 36.5 cent/kW.hr of cost energy consumption per kW by referring to the tariff of the electricity from TNB website in which this academic building is in the medium voltage general commercial tariff category. The formula of the total cost of energy is shown as below:

$$Total\ cost\ of\ energy$$

$$= energy\ by\ electrical\ appliances\ per\ year\ \left(kW.\frac{hr}{year}\right) x\ 36.5\ cen/kW.hr \quad \textbf{(2.4)}$$

Lastly, the payback period has been calculated based on the formula below:

$$Payback\ period\ (years) = \frac{incremental\ cost(RM)}{Annual\ energy\ saving\ (\frac{RM}{year})} \quad \textbf{(2.5)}$$

Where incremental cost is the price difference between the existing and proposed electrical appliances.

2.11.1.2 Results and Discussion

In this study, it is found that duration usage of the electrical appliances, the electrical consumption/rating of the electrical appliances and number of equipment used for a particular space have affected the energy usage. The analysis of energy consumption of existing electrical appliances and proposed electrical appliances are shown in Figure 2.10

and Figure 2.11. From the result, it is found that the longer the duration of the electrical appliances being used, the higher the energy consumption as the tutorial room 2 with existing electrical appliances which has been used for 36 hours per week consumes the most power, which is 862.56kW.hr/week. Even after the electrical appliances have been replaced by the proposed high efficiency electrical appliances and the quantity of lightning has been decreased, Tutorial Room 2 still consumes the highest power, which is 516.528 kW.hr/week.

Room	Hour Class/Week	Energy Consumed by Lightning kW·hr/Week	Energy Consumed by Projector kW·hr/Week	Energy Consumed by ACON kW·hr/Week	Total Energy Consumption per Week kW·hr/Week
Tutorial Room 1	6	7.680	1.8	134.280	143.760
Tutorial Room 2	36	46.080	10.8	805.680	862.560
Tutorial Room 3	15	19.2	4.5	335.700	359.400
Tutorial Room 4	24	30.720	7.2	537.120	575.040
Tutorial Room 5	5	6.4	1.5	111.9	119.8
TOTAL					2060.56

*Energy consumption per year × 52.

Figure 2.10: Analysis of energy consumption characteristics of existing equipment

(Abubakar et.al, 2015)

Room	Hour Class/Week	Energy Consumed by Lightning kW·hr/Week	Energy Consumed by Projector kW·hr/Week	Energy Consumed by ACON kW·hr/Week	Total Energy Consumption per Week kW·hr/Week
Tutorial Room 1	6	5.0400	0.480	80.5680	86.0880
Tutorial Room 2	36	30.240	2.880	483.408	516.528
Tutorial Room 3	15	12.600	1.200	201.420	215.220
Tutorial Room 4	24	20.160	1.920	322.272	344.352
Tutorial Room 5	5	4.2000	0.400	67.1400	71.7400
TOTAL					1233.928

*Energy consumption per year × 52.

Figure 2.11: Analysis of energy consumption characteristics of proposed equipment

(Abubakar et.al, 2015)

Besides that, it is found that air conditioning system has consumed the highest power in a building, which is more than 90% even the existing electrical appliances have been replaced by the proposed high efficiency electrical appliances. The existing air conditioning system consumes the highest power, which is 98.2% (3.73kW) followed by projector with 7.39% (0.3kW) and lighting with 0.79% (0.032kW). Meanwhile, the proposed high efficiency air conditioner also has the highest power consumption with 95.7% (2.238 kW) followed by projector with 3.4% (0.08kW) and the lighting lamp with 0.9% (0.021kW).

Moreover, it is found that a combination of decrement in the quantity of lighting lamp from 40 lamps to 35 lamps and usage of high efficiency electrical appliances have helped to reduce the energy consumption. For tutorial room 2, its existing electrical consumption is 862.56kW.hr/week and becomes 516.528 kW.hr/week if replaced with the high efficiency electrical appliances. The university can save up 346.032kW.hr/week, 17993.664 kW.hr/year and RM 6567.69/year for this tutorial room which is quite an efficient energy saving step.

Lastly, the researchers has undergone analysis on the total energy savings and the results are shown as below (Figure 2.12). From the results, it is found that the usage of high efficiency air conditioning system has helped to save the most energy consumption and its payback period is quite low. Although the payback period of lighting lamp is lower than the air conditioning system, its energy saving rate is incredibly lower than the energy saving rate of air conditioning system.

Equipment's	Number of Quantity	Incremental Price (RM)	Annual Energy Saving in kWh	Energy Bill Saving (RM/years)	Payback Period (years)
Air conditioner	30	1488	40033.344	14612.17056	0.1
Projector	5	2757.1	983.84	359.1016	7.678
Lighting lamps	80	25	1967.68	718.2032	0.035

Figure 2.12: Energy efficiency measures for air conditioner, projector and lighting lamps. (Abubakar et.al, 2015)

2.11.1.3 Conclusion

From this study, it is found that the usage of high efficiency lighting lamp and air conditioning system have helped to reduce electrical consumption in a huge amount. However, the proposed high efficiency electrical appliances are more expensive than the existing electrical appliances. Therefore, it is better to undergo analysis on the payback period before proceed to the electricity saving method.

2.11.2 A Study on the Potential of Cost and Energy – A Survey at Playford Building, University of South Australia by Ramli, Imrah, Joefferie and Mohammad (2011)

This study is a study on the power consumption of air conditioning system, lighting system and computer system in academic building for existing condition and proposed condition. Both of the power consumptions and the cost of energy consumption have been obtained based on theoretical calculations. The payback period and saving percentage have been determined to determine the efficiency of the new suggestions such as reduce number of lights in specified area, change the T8 fluorescent tube to T5, change 50 W halogen light to

35 W halogen light, change the standby mode of computers, replace the computers in office with laptops and install timer control switch on air conditioner. The results have shown that the installation of timer control switch on air conditioner and modification of T8 to T5 fluorescent tube have saved the highest power consumption.

2.11.2.1 Methodology

The first step in this energy audit is reviewing the historical data to understand the energy trend, total cost and the electricity tariff. It is found that increment of power consumption is directly proportional to the number of students and the major contributors of the energy consumption are lighting, air conditioners and computers. The air conditioning system has consumed the highest energy usage and the lighting system has consumed 6100MWh/year or 24% of the total energy. After that, the researchers have undergone survey to determine the wastage of energy by study on the behaviour of occupants as well as propose some efficient ways to minimize the energy usage in which they have proposed to reduce number of lights in specified area, change the T8 fluorescent tube to T5, change 50 W halogen light to 35 W halogen light, set sensor on lighting system of specified area, change the standby mode of computers, replace the computers in office with laptops and install timer control switch on air conditioner. They have made the calculations to determine the cost of energy consumption for the modification using the formula as below:

$$\text{Annual Usage} = \text{Total Watts x running}\frac{\text{hours}}{\text{month}}\text{x } 12\,\frac{\text{months}}{\text{year}} \quad \textbf{(2.6)}$$

$$\text{Annual Usage} = \text{Annual Usage x kWh price} \quad \textbf{(2.7)}$$

$$\frac{\text{Total savings}}{\text{year}} = \text{Existing Cost} - \text{Proposed plan cost} \quad \textbf{(2.8)}$$

$$Payback\ period = \frac{Total\ investment\ required}{savings\ per\ year} \quad \textbf{(2.9)}$$

where the kWh price is the average value between peak and off-peak hours which is 11.4592cents/kWh.

2.11.2.2 Results and Discussion

With the help of 26 lamp sensors at the toilet and staircase which set the light to be ON for 12 hours, from 9.00am to 9.00pm, the university can save up to 4380480 watts/year which cost $AUD 501.95/year. This proposal only needs 2.7 years payback period with AUD$1360 cost. Meanwhile, the air conditioning timer control switch which only consumes power for 10 hours per day can help to save the most cost expenses which is $AUD6864.51/year and change of T8 lamp to T5 lamp can help to save $AUD2897.68/year. The whole proposal can help to save up to $AUD11264.5/year with 11 months of payback period. Therefore, it is a great saving plan in the energy audit.

2.11.2.3 Conclusion

The results of this study have shown that the major savings can be done on the air conditioning system and lighting system with low payback period. Therefore, it is considerable to practice this cost savings plan.

2.11.3 Energy Audit of an Industry by Mukesh, Chatterji and Lini (2014)

This case study is a study of energy usage on the machines, air conditioning system and lightning system. All the power factor, energy usage and luminance of lightning system have been measured using power factor meter, power analyser and lux meter. The data taken has been used to analysis the major energy consumption and a comparison has been made between the calculations and measurements to determine the conditions of the machines capacity. It is found that the welding sets and the power press have consumed the most power. Moreover, the machines which don't operate with maximum capacity and the machine which draws high current and consist of low power factor will cause extra cost in the electricity bill.

2.11.3.1 Methodology

This study has been done in Globetech Engineers and Consultant Ltd, E-51, Vishvkarama industrial area, road no.4, Jaipur, Rajasthan which is a manufacturer of complete transformer tanks and fabrication of protection boxes. This manufacturer consists of two floor office building, 3 workshops and one open space. Firstly, the researchers have undergone surveys to determine the quantity and conditions of electrical appliances/equipment. After that, they have reviewed the past electricity bills for 12 months which consists of cost of the power factor, energy consumption in kWh and power factor surcharge. Measurements are also undergone on the respective electrical appliances/equipment to determine their performance based on the voltage (Volt), current (A), RPM, power (kW), apparent power (kVA), reactive power (kVAR) and power factor.

The researchers are then using the data obtained to determine major energy consumption and make some proposals based on the data obtained. They have calculated the efficiency of the proposals and the proposals' respective payback period using the formula below:

$$\text{Payback Period} = \frac{\text{Total Annual Investment}}{\text{Net Annual Savings}} \quad \textbf{(2.10)}$$

2.11.3.2 Results and Discussion

In this study, it is found that the machines such as welding sets, power press and shearing machines consume the major energy as the welding sets consumes 64% of the energy, power press consumes 11% of energy and shearing machines consume 9% of energy. Meanwhile, the lighting load and air conditioner which are usually the major energy consumption in buildings only consume 5% and 2% of energy in the industry. Besides that, it is found that some of the machines' power factor are around 0.60 which means that the machines draw high current and cause the low power factor phenomenon in industry. Even though the lower power factors of machines will not cause higher power consumption, it will cause power factor surcharge as there is an allowable range of power factor set by the authorities. It is also found that some of the motors in the machines have been oversized as they are not operating with their maximum capacity which mean running at full load.

Therefore, it is suggested that to replace the oversized motor which is not running at full load with energy efficient motors and try to maintain the power factors at the allowable range to avoid the power factor surcharge.

2.11.3.3 Conclusion

The results of this study have shown that the usage of machines consume the most power in industry and the machines which are not running at full load will cause higher energy consumption. Therefore, it is better to use energy efficient machines and maintain the power factor at the allowable range.

2.11.4 Electrical Energy Audit Evaluation in Jimma University by Hiwot (2016)

This is a case study on the usage of energy consumption activities in Jimma University and the possibility of energy savings. The researchers have considered the type of electrical equipment/appliances, duration of usage and electrical efficiency capacity in this case study as well as determine the energy consumption activities pattern. It is found that lighting system, air conditioning system and workshop will be the major electrical consumptions. Therefore, the researchers have proposed to use compacted fluorescent tube lamp instead of using fluorescent lamp, increase awareness on the air conditioning system and replace CRT computers with LCD computers. The proposed energy saving method for the air conditioning system will be an efficient method with zero investment.

2.11.4.1 Methodology

The first phase of this study is reviewing the historical data on the university's energy consumption to understand the trend. After reviewing the data, the researchers have undergone interviews and survey to understand the students' behaviour of using the facilities. The energy consumption of all buildings in Jimma University are then being collected by few laboratory technician and researchers. Next, the researchers have undergone analysis to determine the possible energy saving methods. Lastly, the researchers have undergone calculations to determine the amount of energy which can be saved per year which is the difference in the energy consumption, the amount of money that can be saved per year and the simple payback year.

2.11.4.2 Results and Discussion

It is found that lighting system has consumed 22% of the total electrical energy, air conditioning system has consumed 19 % of the total energy and workshop has consumed 18 % of the total energy. According to the survey, 99% of the lightings, 22500 lamps in Jimma University are using Fluorescent Tube Lamps which have consumed 1773900kWh/year. If the university changes the 22500 Fluorescent Tube lamps to compacted fluorescent tube lamp, it might save up 1133325 kWh/year which costs 396664 Birr/year with 1 year payback period. This proposal might be considered as a very efficient energy saving proposal. Meanwhile, by reducing the operation hours of air conditioning system from 4 hours to 3 hours per day, the university can save up 36900kWh/year which cost 12915Birr/year or RM1881.20/year. This energy saving proposal is looking more on the awareness of the students and staff with zero investment and zero payback period. Lastly, it is recommended to replace the CRT computers to LCD computers which may save up 24960 kWh/year which costs 8736 Birr/year with 4 years payback period and 400000 Birr investment. This is considered as the most expensive and less efficient energy saving proposals as we may put the computer in stand mood when nobody else is using the computer or has left the buildings during rest time.

2.11.4.3 Conclusion

The results of this case study have shown that the proposal of energy savings on air conditioning system and lighting system are more efficient with lower value of investment. However, the university can look more on the awareness of the students and staffs on energy savings mechanism besides from replacing the energy consuming appliances.

2.11.5 Energy Methodology in an Organization and Commercial Utility – A Case Study by VinothKumar, Kamalakannan, Kumar (2013)

This is a case study on the energy consumption activities and the effect of energy conversation. The researchers have undergone measurements to obtain the percentage of energy consumption in the whole institution and calculations have been done on the data obtained to determine the cost of energy per month. It is found that air conditioner has consumed 70 % of the total energy, which is around 27562 kWh, system load such as computer system has consumed 8% of the total energy which is around 3099 kWh and lighting system has used 4 % of the total energy which is around 1680 kWh. These three activities are considered as the major energy consumption. After undergo the energy conservation recommendations, the air conditioner can save up to 36% of total energy which is 9796kWh and lighting system can save up to 45% of the energy which is 755kWh which are considered as high efficient energy savings.

2.11.5.1 Methodology

The researchers have classified the energy audit into several phases which are preliminary audit, pre-audit and post audit. In preliminary audit phase, the researchers have reviewed through all the available facilities to determine the load capacity and the facilities' condition. After that, the researchers have undergone measurements on different types of the equipment such as pump, fan, air conditioning system, computer system and lighting system to determine their energy consumption pattern. Some calculations have been done on the data obtained to determine cost per month. At the last stage which is the post audit phase, another survey has been done to ensure there is no missing data and ensure the possibility to implement the Energy Conservation Opportunities (ENCON).

2.11.5.2 Results and Discussion

The results of the case study show that the air conditioner has consumed 70 % of the total energy, which is around 27562 kWhr, system load such as computer system has consumed 8% of the total energy which is around 3099 kWhr and lighting system has used 4 % of the total energy which is around 1680 kWhr. After the researchers have implemented some Energy Conservation Opportunities on air conditioning system such as maintain its temperature at 22℃ to 24℃, install energy saver on the air conditioning system, insulate the walls, insulate the ceiling, use air curtain in front of to avoid false air entry and keep doors/windows closed in air-conditioned space, the institution can save up 36% of the total energy in which the energy consumption decreases from 27562 kWhr to 17766 kWhr. Moreover, when the researchers have implemented some Energy Conservation steps on lighting system such as switch off the lights which are not in used, turn on the light when necessary, use compacted fluorescent lamp, use LED lamps and use electronic chokes instead of EMT chokes, the institution can save up to 45% of energy in which the energy consumption decreases from 1680 kWhr to 25 kWhr. The total savings of electricity bill after implementing the Energy Conservation Opportunities on lighting system, water pumping system, air conditioner and system load(computer) care near to 32% of energy which is around 11008 kWhr.

2.11.5.3 Conclusion

In this case, it is found that major savings can be done on lighting system, air conditioner and water pumping system. Besides from undergoing replacement on the less efficient electrical appliances, it is also important to have the awareness on energy saving and energy conservation mechanism.

