ENERGY AUDIT IN BUILDING: TOOLS TO IMPROVE OVERALL ENERGY EFFICIENCY

AZMA NIZA LAILA BINTI ZAKARIA

BACHELOR OF ELECTRICAL ENGINEERING
(INDUSTRIAL POWER)
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

“I hereby declare that I have read through this report entitle “*Energy Audit in Building: Tools to Improve Overall Energy Efficiency*” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (industrial Power)”

Signature : ………………………………………………..

Supervisor‟s Name : MR. MOHAMAD FAIZAL BIN BAHAROM

Date : ……………………………………………………

ENERGY AUDIT IN BUILDING: TOOLS TO IMPROVE OVERALL ENERGY EFFICIENCY

AZMA NIZA LAILA BINTI ZAKARIA

A thesis submitted in fulfillment of the requirements for the degree of Bachelor of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

I declare that this report entitle "*Energy Audit in Building: Tools to Improve Overall Energy Efficiency*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidate of any degree.

Signature : ……………………………………………

Name : AZMA NIZA LAILA BINTI ZAKARIA

Date : ……………………………………………..

Dedicated to my beloved father, mother, family and my members.

ACKNOWLEDGEMENT

First and foremost, grateful to Allah SWT, with His willing give the opportunity to complete this Final Year Project with the title is Energy Audit in Building: Tools to Improve Overall Energy Efficiency. This report is prepared for Faculty of Engineering Electrical, University Teknikal Malaysia Melaka (UTeM). This report is prepared in order to complete the undergraduate program in Bachelor of Electrical Engineering (Power Industry).

Next, I would like to express my gratitude and appreciation to my supervisor, Mr. Mohamad Faizal bin Baharom whose assign and guided me during this two semester. Besides that, I would like to thanks the Neraca Niaga Sdn Bhd and Dean of Faculty of Technology Engineering (FTK) for their cooperation and permission to do the energy audit project at Factory 1, FTK

Lastly, special thanks to my family for their cooperation, encouragement, suggestion and full of support from beginning until I finished my degree. Also thanks to my friends, Nur Farhani binti Ambo and Nur Lidiya binti Muhammad Ridzuan, those have been contributed with supporting my work and give a hand during this period until it fully complete.

ABSTRACT

The rapid increase of energy consumption will give the worst affect to the environment such as cause the global warming and climate change. Due to the increasing of the awareness programs and energy policy UTeM, the energy audit project is performed at Factory 1, FTK to develop energy efficiency measures. The purposes for this audit are to develop sustainable energy practices, analyze the performance of Energy Efficiency Index (EEI) and reduce energy consumption in the building. Factory 1 consists of 34 laboratories, 9 corridors, 4 toilets and 2 prayers rooms with area 11 692 m^2. These audits are focus on performance of the building using EEI as an indicator, potential saving and energy saving methods. In addition, it also focuses on lighting system, air conditioning system, lab equipment and plug-in equipment. The parameters measures in this project are lux level, relative humidity, temperature and carbon dioxide emissions. Energy audit showed the annual energy consumed from September 2015 until August 2016 is 1,097,704 kWh with annual cost RM 371 561.70 is lower than annual energy consumed from September 2014 which is 1,188,215 kWh with annual cost RM 398 124.10. The annual potential saving after the implementation energy efficiency practices is RM 26,562.40. The performances of the building in term of EEI in September 2015 are decreasing from 125 to 110 $kWh/m^2/yr$. Factory 1 are still in best performance and follow the Malaysia Standard range which is below 135 $kWh/m^2/yr$. From the load apportioning and parameter measures, the energy saving methods are proposed such as increase the temperature of the air conditioning at thermal comforts, lit up the lighting for small area only, switch off the lamps when no person around and using awareness signage. After that, the comparisons between actual data at 2015 are compared with eQUEST software. The simulation is used as one tools to identify the performance of the building. Next, the reduction of energy consumption at Factory 1 can reduce as much as 68.8 tons of CO^2 emissions to the atmosphere and this will lower the global effect and climate change. As a result, it is show that the energy audit is an important tool to save energy consumption, save budget, environment and manage the energy improvement.