2.11.6 Comparison of Results from Previous Researchers

Table 2.4: Comparison of Results from Previous Researchers

Researcher (year)	Building type	Type of Study	Findings	Proposed Energy Savings Measure
Abubakar, Abba, Jamilu (2015)	Academic Building	Electricity Consumption Energy Audit	Air Cond consumes 91.79% of total power and lighting consumes 0.79% of total power.	a) Change T8 lamp to T5 lamp. b) Replace existing 3.730 kW air Cond with 2.237 kW air Cond.
Ramli, Imrah, Joefferie and Mohammad (2011)	Academic building	Energy performance Power Consumption	High efficiency electrical appliances can help to save up to AUD 10964.3/year.	a) Delamping. b) Change T8 to T5. c) Change of halogen 50W to 35W. d) Air Cond timer control switch.
Mukesh, Chatterji and Lini (2014)	Industrial building	Energy Usage Energy Performance	Welding set consumes 64% of the total power and machines consume 29% of the total power.	a) Replace the existing welding machine with inverter welding sets. b) Replace all the oversized motors with energy efficient motors.
Hiwot (2016)	Academic building	Energy Audit Evaluation	Energy usage of air conditioning system can be reduced by	a) Reduce operation hours.

			36900 kWh/year with 0 payback period.	b) Increase users' awareness.
VinothKumar, Kamalakannan, Kumar (2013)	Institutional building	Energy Consumption Energy Conversation	Energy Conservation can help save up to 30% of the total energy.	c) Maintain ideal temperature 22ºC to 24ºC. d) Promote CFL, LED lamps instead of incandescent bulbs. e) Buy the most energy efficient star compliant equipment and appliances.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter is focusing more on the methodology of the research which has included steps of energy audit and the equipment to be used.

3.2 Building Description

This case study has been conducted in the Laboratory Complex of Faculty of Mechanical Engineering of Universiti Teknikal Malaysia Melaka which is located in Ayer Keroh, Malacca. The total area of this laboratory complex is 8243.48m^2 with brick and gypsum wall. It consists of six blocks which are Block A, Block B, Block C, Block D, Block E and Block F.

Figure 3.1: UTeM Mechanical Engineering Laboratory Complex

Most of the blocks are consisting of laboratories such as air conditioning laboratory, vibro-acoustics laboratory, CAD/CAM/CAE Studios, Combustion Laboratory, Conditional Based Maintenance laboratory, Engine Performance Testing Laboratory, Fluid Mechanics Laboratory, Prototype & Innovation Laboratory, Instrumentation Laboratory, Materials Science Laboratory, Mechanics of Machine Laboratory, Racing Vehicle Development workshop, Structural Health Monitoring Laboratory, Structural Mechanics Laboratory, Tribology Laboratory and Vehicle Maintenance and Service Laboratory. This case study has been undergone in welding workshop and machine workshop which are located in Block E (Figure 3.2 and Figure 3.3). The locations of welding workshop and machine workshop have been shown as red circle and pink circle in plan layout respectively. The normal operating hours for the two laboratories are be from 8.00 am to 5.00pm.

Figure 3.2: Welding Workshop

Figure 3.3: Machine Workshop

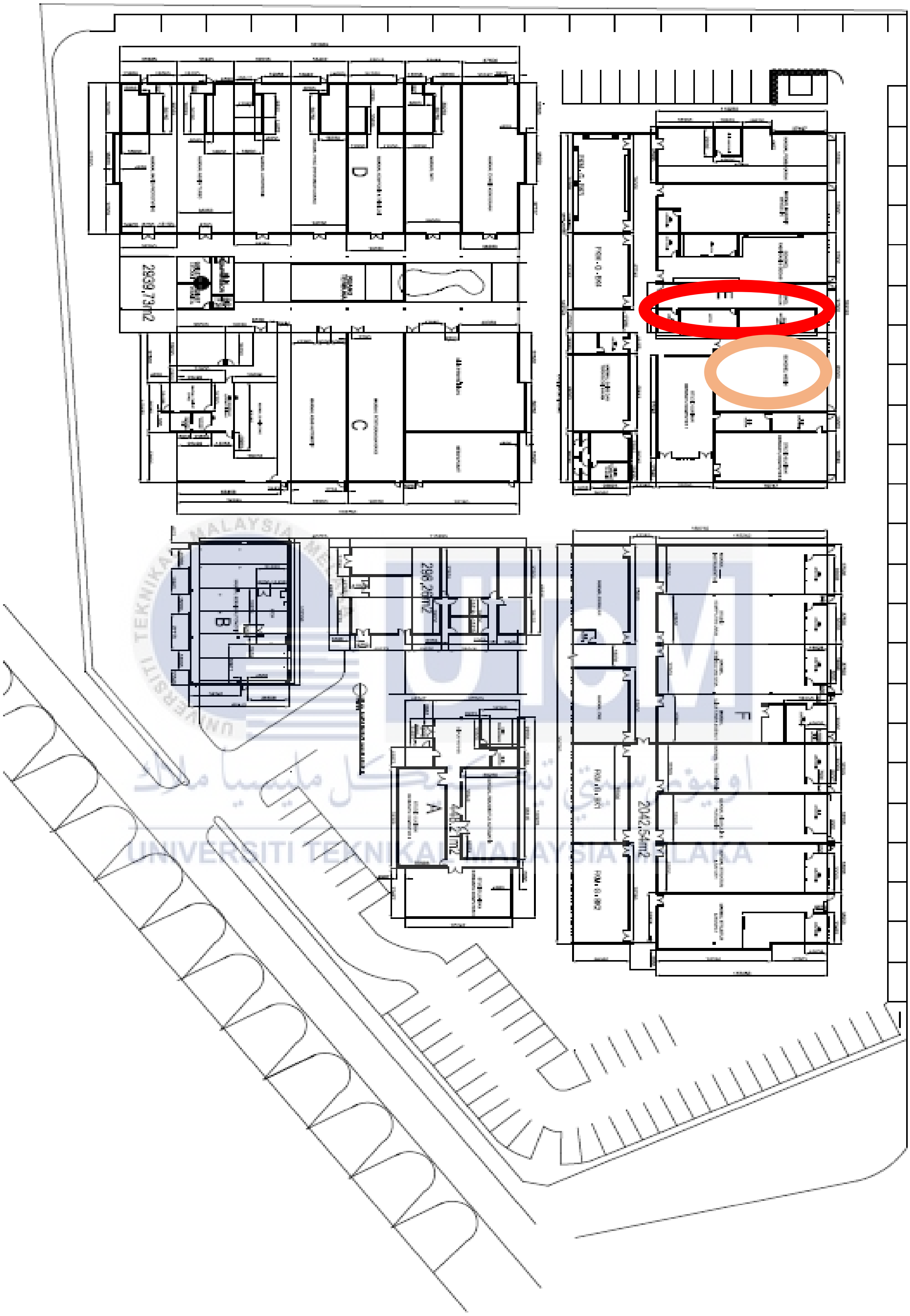


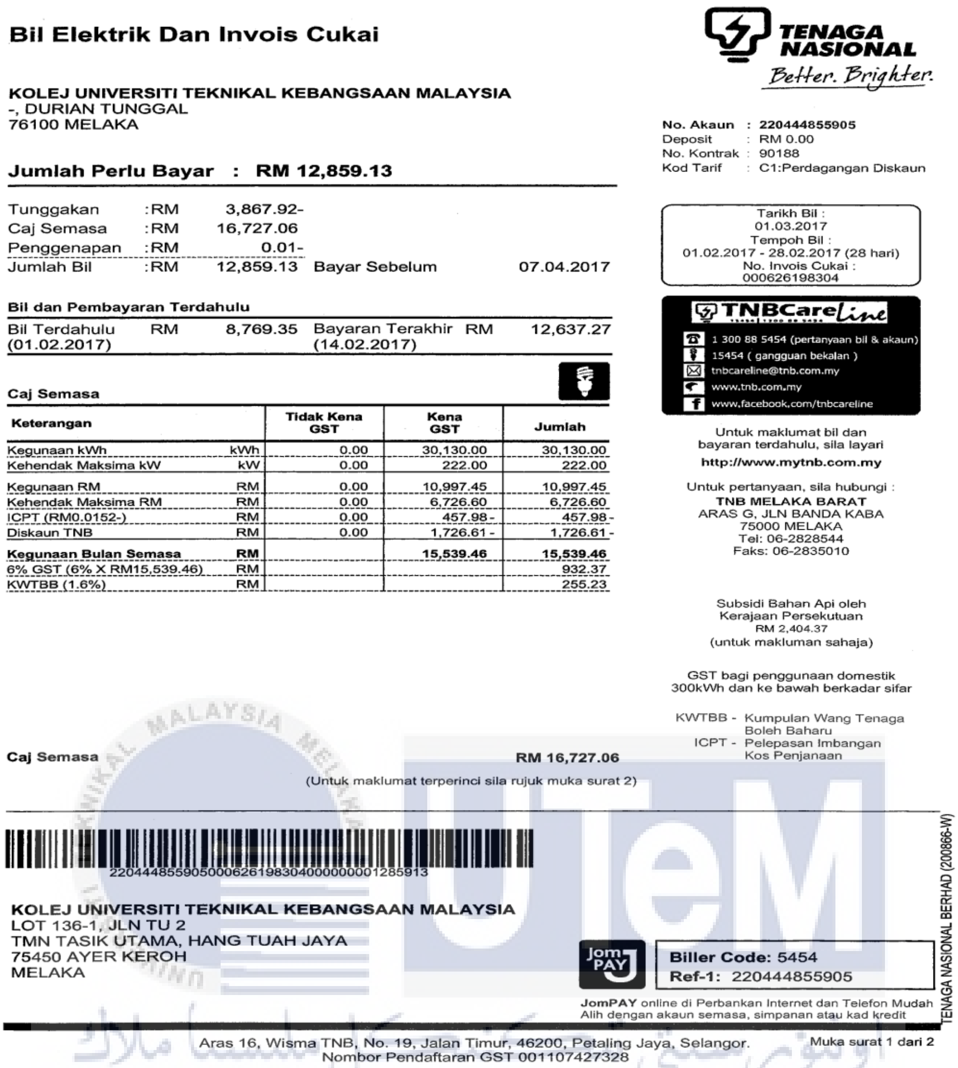
Figure 3.4: Plan Layout

3.3 Energy Audit

Energy audit which is used to check the energy usage and minimize the wastage of energy is getting popular. There are three levels on frequency of measurements in the energy audit which are Level A-monthly or annually energy consumption, level B-daily or month energy consumption and level C-daily or hourly energy consumption. The size of sample, six categories of influencing factors (i.e., climate, building envelope and other characteristics, building services and energy systems, building operation and maintenance, occupant behavior and indoor environmental quality) and other indirect factors have been considered in the level of analysis.

3.3.1 Preliminary Audit

In this phase, review on the engineering plans and electrical bills which have included the amount of purchased energy and the utility rate structure for the past three years have been done to determine the available equipment and understand the energy consumption trend. An electricity bill example of UTeM Mechanical Engineering Laboratory Complex on March 2017 is shown in Figure 3.5.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Caj Semasa

Keterangan		Tidak Kena GST	Kena GST	Jumlah
Kegunaan kWh	kWh	0.00	30,130.00	30,130.00
Kehendak Maksima kW	kW	0.00	222.00	222.00
Kegunaan RM	RM	0.00	10,997.45	10,997.45
Kehendak Maksima RM	RM	0.00	6,726.60	6,726.60
ICPT (RM0.0152-)	RM	0.00	457.98-	457.98-
Diskaun TNB	RM	0.00	1,726.61-	1,726.61-
Kegunaan Bulan Semasa	RM		15,539.46	15,539.46
6% GST (6% X RM15,539.46)	RM			932.37
KWTBB (1.6%)	RM			255.23

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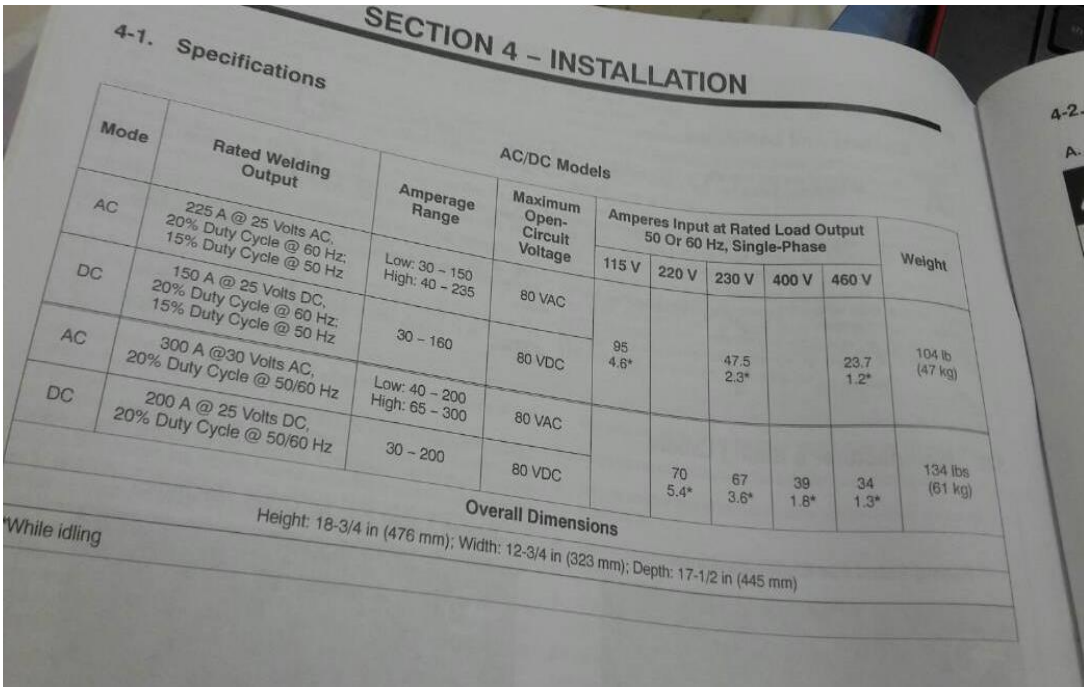
Figure 3.5: Electricity Bill Example

However, the electricity bills in 2016 have been used in this case due to more complete compilation. After that, a tour/visit to UTeM Mechanical Engineering Laboratory Complex has been done to understand the operating characteristics of the facility, the facilities' specifications and their operating and maintenance procedures to determine the potential energy savings, determine the major energy consumptions and minimize the wastage of energy. Normally, the major consumptions are estimated to be the air conditioning system, lighting system and machines. The lists of available equipment and electrical appliance in Welding Workshop and Machine Workshop have been shown in Section 3.3.1.1 and Section 3.3.1.2. Meanwhile, the formulas that used in the calculations are shown in Section 3.3.1.3.



SECTION 4 – INSTALLATION

4-1. Specifications

Mode	Rated Welding Output	Amperage Range	Maximum Open-Circuit Voltage	Amperes Input at Rated Load Output 50 Or 60 Hz, Single-Phase					Weight
				115 V	220 V	230 V	400 V	460 V	
AC	225 A @ 25 Volts AC, 20% Duty Cycle @ 60 Hz; 15% Duty Cycle @ 50 Hz	Low: 30 – 150 High: 40 – 235	80 VAC	95 4.6*		47.5 2.3*		23.7 1.2*	104 lb (47 kg)
DC	150 A @ 25 Volts DC, 20% Duty Cycle @ 60 Hz; 15% Duty Cycle @ 50 Hz	30 – 160	80 VDC						
AC	300 A @30 Volts AC, 20% Duty Cycle @ 50/60 Hz	Low: 40 – 200 High: 65 – 300	80 VAC		70 5.4*	67 3.6*	39 1.8*	34 1.3*	134 lbs (61 kg)
DC	200 A @ 25 Volts DC, 20% Duty Cycle @ 50/60 Hz	30 – 200	80 VDC						
Overall Dimensions									
Height: 18-3/4 in (476 mm); Width: 12-3/4 in (323 mm); Depth: 17-1/2 in (445 mm)									

*While idling

Figure 3.6: Specification of Arc Welding Machine

For example, Arc Welding Machine has a 47.5 Ampere input and 230 Voltage output based on it specification manual. Therefore, the calculation of power consumption has be made based on Power Rating (kW) = Voltage (V) x Current (I). Therefore, the power rating of an Arc Welding Machine is 10.93 kW and the total power rating of 3 Arc Welding Machine is 32.79 kW. The three Arc Welding Machines are assumed to use for 3 hours per day based on the student timetable, the total power consumption of Arc Welding Machine per day is 98.37 kW.

3.3.1.1 Welding Workshop

Welding Workshop which is normally used for welding purpose, shearing purpose and grinding purpose consists of 9 welding stations in which the first 3 welding stations are MIG Welding station, the next three welding stations are Arc Welding station and the last three welding stations are TIG welding station. This workshop consists of five 150W Metal Halide

High Bay, twenty 36W T8 Fluorescent Light, three 7.82kW MIG Welding Machine, three 10.93 kW Arc Welding Machine, three 9.7kW TIG Welding Machine, a 3kW blower motor with 9 exhaust fans and a 11 kW Mechanical Power Shearing Machine. Normally, the mechanical engineering students will use the MIG Welding Machine and Arc Welding Machine only for their laboratory. The checklist of welding workshop is shown in Table 3.1.

Table 3.1: Checklist of Welding Workshop

No.	**Item**	**Power Rating(kW)**	**Quantity**
1.	Metal Halide High Bay  Figure 3.7: Metal Halide High Bay	150W	5
2.	T8 Fluorescent  Figure 3.8: T8 Fluorescent	36W	20

3.	MIG Welding Machine  Figure 3.9: MIG Welding Machine	$P = 200\,V\,x\,34\,A$ $= 7.82kW$	3
4.	Arc Welding Machine(Thunderbolt XL AC/DC)  Figure 3.10: Arc Welding Machine	$P = 230\,V\,x\,47.5A$ $= 10.93\,kW$	3
5.	TIG Welding Machine (MATRIX 400 AC/DC)  Figure 3.11: TIG Welding Machine	$P = 10kVAx0.97$ $= 9.7\,kW$	3

6.	Blower Motor  Figure 3.12: Blower Motor	3kW	1
7.	Mechanical Power Shearing Machine  Figure 3.13: Mechanical Power Shearing Machine	11kW	1

3.3.1.2 Machine Workshop

Machine Workshop which is normally used for milling purpose and turning purpose consists of three 3.7 kW Conventional Vertical Milling Machines, three 3.75 kW Conventional Lathe Machines, a 300W computer set, a 3.75 kW CNC Lathe Machine, a 22.4 kW CNC Milling Machine, a 11 kW Hydraulic Press Brake, six 2.675 kW air Cond, 18 double fitting T8 Fluorescent Lamps and a 0.75 kW drill press machine. Lathe Machine is used to hold the workpiece between two rigid and strong supports called centres or in a chuck or face plate which revolves while the milling machine is used to cut away material by feeding a work piece past a rotating multiple tooth cutter. The checklist of the machine workshop is shown in Table 3.2.

Table 3.2: Checklist of Machine Workshop

No.	**Item**	**Power Rating(kW)**	**Quantity**
1.	Conventional Vertical Milling Machine  Figure 3.14: Conventional Vertical Milling Machine	3.7kW	3

2.	Conventional Lathe Machine  Figure 3.15: Conventional Lathe Machine	3.75kW	3
3.	Computer  Figure 3.16: Computer	300W	1
4.	CNC Lathe Machine  Figure 3.17: CNC Lathe Machine	3.75kW	1

5.	CNC Milling Machine  Figure 3.18: CNC Milling Machine	22.4kW	1
6.	Hydraulic Press Brake  Figure 3.19: Hydraulic Press Brake	11kW	1
7.	Air Cond  Figure 3.20: Air Cond	2.675kW	6

8	T8 Fluorescent  Figure 3.21: T8 Fluorescent	36W	36
9.	Drill Press  Figure 3.22: Drill Press	0.75kW	1

3.3.1.3 Formula for Calculation of Power Consumption

$$Power\ Rating\ (kW)\ =\ Voltage\ (V)\ x\ Current\ (I) \tag{3.1}$$

$$Power\ Rating\ (kW)\ =\ Apparent\ Power\ (kVA)\ x\ Power\ Factor\ (PF) \tag{3.2}$$

$$Total\ Power\ Rating\ (kW)\ =\ Quantity\ of\ item\ x\ Power\ Rating\ (kW) \tag{3.3}$$

$$Total\ Power\ per\ day\ (kW/day)\ =\ Total\ Power\ Rating\ x\ Frequency\ of\ usage\ per\ day\ (hours) \tag{3.4}$$

$$Total\ Power\ per\ month\ (kW/month)\ =\ Total\ Power\ per\ day\ (kW/day)\ x\ 22\ days \tag{3.5}$$

$$Power\ Consumption\ for\ three\ phase\ voltage, P_T\ =\ \sqrt{3}\ VI\ x\ PF \tag{3.6}$$

$$Percentage\ of\ power\ consumption = \frac{Monthly\ Power\ Consumption\ of\ Workshop}{Total\ Monthly\ Power\ Consumption\ of\ the\ Building} \tag{3.7}$$

3.3.2 Utility Analysis

In this phase, utility data collection has been undergone to determine the total energy consumption and demand of the end-user in UTeM Mechanical Engineering Laboratory Complex using Chauvin Arnoux C.A 8435 energy meter. Two of the equipment have been set up at the main power source for 14 days to have a clearer picture on energy usage during peak hours and non-peak hours as well as the difference of energy usage between weekends and weekdays.

Figure 3.23: Chauvin Arnoux C.A 8435 energy meter

Figure 3.24: Measurement using two Chauvin Arnoux C.A 8435

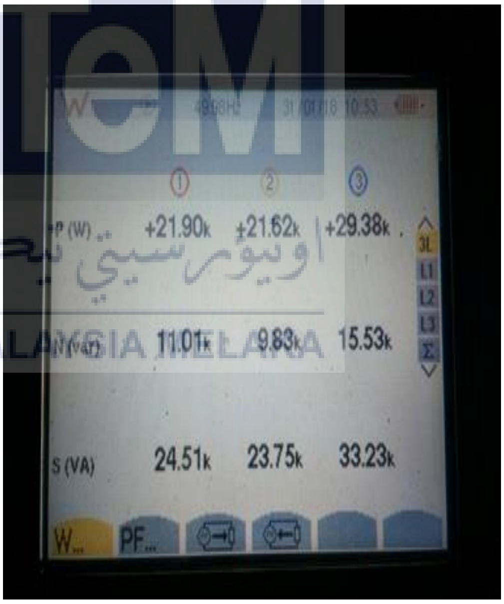


Figure 3.25:Main Circuit of Laboratory Building

Figure 3.26: Recordings of energy meter

After that, data collection has been undergone in Welding Workshop and Machine Workshop during peak hour using digital clamp meter to determine the respective current when different equipment is being used. A detail analysis is conducted then by doing some calculations based on the data obtained. Next, potential energy savings are being identified out and energy conservation measures (ECM) have been proposed.

Figure 3.27: Digital Clamp Meter

3.3.3 Retrofit Analysis

A detailed economic analysis on the energy conservation measures to determine their efficiency, implementation cost and simple payback period. Normally, the ECMs have been done on the major energy consuming systems (i.e., envelope, HVAC, lighting, power, and process). Lastly, all the results and findings included have been summarized in a final report.

3.4 Case Study Flow Chart

This study has focused more on the energy usage and energy efficiency of the equipment. The major steps in the methodology have included reviewing historical data, data collection and retrofit analysis. The flow chart of methodology is shown as below:

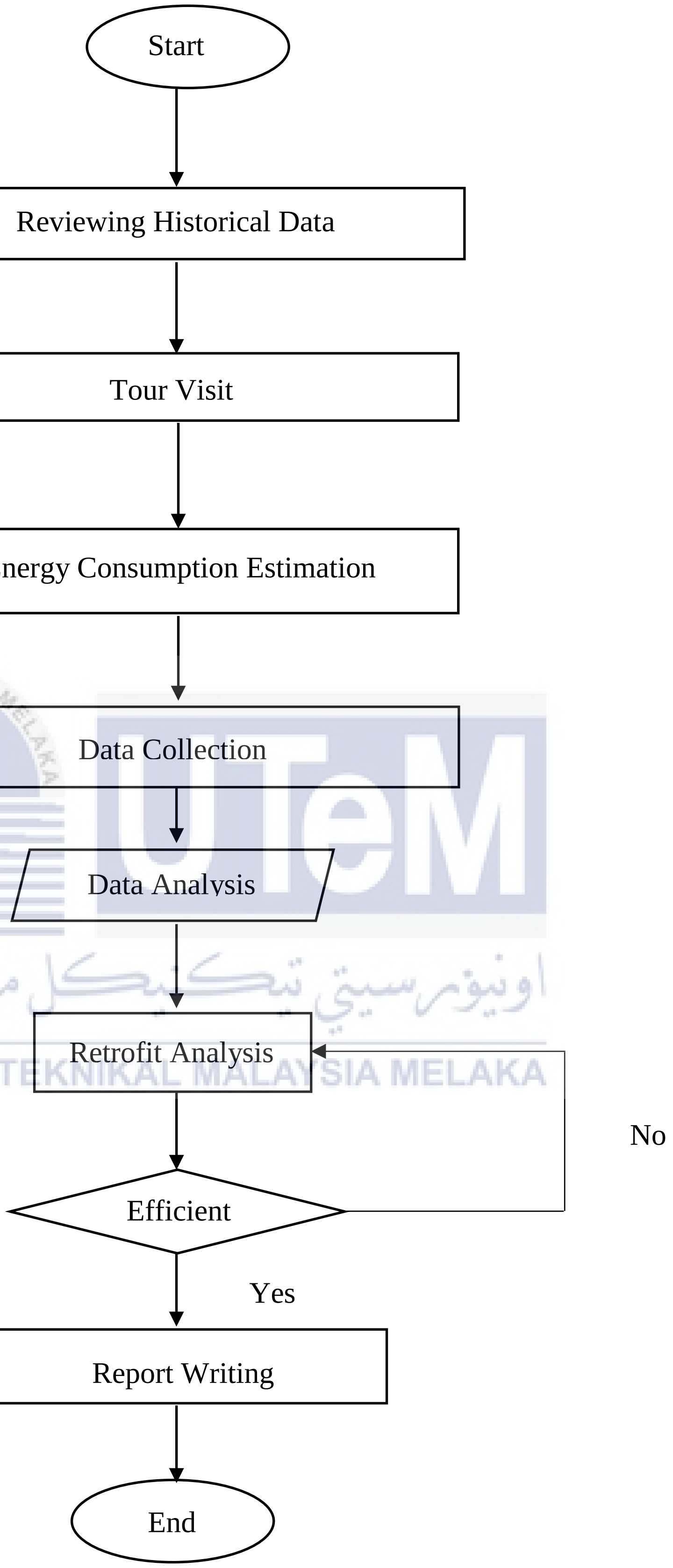


Figure 3.28: Flow Chart

CHAPTER 4

RESULT & DISCUSSION

4.1 Introduction

This chapter has discussed more on the energy consumption of the Mechanical Engineering Laboratory Complex of Universiti Teknikal Malaysia Melaka which has included data obtained using Chauvin Arnoux C.A 8435 and digital clamp meter as well as some basic calculations. The results are then being analyzed to determine the respective energy performance and being compared with the previous electricity bills.

4.2 MS 1525:2014

MS 1525:2014 is a Malaysia code of practice on energy efficiency and use of renewable energy for non-residential buildings which has included the requirements on design of efficient lighting system, minimize losses in electrical power distribution equipment, design of efficient HVAC system and design of good energy management system. This code has recommended to size the ACMV system based on the ASHRAE handbook to meet the room comfort condition in which the recommended design dry bulb temperature is 24ºC to 26ºC, the minimum dry bulb temperature us 23º C, recommended design relative humidity is 50 % - 70 % and the recommended air movement is 0.15 m/s - 0.50 m/s.

Besides that, there are motor efficiency definitions for 2 pole, 4 pole, 6 pole and 3 phase induction motor in MS 1525:2014. The motors which have operated for more than 750 hours will be considered as IE2 (High Efficiency) and IE3 (Premium Efficiency) classification. In this case, most of the equipment are having 4 pole motor, so we will refer to Efficiency Class Definition for 4-Pole Motors at motor class IE2 as shown in table below.

Table 4.1: Efficiency Class Definition for 4-Pole Motors at motor class IE2

Motor Capacity (kW)	**Motor Efficiency (%)**		
	Motor Class IE3	**Motor Class IE2**	**Motor Class IE1**
0.75	82.5	79.6	72.1
1.1	84.1	81.4	75.0
1.5	85.3	82.8	77.2
2.2	86.7	84.3	79.7
3	87.7	85.5	81.5
4	88.6	86.6	83.1
5.5	89.6	87.7	84.7
7.5	90.4	88.7	86.0
11	91.4	89.8	87.6
15	92.1	90.6	88.7
18.5	92.6	91.2	89.3
22	93.0	91.6	89.9
30	93.6	92.3	90.7

4.3 Power Consumption of Workshop

The power consumption of the two workshops have been calculated based on the checklists of workshops which have included the item/equipment, quantity of item, the item's power rating and the total power rating as well as the respective frequency of usage. All the formulas that used in the calculations have been shown as below:

$$Power\ Rating\ (kW) = Voltage\ (V)\ x\ Current\ (I) \quad \textbf{(4.1)}$$

$$Power\ Rating\ (kW) = Apparent\ Power\ (kVA)\ x\ Power\ Factor\ (PF) \quad \textbf{(4.2)}$$

$$Total\ Power\ Rating\ (kW) = Quantity\ of\ item\ x\ Power\ Rating\ (kW) \quad \textbf{(4.3)}$$

$$Total\ Power\ per\ day\ (kW/day) = Total\ Power\ Rating (kW) x\ Frequency\ of\ usage\ per\ day\ (hours/day) \quad \textbf{(4.4)}$$

$$Total\ Power\ per\ month\ (kW/month) = Total\ Power\ per\ day\ (kW/day)\ x\ 22\ days \quad \textbf{(4.5)}$$

$$Power\ Consumption\ for\ three\ phase\ voltage, P_T = \sqrt{3}\ VI\ x\ PF \quad \textbf{(4.6)}$$

$$Percentage\ of\ power\ consumption = \frac{Monthly\ Power\ Consumption\ of\ Workshop}{Total\ Monthly\ Power\ Consumption\ of\ the\ Building} \quad \textbf{(4.7)}$$

4.4 Energy Consumption for Laboratory Building in 2016 (kWh)

4.4.1 Monthly Energy Consumption for Laboratory Building in 2016 (kWh)

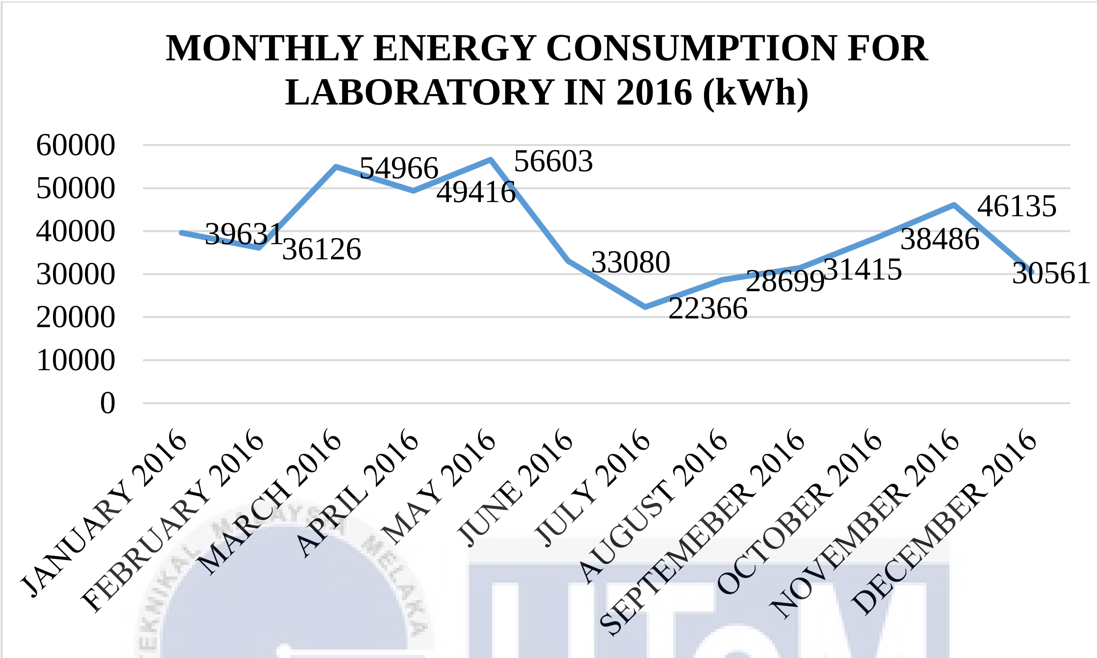


Figure 4.1: Monthly Energy Consumption for Laboratory in 2016(Kwh)

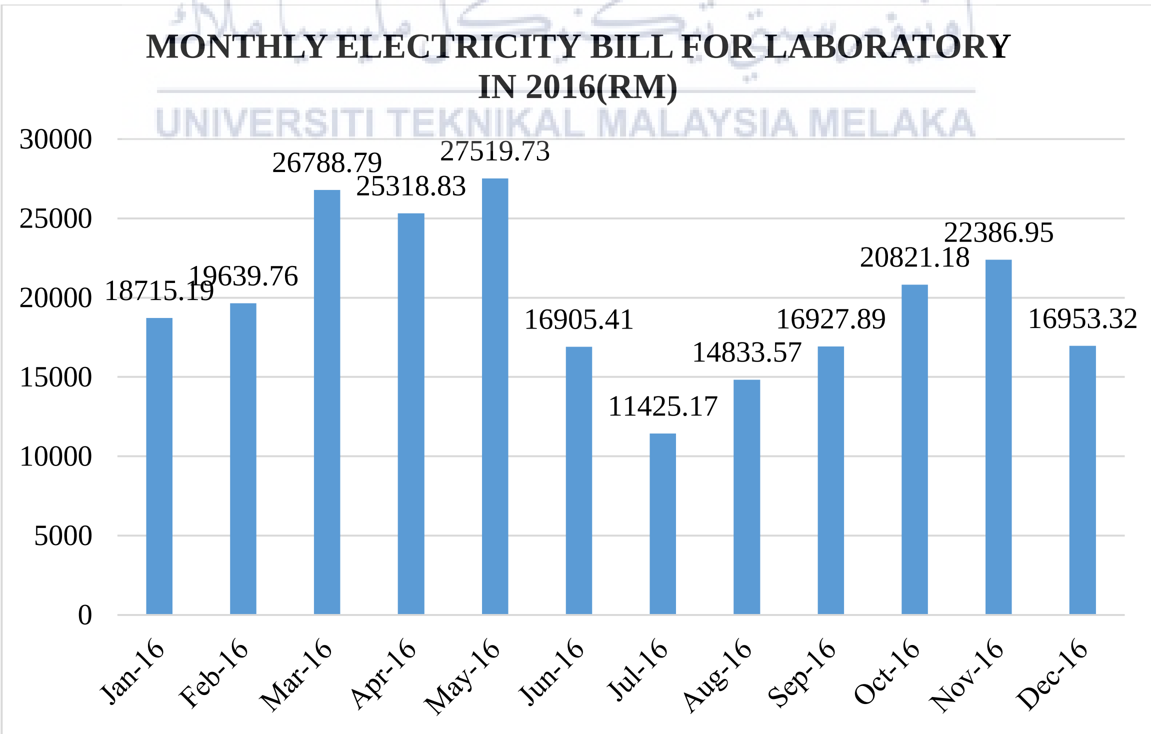


Figure 4.2: Monthly Electricity Bill for Laboratory in 2016(RM)

An analysis of historical data for Mechanical Engineering Laboratory Complex of Universiti Teknikal Malaysia Melaka has been performed by referring to the past electricity bills which are issued by Tenaga Nasional Berhad, an electricity utility company in Peninsular Malaysia. The graphs above have shown the monthly energy consumption for the Laboratory building in 2016 (Kwh) and the respective monthly electricity bill (RM). The peak energy consuming periods are March and May. On the other hand, the energy usage has decreased during semester break periods which are February and June to September. The highest energy consumption throughout 2016 is energy consumption of May 2016 which has consumed 56603kWh, while the lowest energy consumption is energy consumption of July 2016 which has consumed 22366 kWh. The average energy consumption of 2016 is 38957 kWh and the average electricity bill in 2016 is RM19852.98 in which its tariff is RM0.365 per kWh at all the time.

4.4.2 Carbon Foot Print for Laboratory Building In 2016

Carbon footprint is the total set of GHG emissions caused by an organisational event, product or person which is expressed in equivalent amount of CO_2 to understand the key emission sources, develop the savings potential and act as a management tool of reducing the overtime emissions. Besides that, the carbon foot print report may help to develop initiatives for higher energy efficiency and increase the stakeholder engagement. Even in 2010, TNB has started the first attempt to establish the carbon inventory for their thermal power plants to look into the fuel combustion CO_2 emissions. The overall carbon footprint of Malaysia power mix which has been calculated from the weighted average of different energy sources is 0.622 kg CO_2/kWh. (Wendy Tjan, 2009). There are two scopes in the calculation for carbon footprint in which the first scope has included stationary combustion, fugitive emissions and mobile combustion and the respective formula is

$$carbon\ footprint = fuel\ use\ x\ emission\ factor. \quad \textbf{(4.8)}$$

While the second scope of carbon footprint calculation has included other indirect emissions and the respective formula is

$$carbon\ footprint = grid\ emission\ factor\ x\ import\ energy\ consumption. \quad \textbf{(4.9)}$$

In this case, the formula below has been used to calculate the respective carbon footprint in which the energy consumed (kWh) is the average energy consumption for laboratory building in 2016

$$Carbon\ footprint\ = \frac{energy\ consumed\ (kWh) x\ carbon\ emission\ \left(kg\frac{CO2}{kWh}\right)}{total\ area} \quad \textbf{(4.10)}$$

$$= \frac{38957\ x\ 0.622}{8243.28}$$

$$= \ 2.94\ kg\ C0_2\ /\ m^2$$

4.4.3 Maximum Demand for Laboratory Building During 2016

Maximum demand is the highest level of electrical demand monitored in a particular period usually for a month period which is measured in Kilowatt (kW) and generally practiced by most of the utility providers in the world. It can be twice the maximum kilowatt-hours (kWh) supplied during any consecutive thirty minutes in that month. Since maximum demand is the peak load demanded by customer, TNB needs to provide the load whenever customer requires that amount of load after going through generation, transmission and distribution stages as electricity couldn't be stored. Therefore, the Maximum Demand tariff has been structured to reflect the time of day it is used. For electricity bills in Malaysia, Maximum Demand is the highest level of electricity demand recorded by TNB meter during a 30-minute interval in a month and the tariff for each kilowatt of maximum demand per month will be subjected to tariff category. Since UTeM Laboratory Building is in the medium voltage category (C1), the tariff for each kilowatt of maximum demand per month is RM 30.30. (Tenaga Nasional, 2018) The formula that has been used to calculate the charges for maximum demand is shown as below

$$Charges\ for\ maximum\ demand = maximum\ demand\ (kW) x\ tariff (\frac{RM}{kW}) \quad \textbf{(4.11)}$$

The graphs below have shown the maximum demand for laboratory building during 2016 and charges for the maximum demand in laboratory building during 2016.

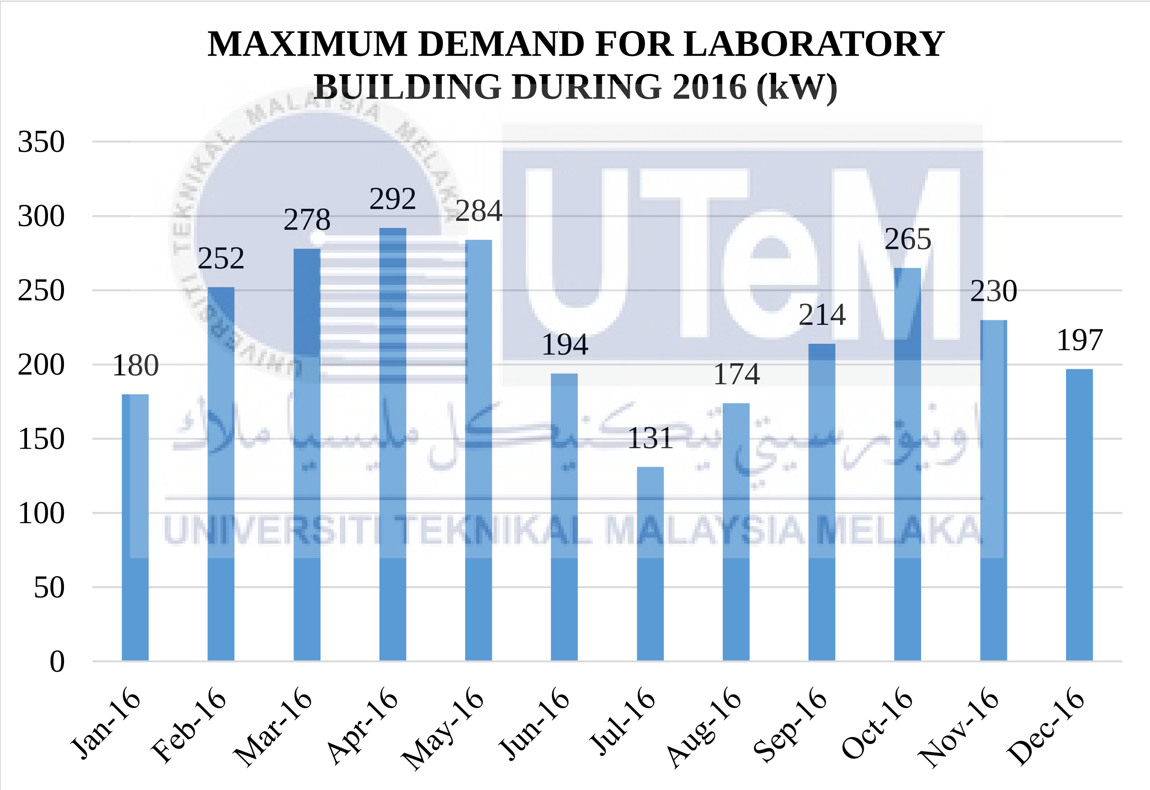


Figure 4.3: Maximum Demand for Laboratory Building during 2016 (kW)

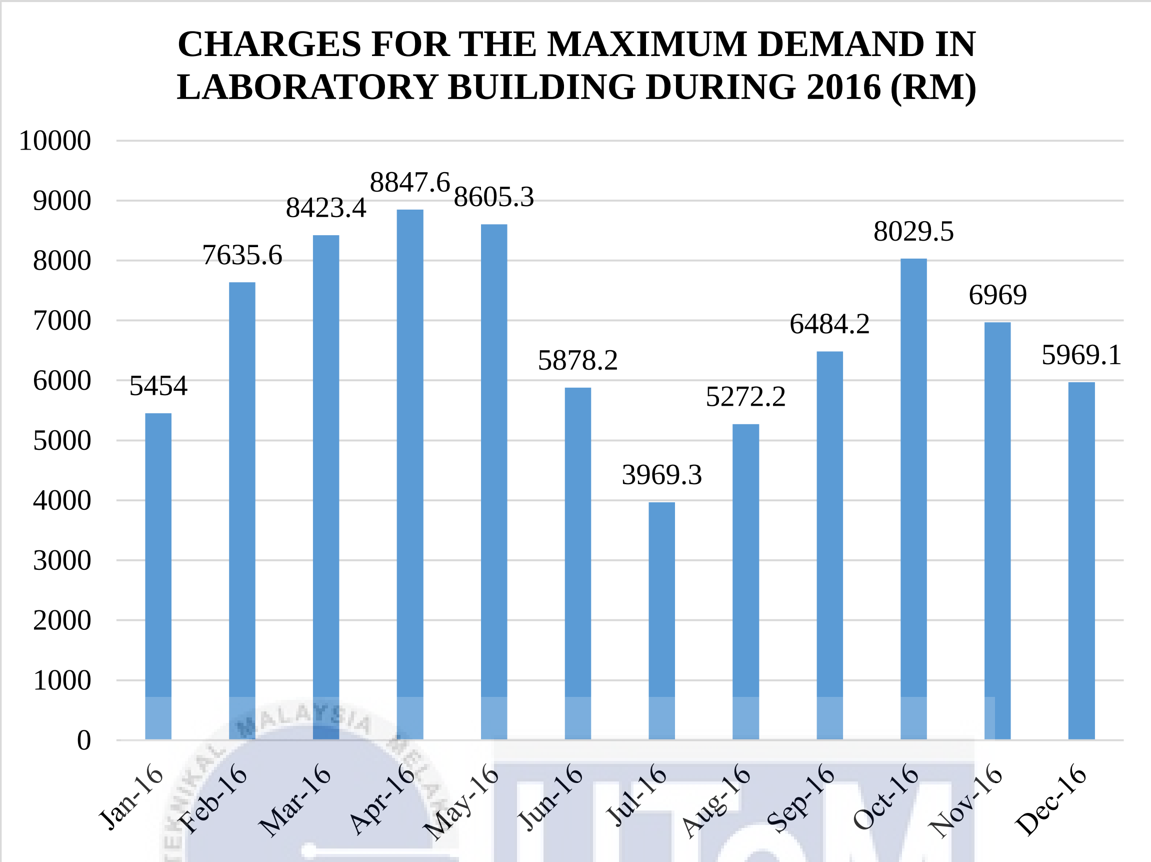


Figure 4.4: Charges for the Maximum Demand In Laboratory Building during 2016 (RM)

The trend of the two graphs are in similar trend with graph of the energy consumption in 2016 which have implied that the maximum demand and the respective charges increase with the energy usage. The average maximum demand for laboratory building during 2016 is 224.25kW which has costed RM 6794.78, roughly one-third of the average electricity bill in 2016, RM19852.98.

4.4.4 Main Energy Consumption for Laboratory Building in 2016 (kWh)

The energy usage of CAD Studio has been expected to have the highest energy consumption due to its available equipment other than the two selected workshop in this case study. CAD Studio which is normally used for lecturing purpose and drawing purpose consists of 45 sets of computer sets, 1 scanner, 3 printers, 35 Uninterrupted power supply power ware,1 projector, 24 36W T8 Fluorescent Light and 5 2.5 HP air cond. The checklist of welding workshop with the respective power rating and quantity are shown in Table 4.2.

Table 4.2: Checklist of CAD Studio

No.	**Item**	**Quantity**	**Power Rating(W)**	**Total Power Rating (kW)**
1.	Computer Set	45	350W	15.750
2.	Color Scanner Epson Expression 1640xl	1	55W	0.055
3.	HP Color Laser Jet 8550N Printer	2	750W	1.500
4.	HP DESIGNJET 800	1	150W	0.150
5.	Uninterrupted power supply power ware	35	1050W	36.750
6.	SANYO PLC-XU56 Projector	1	55W	0.055
7.	T8 Fluorescent Lamp	24	36W	0.864
8.	Air Cond	5	2675W	13.375

4.4.4.1 Estimation of Power Consumption

Estimations have been made on the frequency of usage of the equipment and electrical appliances based on the student timetable to estimate the total power consumption per day as well as the workshop is estimated to operate for 22 days per month.

Table 4.3: Estimation of Power Consumption of CAD Studio

No.	Item	Frequency of usage per day (hours)	Total Power (kW)
1.	Computer Set	6.5	102.375
2.	Color Scanner Epson Expression 1640xl	1	0.055
3.	HP Color Laser Jet 8550N Printer	1	1.500
4.	HP DESIGNJET 800	3	0.450
5.	Uninterrupted power supply power ware	6.5	238.875
6.	SANYO PLC-XU56 Projector	6.5	0.356
7.	T8 Fluorescent Lamp	9	7.776
8.	Air Cond	9	120.375

Total Estimated Power Consumption per Day

$= 102.375 + 0.055 + 1.500 + 0.450 + 238.875 + 0.356 + 7.776 + 120.375$

$= 471.76\ kW$

Total Estimated Power Consumption per month

$= 471.762\ kW\ x\ 22$

$= 10378.76\ kW$

Percentage of Power Consumption compared to power consumption in 2016

$= \frac{10378.76}{38957}\ x\ 100\% = 26.64\%$

4.5 Daily Energy Consumption for Laboratory Building (Wh)

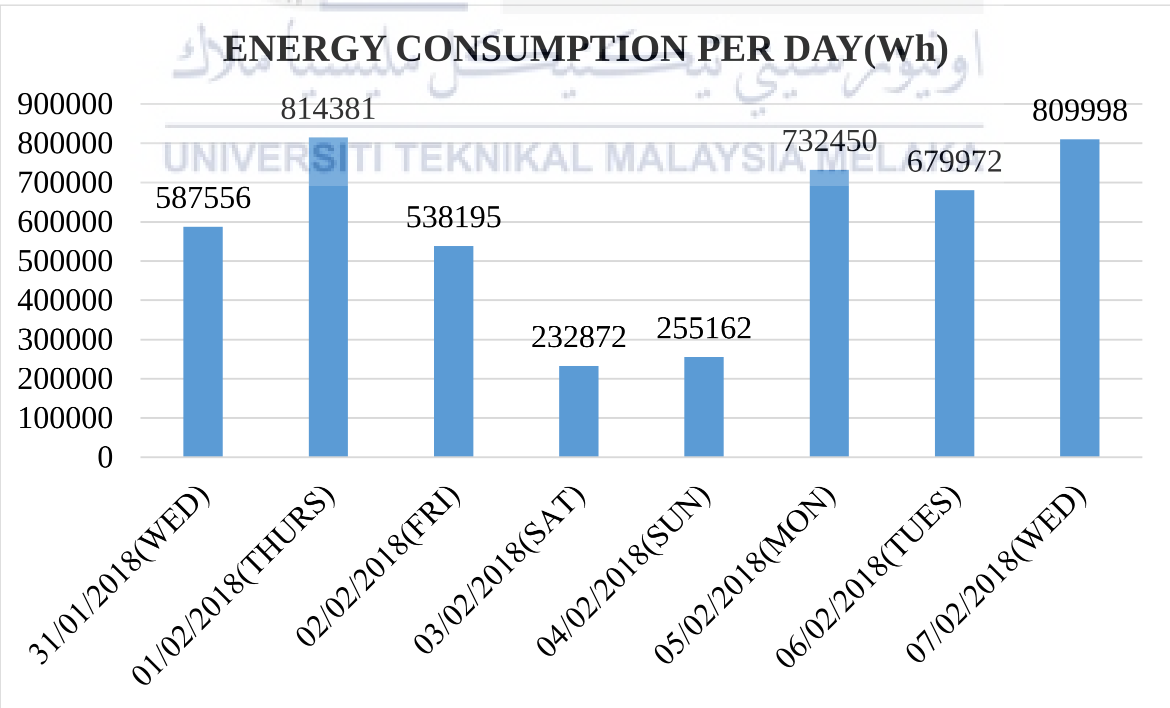


Figure 4.5: Daily Energy Consumption for Laboratory Building Part I

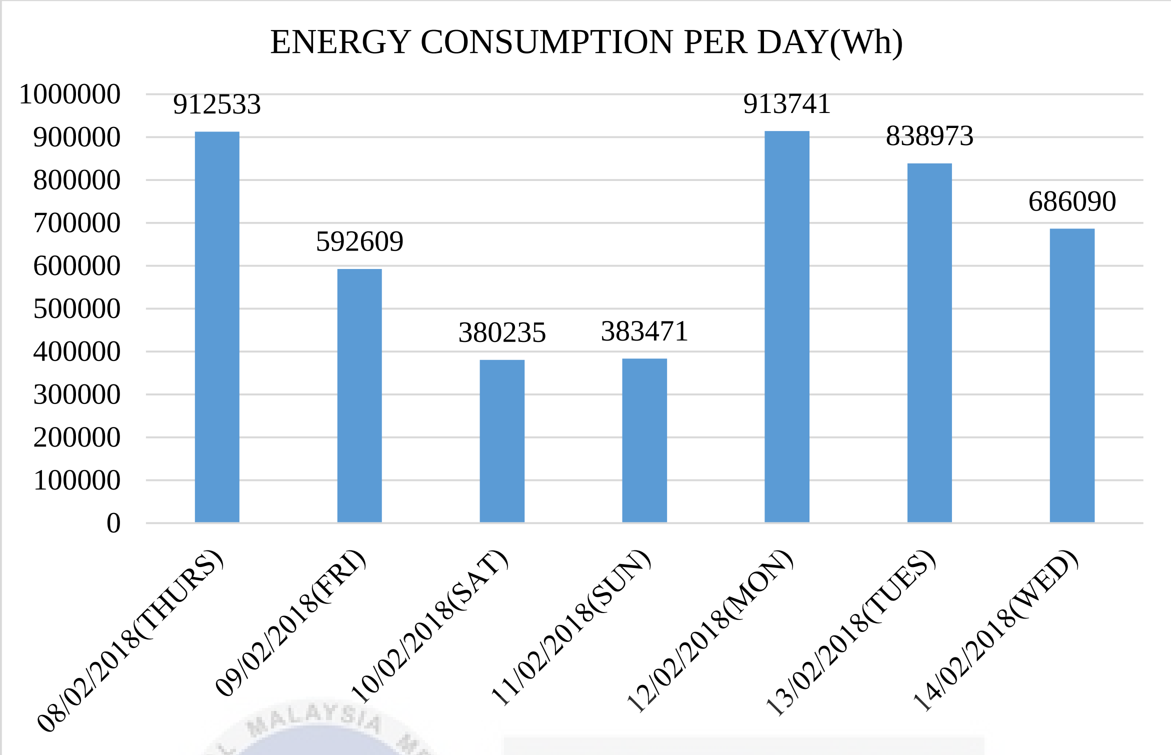


Figure 4.6: Daily Energy Consumption for Laboratory Building Part II

The measurements has been conducted in the main power source of the Mechanical Laboratory Buildings for 14 days, which are from 31/01/2018 (Wednesday) to 14/02/2018 (Wednesday) to determine their respective daily energy consumption using Chauvin Arnoux C.A 8435 and the results of the measurements have been shown in the two graphs above. The energy usage trend for the two weeks has shown that the building has low energy consumption on Saturdays and Sundays due to most of the labs are not opened during weekends unless there is special event or activity and only several lights have been switched on. From the above findings, we have found that the energy consumption for the lighting system is considerably high as their energy consumptions for the two weekends are at least 250kWh. On the other hand, the measurement for Monday to Thursday have shown higher energy consumption compared to Friday due to more lab classes. However, the measurement result for 31/01/2018 and 14/02/2018 is slightly lower than the normal measurement results due to the record timing as we have started the measurement at 11am of 31/01/2018 and have stopped the measurement at 3.50 pm of 14/02/2018. The average energy consumption for the whole Laboratory buildings is 623.55kWh. The monthly energy consumption for the building has been estimated as $623.55\ kWh\ x\ 30 = 18706.5kWh$ and the estimated yearly energy consumption is $623.55kWh\ x\ 365\ = 227.60MWh$. The energy use intensity (EUI) of the building, EUI has been determined using the formula as shown in equation (4.12).

The energy use intensity (EUI) of the building

$$= \frac{227.60\ KWh\ used\ in\ a\ year\ x\ 3.412\ kBTU\ per\ kWh}{8243.28m^2 x\ 10.7639\ feet^2/m^2} \qquad \textbf{(4.12)}$$

$$= \frac{776.57kBTU}{88729.84\ feet^2} = 8.75\ BTU/feet^2$$

4.6 Power Consumption Performance for Laboratory Building (W)

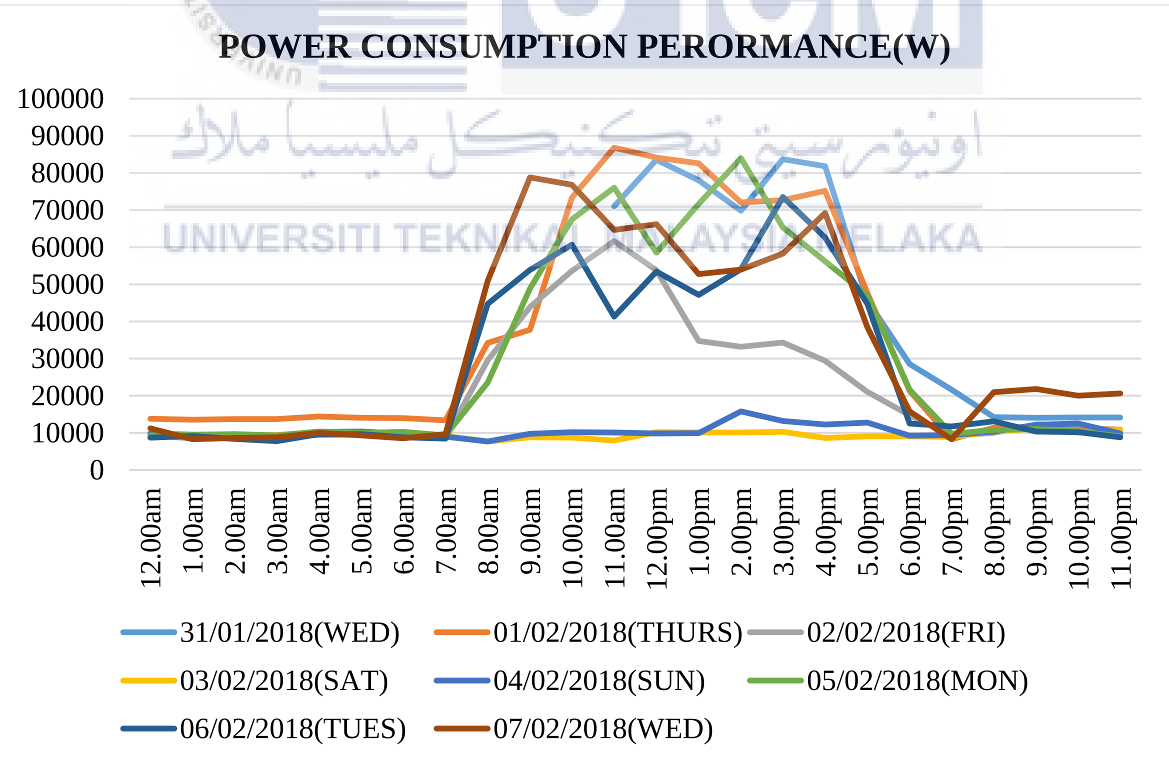


Figure 4.7: Power Consumption Performance for Laboratory Building Part I

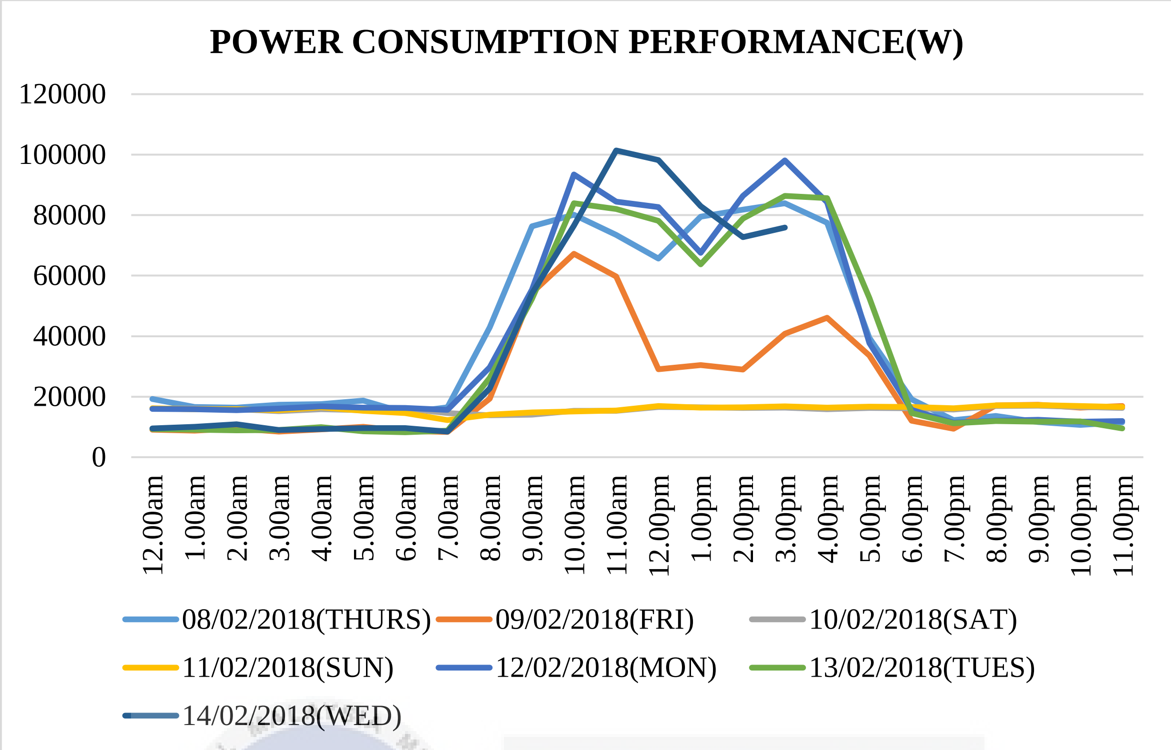


Figure 4.8: Power Consumption Performance for Laboratory Building Part II

The measurements has been undergone in the main power source of the Mechanical Laboratory Buildings for 14 days, which are from 31/01/2018 (Wednesday) to 14/02/2018(Wednesday) to determine their respective power consumption performance. The two graphs above have shown the hourly power consumption performance for the two weeks. Most of the graph lines in the two graphs have shown that the high power consumption occurs during 7.00 am to 6.00 pm as the labs are operating from 8.00am to 5.00pm. As most of the laboratory sessions start at 9.00 am and 2.00pm and last for 3 hours, the energy consumptions at these sessions are higher than other sessions and the power consumptions have decreased during lunch hours. However, the hourly power consumption graphs are different for every weekdays due to different energy demand. The graph lines for weekends have shown average graph lines with slightly increment during afternoon due to derating value in which the surrounding temperature will affect the conductivity of cable especially during hot weather.

4.7 Power Consumption Performance for Laboratory Building at 12/02/2018

Since the daily energy consumption for 12/02/2018 (Monday) is the highest among the 15 days, which is consuming 913741Wh, its power consumption performance graph as shown in Figure 4.9 has been selected to undergo detailed analysis.

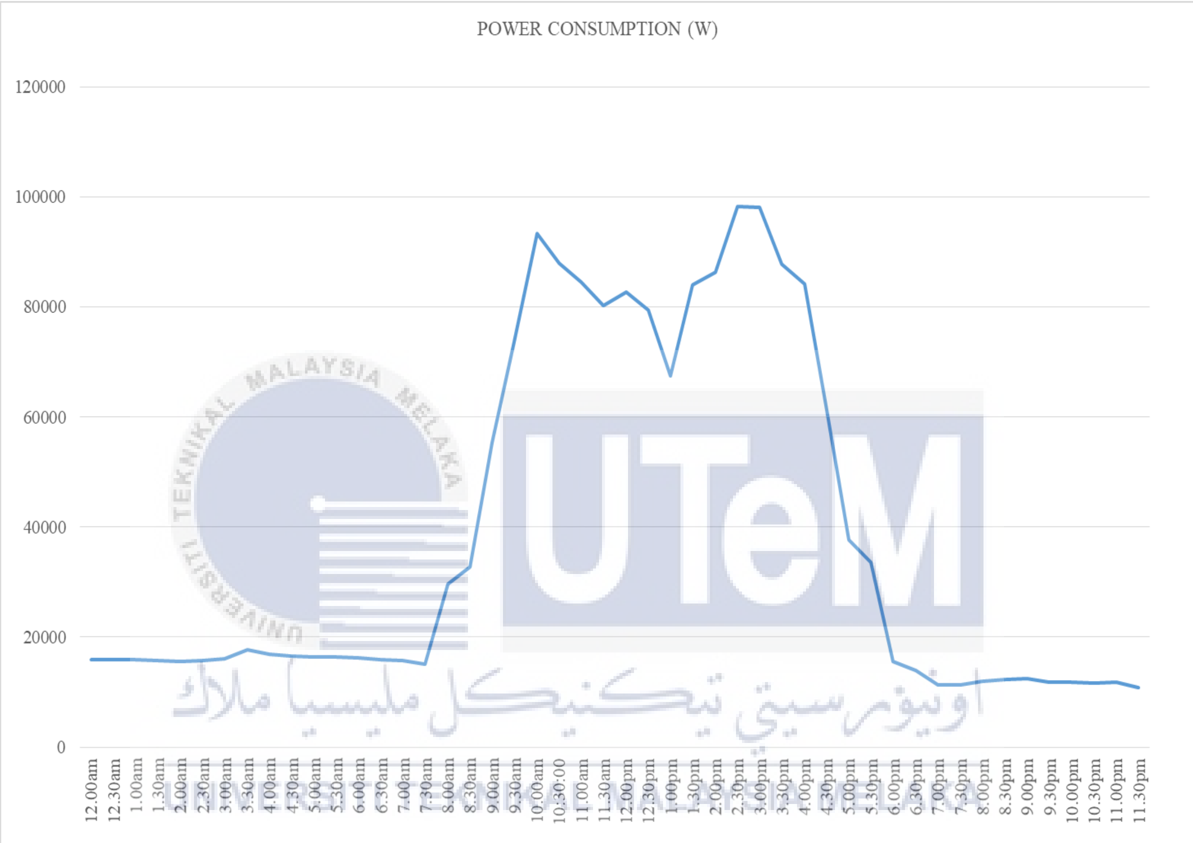


Figure 4.9: Power Consumption Performance for Laboratory Building at 12/02/2018

The graph above has shown that the power consumption for Mechanical Engineering Laboratory Building has remained below 200000W from 12.00am to 7.30am and has increased gradually after 7.30 am due to some of staffs including the lecturers, officers, technicians, guards and cleaners have started to work as well as switch on some of the systems and machines. After the energy usage has increased till 93401W at 10.00am, it has experienced a declining graph line until it has achieved 67538W at 1.00pm as the lunch hour for all staffs and students are 1.00pm. Even the graph line has declined, it is still higher compared to midnight session and night session because the staffs don't switch off the unnecessary equipment during lunch hours and the equipment especially the machines would consume a certain amount of energy even they are in idle mode.

4.8 Power Factor for Mechanical Engineering Laboratory

Power Factor is an index to measure the efficiency of electricity which ranges from 0 to 1.0. For Malaysia users who have taken supply at 33kV or below, it is advisable to maintain the power factor above 0.85. Otherwise, there will be power factor surcharge. Actually, a high power factor is important to prevent the power factor surcharge, have a longer lifespan of the electrical appliances, reduce electricity wastage and reduce the carbon dioxide emission. (Tenaga Nasional, 2018) Power factors for the Mechanical Engineering Laboratory during 31/01/2018 to 14/02/2018 has been shown in the two graphs below.

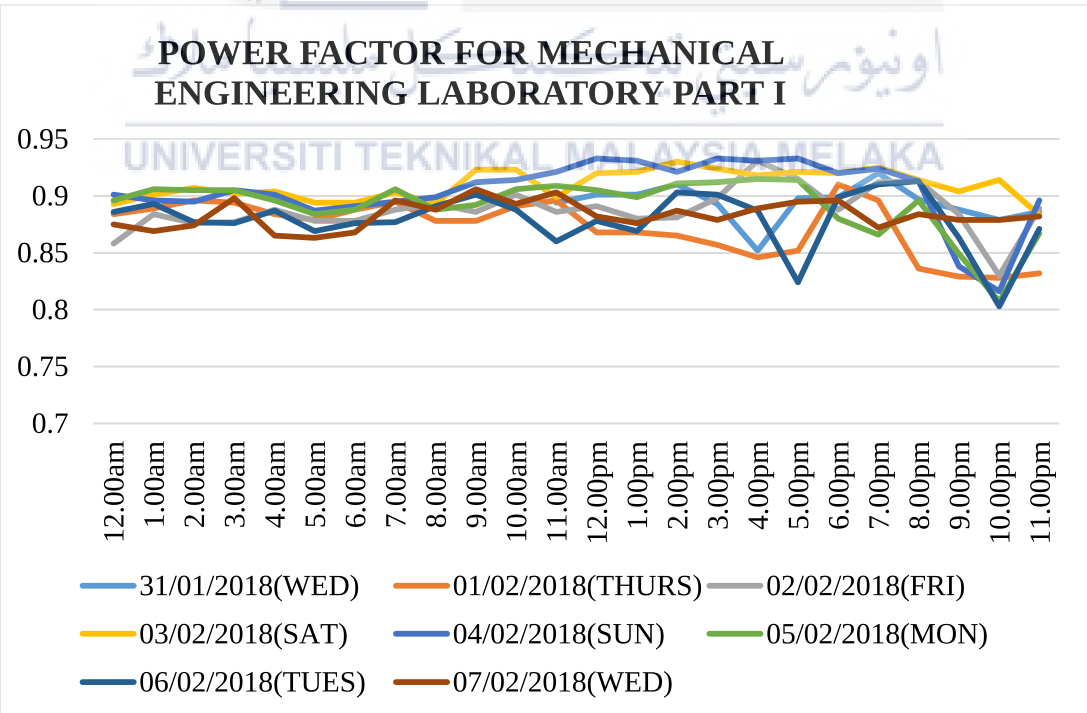


Figure 4.10: Power Factor for Mechanical Engineering Laboratory Part I

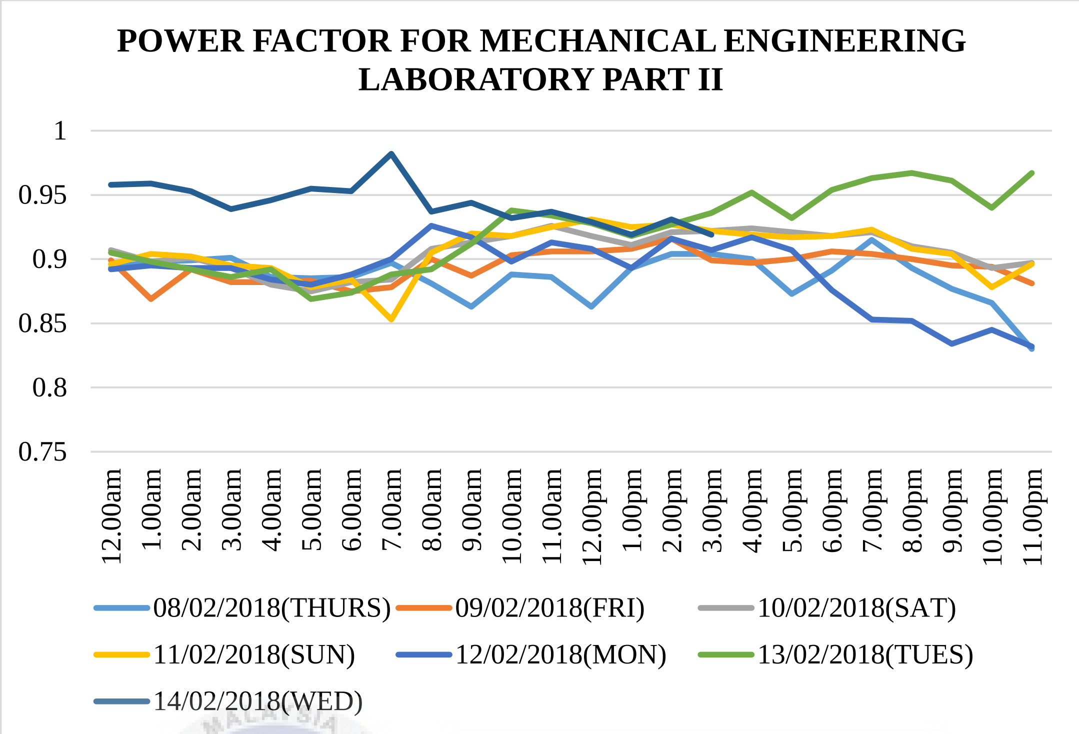


Figure 4.11: Power Factor for Mechanical Engineering Laboratory Part II

Figure 4.10 and 4.11 have shown that the power factors for the laboratory building was above 0.85 at most of the time. However, the power factor has dropped below 0.85 at sometimes which will being charged for power factor surcharge and cause the lifespan of the equipment to be reduced. The average power factor for the two weeks is 0.89.

4.9 Thermal Comfort and Power Consumption of Welding Workshop

4.9.1 Thermal Comfort of Welding Workshop

The thermal comfort for the welding workshop has been measured and the results are shown in the Table 4.4 below.

Table 4.4: Thermal Comfort of Welding Workshop

Condition	Session	Physical Parameter		
		Air Temperature(ºC)	**Relative Humidity (%)**	**Air Velocity (m/s)**
Without occupant	Morning (10-12pm)	28.11	78.40	0.23
Without occupant	Afternoon (2pm-5pm)	30.09	67.63	0.14
With Occupants	Morning (10-12pm)	31.37	62.26	0.24
With Occupants	Afternoon (2pm-5pm)	33.00	56.30	0.13

4.9.2 Checklist of Welding Workshop

Welding Workshop which is normally used for welding, shearing and grinding purpose consists of five 150W Metal Halide High Bay, twenty 36W T8 Fluorescent Light, three 7.82kW MIG Welding Machine, three 10.93 kW Arc Welding Machine, three 9.7kW TIG Welding Machine, a 3kW blower motor with 9 exhaust fans and a 11 kW Mechanical Power Shearing Machine. The checklist of welding workshop with the respective power rating and quantity is shown in Table 4.5.

Table 4.5: Checklist of Welding Workshop

No.	Item	Quantity	Power Rating(kW)	Total Power Rating (kW)
1.	Metal Halide High Bay	5	150W	0.75
2.	T8 Fluorescent	20	36W	0.72
3.	MIG Welding Machine	3	$P = 200\,V\,x\,34\,A$ $= 7.82kW$	23.46
4.	Arc Welding Machine(Thunderbolt XL AC/DC)	3	$P = 230\,V\,x\,47.5A$ $= 10.93\,kW$	32.79
5.	TIG Welding Machine (MATRIX 400 AC/DC)	3	$P = 10\,kVA\,x\,0.97$ $= 9.7\,kW$	29.1
6.	Blower Motor	1	3kW	3
7.	Mechanical Power Shearing Machine	1	11kW	11

4.9.3 Estimation of Power Consumption

Estimations have been made on the frequency of usage of the equipment and electrical appliances based on the student timetable to estimate the total power consumption per day as well as the workshop is estimated to operate for 22 days per month.

Table 4.6: Estimation of Power Consumption of Welding Workshop

No.	**Item**	**Frequency of usage per day (hours)**	**Total Power (kW)**
1.	Metal Halide High Bay	6.5	4.875
2.	T8 Fluorescent	6.5	4.68
3.	MIG Welding Machine	3	70.38
4.	Arc Welding Machine(Thunderbolt XL AC/DC)	3	98.37
5.	TIG Welding Machine (MATRIX 400 AC/DC)	-	-
6.	Blower Motor	6.5	19.5
7.	Mechanical Power Shearing Machine	1	11

Total Estimated Power Consumption per Day

$= 4.875 + 4.68 + 70.38 + 98.37 + 19.5 + 11$

$= 208.81\ kW$

Total Estimated Power Consumption per month

$= 208.81\ kW\ x\ 20$

$= 4593.82kW$

4.9.4 Exact Power Consumption

4.9.4.1 Power Consumption of Welding Workshop

Only the power consumption of the machines / equipment are able to be determined due to the circuit design of the Mechanical Engineering Laboratory Complex. All of the air conditioning systems in the building are designed in a separated circuit with the equipment circuit. Therefore, the current readings (A) for different type of machine operations have been taken using digital clamp meter and the respective power consumptions have been calculated. The current readings and the respective power consumptions have been shown in the table below. Since the power source for the workshop is three phase power source, all the power consumptions in this lab have been calculated based on the formula below.

$$Power\ Consumption\ for\ three\ phase\ voltage, P_T = \sqrt{3}\ VI\ x\ PF \qquad \textbf{(4.13)}$$

Table 4.7: Power Consumption of Welding Workshop

TYPE OF OPERATION	Current (A)	Power Consumption (kW)
One Arc Welding Machine	$4.29A$	$P_T = \sqrt{3}\ VI\ x\ PF$ $P_T = \sqrt{3}\ x\ 415\ x\ 4.29\ x\ 0.89$ $= 2.74kW$
One Arc Welding Machine and one MIG welding machine	5.89 A	$P_T = \sqrt{3}\ x\ 415\ x\ 5.89\ x\ 0.89$ $= 3.77kW$
One arc welding machine with blower on	9.67A	$P_T = \sqrt{3}\ x\ 415\ x\ 9.67\ x\ 0.89$

		$= 6.17kW$
One Arc Welding Machine, one MIG welding machine with blower and Mechanical Power Shearing Machine on	11.75A	$P_T = \sqrt{3}\ x\ 415\ x\ 11.75\ x\ 0.89$ $= 7.52kW$

4.9.4.2 Power Consumption of Equipment

The actual power consumption of each equipment has been determined then using some basic calculations.

$Power\ consumption\ of\ 1\ Arc\ Welding\ machine\ =\ 2.74kW$

$Power\ consumption\ of\ 1\ MIG\ Welding\ machine$

$= Power\ consumption\ of\ 1\ Arc\ Welding\ Machine\ and\ 1\ MIG\ Welding\ machine -$
$power\ consumption\ of\ 1\ Arc\ Welding\ machine$

$= 3.77\ kW - 2.74kW$

$= 1.03\ kW$

$Power\ consumption\ of\ 1\ blower$

$=\ Power\ consumption\ of\ 1\ Arc\ Welding\ Machine\ and\ 1\ blower\ -$
$Power\ consumption\ of\ 1\ Arc\ Welding\ machine$

$= 6.17kW - 2.74kW$

$= 3.43kW$

$Power\ consumption\ of\ 1\ Mechanical\ Power\ Shearing\ Machine$

$= Power\ consumption\ of\ 1\ Arc\ Welding\ Machine, 1\ MIG\ welding\ machine, 1\ blower$

$and\ 1\ Mechanical\ Power\ Shearing\ Machine - Power\ consumption\ of\ 1\ blower$

$- Power\ consumption\ of\ 1\ Arc\ Welding\ Machine$

$- Power\ consumption\ of\ 1\ MIG\ Welding\ Machine$

$= 7.52kW - 2.74kW - 1.03kW - 3.43kW$

$= 0.32kW$

4.9.4.3 Comparison of Estimated Power Consumption and Exact Power Consumption

The exact power consumption of each equipment has been compared with the estimated power rating of the equipment.

Table 4.8: Comparison of Estimated Power Consumption and Exact Power Consumption

Type of Equipment	Estimated Power Consumption (kW)	Exact Power Consumption (kW)
Arc Welding Machine	10.93	2.74
MIG Welding Machine	7.82	1.03
Blower Motor	3	3.43
Mechanical Power Shearing Machine	11	0.32

The results in Table 4.8 shows a huge difference, at least 15% of difference, between estimated power consumption and exact power consumption as the power rating which is considered as the highest allowable power input of an equipment has been used in estimating the power consumptions. Normally, the actual power consumption is lower than the power rating due to different applications and settings. Therefore, the exact power consumptions for Arc Welding Machine, MIG Welding Machine and Mechanical Power Shearing Machine are lower than their power ratings as expected, while the exact power consumption for Blower Motor are slightly higher than the power rating which will bring damage to the equipment as its operating temperature has exceeded safe levels.

4.9.4.4 Efficiency of Equipment

Table 4.9 has shown the efficiency of motor in the equipment and it is found that all of the equipment doesn’t have a satisfying motor efficiency by referring to Efficiency Class Definition for 4-Pole Motors at motor class IE2 in MS1525-2014

Table 4.9: Motor efficiency of equipment in Welding Workshop

Type of Equipment	Estimated Power Consumption (kW)	Exact Power Consumption (kW)	Motor Efficiency (%)
Arc Welding Machine	10.93	2.74	$\frac{10.93 - (10.93 - 2.74)}{10.93} x100\%$ = 25.07%
MIG Welding Machine	7.82	1.03	$\frac{7.82 - (7.82 - 1.03)}{7.82} x100\%$

			= 13.43%
Blower Motor	3	3.43	Not Applicable
Mechanical Power Shearing Machine	11	0.32	$\frac{11-(11-0.32)}{11}\ x100\%$ = 2.91%

4.9.4.5 Exact Power Consumption

The exact total power consumption of Welding Workshop has been determined again using exact power consumption of equipment and the estimated data of lighting system and air conditioning system. The results have been shown in table below.

Table 4.10: Exact Power Consumption of Welding Workshop

No.	Item	Power Consumption (W)	Quantity	Frequency of usage per day (hours)	Total Power (kW)
1.	Metal Halide High Bay	5	150W	6.5	4.875
2.	T8 Fluorescent	20	36W	6.5	4.68
3.	MIG Welding Machine	3	1.03kW	3	9.27
4.	Arc Welding Machine	3	2.74kW	3	24.66

	(Thunderbolt XL AC/DC)				
5.	TIG Welding Machine (MATRIX 400 AC/DC)	3	1.03kW	-	-
6.	Blower Motor	1	3.43kW	6.5	22.30
7.	Mechanical Power Shearing Machine	1	0.32kW	1	0.32

Total Estimated Power Consumption per Day

$= 4.875 + 4.68 + 9.27 + 24.66 + 22.30 + 0.32$

$= 66.11\ kW$

Total Estimated Power Consumption per month

$= 66.11\ kW\ x\ 22$

$= 1454.42 kW$

$Percentage\ of\ power\ consumption$

$$= \frac{Monthly\ Power\ Consumption\ of\ Workshop}{Total\ monthly\ Power\ Consumption\ of\ the\ Building}$$

$$= \frac{1454.42}{18706.5}\ x\ 100\% = 7.77\%$$

4.10 Thermal Comfort and Power Consumption of Machine Workshop

4.10.1 Thermal Comfort of Machine Workshop

The thermal comfort for the Machine workshop has been measured and the results have been shown in the table below.

Table 4.11: Thermal Comfort of Machine Workshop

Condition	Session	Physical Parameter		
		Air Temperature(°C)	Relative Humidity (%)	Air Velocity (m/s)
Without occupant	Morning (10-12pm)	19.50	52.80	0.20
Without occupant	Afternoon (2pm-5pm)	18.80	57.40	0.16
With Occupant	Morning (10-12pm)	20.90	58.60	0.10
With Occupant	Afternoon (2pm-5pm)	20.80	56.70	0.12

4.10.2 Checklist of Machine Workshop

Machine Workshop which is normally used for milling purpose and turning purpose consists of three 3.7 kW Conventional Vertical Milling Machines, three 3.75 kW Conventional Lathe

Machines, a 300W computer set, a 3.75 kW CNC Lathe Machine, a 22.4 kW CNC Milling Machine, a 11 kW Hydraulic Press Brake, six 2.675 kW air Cond, 18 double fitting T8 Fluorescent Lamps and a 0.75 kW drill press machine. The checklist of the machine workshop is shown in Table 4.12.

Table 4.12: Checklist of Machine Workshop

No.	**Item**	**Quantity**	**Power Rating**	**Total Power(Watt)**
1.	Conventional Vertical Milling Machine	3	3.7kW	11.1
2.	Conventional Lathe Machine	3	3.75kW	11.25
3.	Computer	1	300W	0.3
4.	CNC Lathe Machine	1	3.75kW	3.75
5.	CNC Milling Machine	1	22.4kW	22.4
6.	Hydraulic Press Brake	1	11kW	11
7.	Air Cond	6	2.675kW	16.05
8	T8 Fluorescent	36	36W	1.296
9.	Drill Press	1	0.75kW	0.75

4.10.3 Estimation of Power Consumption

Estimations have been made on the frequency of usage of the equipment and electrical appliances based on the student timetable to estimate the total power consumption per day as well as the workshop is estimated to operate for 22 days per month.

Table 4.13: Estimation of Power Consumption of Machine Workshop

No.	Item	Frequency of usage per day (hours)	Total Power (kW)
1.	Conventional Vertical Milling Machine	4.5	49.95
2.	Conventional Lathe Machine	4.5	50.63
3.	Computer	5	1.5
4.	CNC Lathe Machine	3	11.25
5.	CNC Milling Machine	2	44.8
6.	Hydraulic Press Brake	1	11
7.	Air Cond	6.5	104.33
8	T8 Fluorescent	6.5	8.42
9.	Drill Press	3	2.25

Total Estimated Power Consumption per Day

$$= 49.95 + 50.63 + 1.5 + 11.25 + 44.8 + 11 + 104.33 + 8.42 + 2.25$$

$= 287.11\ kW$

The workshop is estimated to operate for 22 days per month.

Total Estimated Power Consumption per month = 287.11 kW x 22 = 6316.42 kW

4.10.4 Exact Power Consumption

4.10.4.1 Power Consumption of Machine Workshop

Only the power consumption of the machines / equipment are able to be determined due to the circuit design of the Mechanical Engineering Laboratory Complex. All of the air conditioning systems in the building are designed in a separated circuit with the equipment circuit. Therefore, the current readings (A) for different type of machine operations have been taken using digital clamp meter and the respective power consumptions have been calculated. The current readings and the respective power consumptions have been shown in the table below. Since the power source for the workshop is three phase power source, all the power consumptions in this lab will be calculated based on the formula below.

$$Power\ Consumption\ for\ three\ phase\ voltage, P_T = \sqrt{3}\ VI\ x\ PF \quad \textbf{(4.14)}$$

Table 4.14: Exact Power Consumption of Machine Workshop

Type Of Operation	Current(A)	Power Consumption(kW)
All Conventional Vertical Milling Machine	12.8	$P_T = \sqrt{3}\ x\ 415\ x\ 12.8\ x\ 0.89$ = 8.19kW
All Conventional Vertical Milling Machine and 1 CNC Lathe Machine	17.1A	$P_T = \sqrt{3}\ x\ 415\ x\ 17.1\ x\ 0.89$ = 10.94kW

All Conventional Vertical Milling Machine and one Hydraulic Press Brake	23.5A	$P_T = \sqrt{3}\ x\ 415\ x\ 23.5\ x\ 0.89$ = 15.03kW
All Conventional Vertical Milling Machine, 1 CNC Lathe Machine, 1 CNC Milling Machine and 1 Hydraulic Press Brake	$34.1A$	$P_T = \sqrt{3}\ x\ 415\ x\ 34.1\ x\ 0.89$ = 21.81kW

4.10.4.2 Power Consumption of Equipment

The actual power consumption of each equipment has been determined then using some basic calculations.

$Power\ consumption\ of\ 3\ Conventional\ Vertical\ Milling\ Machines\ =\ 8.19\ kW$

$Power\ consumption\ of\ 1\ Conventional\ Vertical\ Milling\ Machine\ =\ 2.73\ kW$

$Power\ consumption\ of\ 1\ CNC\ Lathe\ Machine$

$= Power\ consumption\ of\ 3\ Conventional\ Vertical\ Milling\ Machine\ and\ 1\ CNC\ Lathe\ Machine - Power\ consumption\ of\ 3\ Conventional\ Vertical\ Milling\ Machine$

$= 10.94\ kW - 8.19\ kW$

$= 2.75\ kW$

$Power\ consumption\ of\ 1\ Hydraulic\ Press\ Brake$

$= Power\ consumption\ of\ 3\ Conventional\ Vertical\ Milling\ Machine\ and\ 1\ Hydraulic\ Press\ Brake - Power\ consumption\ of\ 3\ Conventional\ Vertical\ Milling\ Machine$

$= 15.03\ kW - 8.19kW$

$= 6.84\ kW$

$Power\ consumption\ of\ 1$ CNC Milling Machine

$= \ Power\ consumption\ of\ 3\ Conventional\ Vertical\ Milling\ Machines, 1\ CNC\ Lathe\ Machine, 1\ CNC\ Milling\ Machine\ and\ 1\ Hydraulic\ Press\ Brake - \ Power\ consumption\ of\ 3\ Conventional\ Vertical\ Milling\ Machines - Power\ consumption\ of\ \ 1\ CNC\ Lathe\ Machine - \ \ Power\ consumption\ of\ 1\ Hydraulic\ Press\ Brake$

$= 21.81\ kW - 8.19kW - 2.75kW - 6.84\ kW$

$= 4.03kW$

4.10.4.3 Comparison of Estimated Power Consumption and Exact Power Consumption

Table 4.15: Comparison of Estimated Power Consumption and Exact Power Consumption

Type of Equipment	Estimated Power Consumption (kW)	Exact Power Consumption (kW)
Conventional Vertical Milling Machine	3.7kW	2.73 kW
CNC Lathe Machine	3.75kW	2.75 kW
CNC Milling Machine	22.4kW	4.03kW
Hydraulic Press Brake	11kW	6.84 kW

The table above has shown a big difference, at least 30% of difference, between estimated power consumption and exact power consumption as the power rating which is considered as the highest allowable power input of an equipment has been used in estimating the power consumptions. Normally, the actual power consumption is lower than the power rating due to different applications and settings. Therefore, the exact power consumptions for Conventional Vertical Milling Machine, CNC Lathe Machine, CNC Milling Machine and Hydraulic Press Brake are lower than their power ratings as expected.

4.10.4.4 Efficiency of Equipment

Table 4.16 has shown the efficiency of motor in the equipment and it is found that all of the equipment don't have satisfying motor efficiency by referring to Efficiency Class Definition for 4-Pole Motors at motor class IE2 in MS1525-2014

Table 4.16: Motor efficiency of equipment in Machine Workshop

Type of Equipment	**Estimated Power Consumption (kW)**	**Exact Power Consumption (kW)**	**Motor Efficiency (%)**
Conventional Vertical Milling Machine	3.7kW	2.73 kW	$\frac{3.7-(3.7-2.73)}{3.7} x100\%$ = 73.78%
CNC Lathe Machine	3.75kW	2.75 kW	$\frac{3.75-(3.75-2.75)}{3.75} x100\%$ = 73.33%

CNC Milling Machine	22.4kW	4.03kW	$\frac{22.4-(22.4-4.03)}{22.4} x100\%$ = 17.99%
Hydraulic Press Brake	11kW	6.84 kW	$\frac{11-(11-6.84)}{11} x100\%$ = 62.18%

4.10.4.5 Exact Power Consumption

The exact total power consumption of Machine Workshop has been determined again by using exact power consumption of equipment and the estimated data of lighting system, some equipment and air conditioning system. The results have been shown in table below.

Table 4.17: Exact Power Consumption of Machine Workshop

No.	Item	Power Consumption (W)	Quantity	Frequency of usage per day (hours)	Total Power (kW)
1.	Conventional Vertical Milling Machine	2730 W	3	4.5	36.86
2.	Conventional Lathe Machine	3750W	3	4.5	50.63
3.	Computer	300W	1	5	1.5

4.	CNC Lathe Machine	2750 W	1	3	8.25
5.	CNC Milling Machine	4030 W	1	2	8.06
6.	Hydraulic Press Brake	6840 W	1	1	6.84
7.	Air Cond	2675 W	6	6.5	104.325
8.	T8 Fluorescent	36W	36	6.5	8.424
9.	Drill Press	750 W	1	3	2.25

Total Estimated Power Consumption per Day

$= 36.86 + 50.63 + 1.50 + 8.25 + 8.06 + 6.84 + 104.325 + 8.424 + 2.25$

$= 227.14\ kW$

Total Estimated Power Consumption per month

$= 227.14\ kW\ x\ 22$

$= 4997.06\ kW$

$$Percentage\ of\ power\ consumption = \frac{Power\ Consumption\ of\ Workshop}{Total\ Power\ Consumption\ of\ the\ Building}$$

$$= \frac{4997.06}{18706.5}\ x\ 100\% = 26.71\%$$

4.11 Discussion

From the data obtained and above calculations, it is found that Machine Workshop has higher monthly power consumption than the Welding Workshop in which the difference between the two workshops is about 3542.64kW. Machine Workshop is estimated to consume 4997.06kW per month, while Welding Workshop is estimated to consume 1454.42kW per month. The huge difference between the power consumption of the two workshops are due to the existence of heavily power consumed machines and air conditioning system in Machine Workshop as the daily power consumption of air conditioning system is 104.325kW which is considered as about half of the daily power consumption in Machine Workshop and this has implied that the power consumption of the air conditioning system is comparable with the total power consumption of the other equipment. Besides that, Machine Workshop's power consumption is roughly about 26.71 % of the total monthly power consumption in Mechanical Engineering Laboratory Complex which is consider as one of the major power consumption for the building, while the power consumption of the Welding Machine is only 7.77% of the total monthly power consumption in the building. Besides that, it is found that most of the equipment in the two laboratories are under standard efficiency. Therefore, it is recommended to reduce the total power consumption in the building by reducing the energy usage of the air conditioning system or increase the energy efficiency of those equipment.

4.12 Retrofit Analysis

Retrofit analysis is an innovative process to improve the energy efficiency and reduce the energy consumption of a building by reducing the operation hours or use a higher efficiency equipment. Based on the data above, the energy consumption for the machine lab can be reduced by increasing the set point temperature as its measured air temperature is lower than the standard temperature by 2 to 3 °C without affecting the occupant's thermal comfort according to MS 1525:2014. From the questionnaire survey, it is found that almost half of the respondents have voted for intervals (-3,-2) which implies that the environment is not acceptable and the estimated neutral temperature is about 23.5°C based on their perception.

Table 4.18: Thermal sensation votes in Machine Workshop

ASHRAE Scale		Machine Workshop		
		Morning	Afternoon	Total
Hot	+3	0	0	0
Warm	+2	0	0	0
Slightly warm	+1	0	0	0
Neutral	0	0	0	0
Slightly cool	-1	5	7	12
Cool	-2	2	2	4
Cold	-3	1	3	4
Total				20

When the setting temperature is higher than previous setting, the compressor inside the refrigeration system will take shorter time to maintain the desired temperature as compressor is the most power consuming device in the whole system. Besides that, it is recommended to shut down 2-3 units of the air-conditioning unit as the machine lab consists of 6 units of split unit air conditioning system and maintain the setting temperature at 20 °C - 21 °C which is the alternative of raising the desired temperature without affects the thermal comfort of the users. This method can help to save up at least 30% of the current electricity usage if two of the split units have been shut down and the rest of split units are still operating at the setting temperature of 20 ºC - 21 ºC. Each split unit in this lab is expected to consume 2.675kW per hour and is expected to operate for 6.5 hours.

Existing power consumption for each split unit per day = $2.675\ x\ 6.5 = 17.39\ kW$

Since there are 6 split units in this lab, so

Total existing power consumption for air-conditioning system per day

= $17.39kW\ x\ 6 = 104.33\ kW$

As two of the split units have been shut down and only the four units are operating,

Proposed power consumption for air-conditioning system per day

= $17.39kW\ x\ 4 = 69.56\ kW$

$$\text{Total savings} = \text{Existing Power Consumption} - \text{Proposed plan power consumption}$$

$$= 104.33 - 69.56 = 34.77kW$$

Percentage of power savings = $\frac{Total\ savings}{Existing\ Power\ Consumption}\ x\ 100\ \%$

$$= \frac{34.77\ kW}{104.33kW}\ x\ 100\% = 33.33\%$$

Amount of savings per day = $34.77kW\ x\ \frac{RM0.365}{kW} = RM12.69$

Amount of savings per month = $\frac{RM12.69}{day}\ x\ 30\ days = RM\ 380.73$

This implementation has helped to save at least RM380.73 of the monthly electricity bill with zero implementation cost. Moreover, it is recommended to use programmable thermostat which can help to control the temperature setting automatically. When there are only few people inside the lab, the thermostat will help to raise the temperature without affect the standard thermal comfort and otherwise. This implementation will save up the most electricity usage during the windy and rainy season.

On the other hand, the electricity usage of the power consuming machines can be reduced by installing a motor soft starter to lower the motor acceleration and energy demand flow when the motor is being started up as well as reduce the mechanical stress on motor due to the reduced amplitude of the pulse of the starting torque motor. (Gritter et al, 2000) In motor, torque is a measure of rotational force to cause the shaft to be rotated and the starting torque is the torque when an electrical motor starting at zero speed. When a motor is being started, the torque of the motor will increase sharply and the energy demand for start-up will more than the energy demand when the motor is being operated. Therefore, when there are many motors in UTeM Mechanical Engineering Laboratory buildings being started up at the same time, the energy demand will increase sharply and the energy demand will be more than allowable demand power by Tenaga Nasional Berhad which has caused UTeM to be charged for an average of RM6794.78 in 2016. The tariff for each kilowatt of maximum demand per month is RM 30.30 and the average maximum demand for the building is 224.25kW. If this implementation is able to reduce at least half of the maximum demand, UTeM can save up to at least half of the maximum demand surcharge.

Existing Maximum Demand = $224.25\ kW$

Proposed plan maximum demand $=\ 0.5\ x\ 224.25 =\ 112.13kW$

Total reduction in maximum demand = $224.25kW - 112.13kW = 112.12kW$

Total savings in maximum demand surcharge = $112.12\ kW\ x \frac{RM30.30}{kW} = RM3397.24$

Percentage of maximum demand savings = $\frac{RM6794.78 - RM3397.24}{RM6794.78}\ x\ 100\% = 50\%$

Apart from that, implementation of torque control soft starter will consume lesser reactive power and active power compared to the ordinary usage of motor especially when the motor has been used on intensive works. (José et al, 2011) Normally, the power system which is being on power consuming machine is three phase system which is more economical and able to transmit the power more efficiently. It will consist of reactive power which is the power being wasted during power transmission and active power which is the exact energy consumption with the presence of inductance and capacitance in the star and delta circuits. Since both of the powers have been reduced using the implementation of soft starter, the electricity bill will also being reduced. There is an almost similar way which is using a variable speed drive to deliver energy output that matches the required load. This method also eliminate the low power factor problems and voltage fluctuations on motor torque.

On the other hand, it is possible to use synchronous motor instead of induction motor to save up to around 30% of energy. (Perrat, 2010) In a real case study on the airport luggage carrier with similar size of induction motor and synchronous motor which are 1.5kW, it is found that synchronous motor consume lower energy than the other motor at every different type of operating conditions such as running continuously in one direction, no load on the motors, 10 kg of load, 30 kg of load and 50kg of load. Although the application of synchronous motors can help to save up to almost one third of the energy, the initial implementation cost could be quite high for UTeM management as there are many equipment or machines in the Mechanical Engineering Laboratory Complex.

Moreover, Tenaga Nasional Berhad has set a standard power factor for every user according to the respective energy supply quota. For UTeM Mechanical Engineering Laboratory Complex, the minimum allowable power factor is 0.85. However, it is found that the power factor for the building has dropped below 0.85 at sometimes which will being charged for power factor surcharge and cause higher active power losses which implies that the energy is not fully utilised or being used efficiently. A low power factor which indicates poor utilization of electrical power will pull up more load and direct affects the electricity bill.The power that required for transmission, distribution network, transformers, alternators and the equipment connected to the system will become high and UTeM has to pay more electricity bill than what is actually being used. However, it is not recommended to install a capacitor bank which is a group of interconnected capacitors to improve the power factor performance as the poor power factor performance only occurs at low frequency rate and the implementation cost for the capacitor bank is quite high. Moreover, low power factor may occur due to the low efficiency of motor in the machine which indicates the motor is operating at less than full load. It is recommended to check the power factor of the machines using power clamp meter to determine the machine with low power factor and send them for rewinding to increase the respective power factor. Hence, the energy efficiency of the respective machine will be increased and reduce the energy demand which will reduce the electricity bill as well.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

As a conclusion, energy audit is a very appropriate and suitable approach that used to eliminate the wastage of energy and increase the energy efficiency of the equipment by propose some energy conservation measures. Therefore, it is important to conduct preliminary analysis which has included reviewing historical data and a tour visit to the building to understand its power consumption trend, have a complete list of the available equipment or system in the building which has included their respective power rating, frequency of usage and quantity to estimate the power consumption and data collection using energy meter or digital clamp meter. After that, exact power consumption has been determined based on the data obtained to make comparison, determine the major power consumptions and the potential energy savings. Lastly, a retrofit analysis has been conducted to determine the efficiency of the propose energy saving measures based on the calculation.

From this case study, it is found that daily power consumption for Machine Workshop is at least 160kW higher than the daily power consumption for Welding Workshop due to the available heavy power consumed machines and air conditioning system. Besides that, the power consumption for Machine Workshop is around 27 % of the total power consumption of the building, so it is recommended to increase temperature settings of spilt units by around 2°C - 3°C, reduce the operating quantity of air conditioning units from 6 units to 3-4 units, install a motor soft starter on the equipment to lower the motor acceleration and energy demand flow when the motor is being started up and implementation of torque control soft starter to reduce the energy consumption, reduce the maximum demand and solve the low power factor in Machine Workshop.

Lastly, there are few recommendations that can be considered as reference or future guidelines in energy audit of laboratory building such as

a) Undergo detail study on the engineering drawings of the whole building to have a more effective energy efficiency program as some buildings may consist of old electrical circuit design which is hard to implement energy efficiency program for a specified workshop.
b) Retake the data measurement for the building as the data may change from time to time.
c) Determine the exact period or timing of maximum demand occurs.
d) Determine the exact motor efficiency of the equipment.
e) Undergo the energy efficiency program in the building to determine the exact energy savings.

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APPENDIX A1: Gantt chart for PSM 1

Final Year Project 1

Activity	Weeks															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Project Briefing and Planning	■															
Literature Review and Collecting Information		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Preparation of Progress Report					■	■	■	■								
Reviewing Historical Data						■	■	■								
Submission Progress Report									■							
Walk-through Visit										■						
Selection of Lab											■					
Preparation for Presentation and Draft Final Report										■	■	■	■	■	■	■
Submission Draft Final Report														■		
Presentation Seminar Final Year Project 1																■

APPENDIX A2: Gantt chart for PSM 2

Final Year Project 2

Activity	Weeks															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Project Briefing and Planning																
Literature Review and Collecting Information																
Perform Preliminary Experiment Work																
Perform Repeating Experiment Work																
Capturing Repeating Experimental Result																
Preparation Final Report																
Correction Final Report																
Submission Final Report																
Final Year Presentation Seminar																

APPENDIX B: Data Sheet for Power Consumption Performance of Laboratory Building

Recording				
Date:	Time:	PT (W)	PFT	EpT (Wh)
31/01/2018	11:00:00	71035	0.894	11839
31/01/2018	11:30:00	87028	0.906	52244
31/01/2018	12:00:00	83560	0.901	93697
31/01/2018	12:30:00	77930	0.902	132818
31/01/2018	13:00:00	78036	0.901	172989
31/01/2018	13:30:00	70433	0.91	207765
31/01/2018	14:00:00	69803	0.91	241949
31/01/2018	14:30:00	84383	0.91	281342
31/01/2018	15:00:00	83742	0.893	322855
31/01/2018	15:30:00	73857	0.882	360938
31/01/2018	16:00:00	81766	0.852	401773
31/01/2018	16:30:00	75489	0.844	440559
31/01/2018	17:00:00	45679	0.898	470018
31/01/2018	17:30:00	33143	0.901	487680
31/01/2018	18:00:00	28573	0.899	502524
31/01/2018	18:30:00	21699	0.912	513798
31/01/2018	19:00:00	21651	0.92	524625
31/01/2018	19:30:00	21891	0.905	535328
31/01/2018	20:00:00	14210	0.897	543339
31/01/2018	20:30:00	13954	0.893	550341

31/01/2018	21:00:00	14073	0.888	557360
31/01/2018	21:30:00	14125	0.887	564383
31/01/2018	22:00:00	14120	0.879	571458
31/01/2018	22:30:00	14058	0.872	578572
31/01/2018	23:00:00	14104	0.886	585641
31/01/2018	23:30:00	13309	0.882	592554
01/02/2018	00:00:00	13794	0.884	599395
01/02/2018	00:30:00	13891	0.881	606267
01/02/2018	01:00:00	13568	0.889	613048
01/02/2018	01:30:00	13367	0.891	619815
01/02/2018	02:00:00	13694	0.896	626577
01/02/2018	02:30:00	13504	0.888	633366
01/02/2018	03:00:00	13681	0.894	640137
01/02/2018	03:30:00	14164	0.885	647051
01/02/2018	04:00:00	14403	0.884	654118
01/02/2018	04:30:00	13978	0.876	661125
01/02/2018	05:00:00	14083	0.879	668153
01/02/2018	05:30:00	14126	0.88	675219
01/02/2018	06:00:00	13952	0.888	682244
01/02/2018	06:30:00	13296	0.895	689063
01/02/2018	07:00:00	13375	0.895	695751
01/02/2018	07:30:00	13815	0.905	702670
01/02/2018	08:00:00	34249	0.878	715545
01/02/2018	08:30:00	36431	0.876	733659
01/02/2018	09:00:00	37746	0.878	753825
01/02/2018	09:30:00	59313	0.892	779451

01/02/2018	10:00:00	73321	0.891	814816
01/02/2018	10:30:00	86562	0.889	858618
01/02/2018	11:00:00	86827	0.896	901167
01/02/2018	11:30:00	91435	0.873	944430
01/02/2018	12:00:00	84163	0.868	986965
01/02/2018	12:30:00	79989	0.87	1028481
01/02/2018	13:00:00	82599	0.868	1067578
01/02/2018	13:30:00	65861	0.85	1103045
01/02/2018	14:00:00	72060	0.865	1139479
01/02/2018	15:00:00	72626	0.857	1210076
01/02/2018	15:30:00	78333	0.845	1248709
01/02/2018	16:00:00	75155	0.846	12526
01/02/2018	16:30:00	81552	0.852	52693
01/02/2018	17:00:00	47632	0.852	82031
01/02/2018	17:30:00	33395	0.9	100564
01/02/2018	18:00:00	21254	0.91	113181
01/02/2018	18:30:00	9239	0.882	119807
01/02/2018	19:00:00	8235	0.896	124052
01/02/2018	19:30:00	8709	0.886	128526
01/02/2018	20:00:00	11359	0.836	133899
01/02/2018	20:30:00	11667	0.836	139681
01/02/2018	21:00:00	11596	0.829	145499
01/02/2018	21:30:00	10867	0.853	150888
01/02/2018	22:00:00	11245	0.828	156553
01/02/2018	22:30:00	10552	0.858	161787
01/02/2018	23:00:00	10880	0.832	167276

01/02/2018	23:30:00	10110	0.82	172545
02/02/2018	00:00:00	9375	0.858	177593
02/02/2018	00:30:00	8450	0.887	181953
02/02/2018	01:00:00	8454	0.884	186355
02/02/2018	01:30:00	8420	0.881	190720
02/02/2018	02:00:00	8810	0.876	195180
02/02/2018	02:30:00	9098	0.876	199618
02/02/2018	03:00:00	9073	0.877	204051
02/02/2018	03:30:00	9555	0.876	208623
02/02/2018	04:00:00	9432	0.888	213514
02/02/2018	04:30:00	9114	0.883	218281
02/02/2018	05:00:00	9457	0.878	222969
02/02/2018	05:30:00	9629	0.878	227646
02/02/2018	06:00:00	9272	0.878	232240
02/02/2018	06:30:00	8610	0.89	236723
02/02/2018	07:00:00	8440	0.888	240947
02/02/2018	07:30:00	19585	0.894	249490
02/02/2018	08:00:00	29548	0.893	262057
02/02/2018	08:30:00	33520	0.885	277850
02/02/2018	09:00:00	43891	0.886	299255
02/02/2018	09:30:00	46348	0.908	322404
02/02/2018	10:00:00	53652	0.901	347392
02/02/2018	10:30:00	56139	0.891	375741
02/02/2018	11:00:00	61620	0.886	405285
02/02/2018	11:30:00	62045	0.878	436140
02/02/2018	12:00:00	53785	0.891	465390

02/02/2018	12:30:00	36214	0.893	485999
02/02/2018	13:00:00	34702	0.88	503959
02/02/2018	13:30:00	32880	0.88	520658
02/02/2018	14:00:00	33146	0.881	537586
02/02/2018	14:30:00	36581	0.892	554875
02/02/2018	15:00:00	34286	0.898	572101
02/02/2018	15:30:00	37053	0.915	591294
02/02/2018	16:00:00	29427	0.931	607363
02/02/2018	16:30:00	27521	0.929	621183
02/02/2018	17:00:00	21014	0.915	632699
02/02/2018	17:30:00	20470	0.906	642956
02/02/2018	18:00:00	14722	0.888	651945
02/02/2018	18:30:00	9347	0.909	656602
02/02/2018	19:00:00	9191	0.912	661154
02/02/2018	19:30:00	9338	0.914	665743
02/02/2018	20:00:00	10044	0.913	670634
02/02/2018	20:30:00	10288	0.914	675925
02/02/2018	21:00:00	12271	0.884	682249
02/02/2018	21:30:00	12788	0.85	688574
02/02/2018	22:00:00	12452	0.83	694833
02/02/2018	22:30:00	11553	0.827	700613
02/02/2018	23:00:00	9795	0.889	706036
02/02/2018	23:30:00	9629	0.893	710984
03/02/2018	00:00:00	9738	0.893	715788
03/02/2018	00:30:00	9524	0.896	720591
03/02/2018	01:00:00	9240	0.901	725363

03/02/2018	01:30:00	5163	0.872	729465
03/02/2018	02:00:00	9167	0.907	733611
03/02/2018	02:30:00	9709	0.908	738378
03/02/2018	03:00:00	9423	0.902	742969
03/02/2018	03:30:00	10135	0.907	747815
03/02/2018	04:00:00	10254	0.904	753013
03/02/2018	04:30:00	9731	0.895	758087
03/02/2018	05:00:00	9947	0.894	763061
03/02/2018	05:30:00	10334	0.888	768071
03/02/2018	06:00:00	10268	0.894	773070
03/02/2018	06:30:00	9066	0.905	777692
03/02/2018	07:00:00	9125	0.903	782281
03/02/2018	07:30:00	7990	0.899	786728
03/02/2018	08:00:00	7646	0.893	790621
03/02/2018	08:30:00	7611	0.901	794452
03/02/2018	09:00:00	8787	0.923	798757
03/02/2018	09:30:00	8757	0.928	803144
03/02/2018	10:00:00	8713	0.923	807517
03/02/2018	10:30:00	15343	0.912	814897
03/02/2018	11:00:00	7905	0.899	821072
03/02/2018	11:30:00	10042	0.925	825611
03/02/2018	12:00:00	10173	0.92	830665
03/02/2018	12:30:00	10233	0.919	835769
03/02/2018	13:00:00	10090	0.921	840835
03/02/2018	13:30:00	10309	0.93	845905
03/02/2018	14:00:00	10077	0.93	850954

03/02/2018	14:30:00	10305	0.926	856054
03/02/2018	15:00:00	10282	0.924	861153
03/02/2018	15:30:00	10352	0.927	866314
03/02/2018	16:00:00	8652	0.918	871120
03/02/2018	16:30:00	9126	0.924	875659
03/02/2018	17:00:00	9019	0.921	880175
03/02/2018	17:30:00	9192	0.919	884695
03/02/2018	18:00:00	9072	0.92	889232
03/02/2018	18:30:00	9001	0.923	893755
03/02/2018	19:00:00	8846	0.925	898192
03/02/2018	19:30:00	9120	0.919	902635
03/02/2018	20:00:00	10329	0.914	907553
03/02/2018	20:30:00	10948	0.913	912865
03/02/2018	21:00:00	11089	0.904	918174
03/02/2018	21:30:00	10538	0.907	923507
03/02/2018	22:00:00	10121	0.914	928753
03/02/2018	22:30:00	9986	0.9	933746
03/02/2018	23:00:00	10801	0.883	938880
03/02/2018	23:30:00	9112	0.896	943806
04/02/2018	00:00:00	9828	0.901	948660
04/02/2018	00:30:00	9799	0.908	953414
04/02/2018	01:00:00	9485	0.896	958041
04/02/2018	01:30:00	9449	0.902	962700
04/02/2018	02:00:00	8975	0.895	967309
04/02/2018	02:30:00	8936	0.893	971948
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11/02/2018	03:00:00	15529	0.895	5358700
11/02/2018	03:30:00	16830	0.893	5366686
11/02/2018	04:00:00	16494	0.893	5375071

11/02/2018	04:30:00	15545	0.876	5383153
11/02/2018	05:00:00	15318	0.878	5385701
11/02/2018	05:30:00	15526	0.874	5388252
11/02/2018	06:00:00	14609	0.884	5390805
11/02/2018	06:30:00	15521	0.894	5398539
11/02/2018	07:00:00	12297	0.853	5406079
11/02/2018	07:30:00	12545	0.876	5413532
11/02/2018	08:00:00	14870	0.913	5420644
11/02/2018	08:30:00	14949	0.917	5436563
11/02/2018	09:00:00	14794	0.92	5443990
11/02/2018	09:30:00	14847	0.921	5451397
11/02/2018	10:00:00	15066	0.918	5458864
11/02/2018	10:30:00	15198	0.921	5466464
11/02/2018	11:00:00	15440	0.925	5474141
11/02/2018	11:30:00	16525	0.928	5481821
11/02/2018	12:00:00	16910	0.931	5489891
11/02/2018	12:30:00	16696	0.929	5498352
11/02/2018	13:00:00	16357	0.925	5506665
11/02/2018	13:30:00	16269	0.928	5514867
11/02/2018	14:00:00	16528	0.927	5522970
11/02/2018	14:30:00	16427	0.921	5531177
11/02/2018	15:00:00	16756	0.922	5539414
11/02/2018	15:30:00	16358	0.919	5556093
11/02/2018	16:00:00	16919	0.923	5559001
11/02/2018	16:30:00	16675	0.92	5564547
11/02/2018	17:00:00	16664	0.917	5572949

11/02/2018	17:30:00	16606	0.914	5581341
11/02/2018	18:00:00	16550	0.918	5589711
11/02/2018	18:30:00	16398	0.917	5598064
11/02/2018	19:00:00	16162	0.923	5606320
11/02/2018	19:30:00	16237	0.92	5614536
11/02/2018	20:00:00	17095	0.908	5622657
11/02/2018	20:30:00	17292	0.909	5631151
11/02/2018	21:00:00	17256	0.904	5639782
11/02/2018	21:30:00	16758	0.896	5648387
11/02/2018	22:00:00	16629	0.875	5659580
11/02/2018	22:30:00	16833	0.888	5665172
11/02/2018	23:00:00	16563	0.896	5673462
11/02/2018	23:30:00	15774	0.893	5681700
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12/02/2018	02:00:00	15571	0.893	5721607
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