ABSTRAK

Peningkatan pesat penggunaan tenaga memberikan kesan yang teruk kepada alam sekitar seperti pemanasan global dan perubahan iklim. Disebabkan peningkatan program kesedaran dan dasar tenaga UTeM, projek audit tenaga telah dijalankan di Factory 1, FTK untuk meningkatkan langkah kecekapan tenaga. Tujuan audit tenaga ini adalah untuk memajukan amalan tenaga lestari, menganalisis prestasi Indeks Kecekapan Tenaga (EEI) dan mengurangkan penggunaan tenaga. Factory 1 terdiri daripada 34 makmal, 9 koridor, 4 tandas dan 2 bilik solat dengan keluasan 11 692 m^2. Di samping itu, projek ini fokus kepada lampu, penghawa dingin, peralatan makmal dan plug-in. Parameter yang diukur ialah tahap kecerahan, kelembapan, suhu dan karbon dioksida. Projek audit ini menunjukkan tenaga tahunan yang digunakan dari bulan September 2015 adalah 1,097,704 kWh dengan kos tahunan RM 371 561,70 adalah lebih rendah berbanding bulan September 2014 yang menggunakan tenaga sebanyak 1,188,215 kWh dengan kos tahunan RM 398 124.10. Potensi penjimatan tahunan selepas pelaksanaan amalan kecekapan tenaga adalah RM 26,562.40. Prestasi bangunan berdasarkan EEI pada September 2015 sehingga August 2016 semakin berkurangan 125 kepada 110 kWh /m^2/tahun. Factory 1 masih dalam prestasi terbaik dan mengikuti julat Standard Malaysia iaitu di bawah 135 kWh / m^2/ tahun. Berdasarkan penggunaan beban dan parameter yang telah diukur, kaedah penjimatan tenaga yang dicadangkan seperti meningkatkan suhu penyaman udara pada tahap keselesaan, nyalakan lampu untuk kawasan yang kecil sahaja, matikan lampu apabila tiada orang di sekeliling dan menggunakan papan tanda kesedaran. Selepas itu, perbandingan antara data sebenar pada 2015 dengan perisian eQUEST telah dijalankan. Simulasi ini digunakan sebagai salah satu alat untuk mengenal pasti prestasi bangunan. Seterusnya, pengurangan penggunaan tenaga di Factory 1 boleh mengurangkan sebanyak 68.8 tan pelepasan CO_2 ke atmosfera dan ini akan mengurangkan kesan pemanasan global dan perubahan iklim. Hasilnya, ia menunjukkan bahawa audit tenaga adalah satu alat yang penting untuk menjimatkan penggunaan tenaga, menjimatkan bajet, alam sekitar dan menguruskan peningkatan tenaga.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

The fast increasing in the quantity of commercials, industrials, residential and institutional buildings has a serious effect on the evolution of the country and brings to increase in world energy demand. Be aware of the limited energy resources, the development should run in parallel with energy production and energy consumption [1]. Since energy crisis in 1970, engineers, architects and building developers are better fitted out to design, build and maintain buildings more efficiently to diminish energy consumption and electricity usage. Based on the effort to sustainable the building practice, The Malaysian Standard MS 1525:2007, Code of Practice on Energy Efficiency and use of Renewable Energy for Non- Residential Buildings has been introduced. The standard briefly explain the engineering, architectural, landscaping and site planning aspects in designing to optimize the energy efficiency of a building [2].

The nation development contributed to the improvement and development of higher-education institutions to cover the increasing number of local as well as international students. Presently, each state of the Malaysia has at least one public or private higher-education institution. The Malaysian Ministry of Education (MOE) and the Malaysian Ministry of Higher Education (MOHE) has insisted all education centers to play their role to reduce energy wastage and save energy. This initiative is important because in general, all universities have large building, comprehensive facilities as well as large numbers of users.

Hence, as one of institutions in Malaysia, UTeM also took part in the implementation of energy efficiency programs. For the purpose of energy sustainability and conservation, UTeM had released an energy policy and conducted many energy efficiency awareness campaigns in the institutions. One of the energy saving programs, the energy audit is conducted at Factory 1, Faculty of Engineering Technology (FTK) of Universiti Teknikal Malaysia Melaka (UTeM). The walk through audit is conducted to get the gross floor area for Factory 1 which is 74m X 158 m with equivalent to 11,692 m^2. Factory 1 consists of 34 laboratories, 9 corridors, 4 toilets, and 2 prayers room. In addition, it also consists of Main Switch Board (MSB), 9 Sub Switch Board (SSB) and 8 Air Handling Unit (AHU) rooms.

1.2 Problem Statement

Currently, the global warming and climate change are getting worse due to the increasing 40% of the energy consumption over the world [3]. The statistic energy consumption by electricity at Malaysia at 2012 is 21% by Suruhanjaya Tenaga [4]. With concern about energy consumption, global warming and lack of non-renewable resources, the government of Malaysia has implementing several of energy policies to reduce the energy usage. In order to reduce the energy consumption and increase the energy efficiency and also decrease the environmental effect, UTeM are introducing the energy policy, 2015 [5] which committed to improve efficiency and conservation of energy continuously throughout the campus and success teaching and learning, research and service operations through the implementation of energy efficient management, and effectively. Based on the statistic of energy consumption UTeM, FTK are consumed 60% more energy compared with other faculty. This is happen due to plenty of laboratories equipment that using high power and energy. Then, the energy audit is conducted at Factory 1 to increase the awareness and energy management practices at building. In addition, energy audit is conduct at FTK in order to know the Energy Efficiency Index (EEI) and potential saving at the building. Moreover, the purpose of the energy audit is to reduce the energy consumption at the building and decrease the carbon dioxide emissions. The energy audit at Factory 1 follows Suruhanjaya Tenaga Malaysia and Malaysian

Standard MS 1525:2007, Code of Practice on Energy Efficiency and use of Renewable Energy for Non- Residential Buildings.

This project has an objective that should be achieved to complete the problem statement above.

1.3 Objectives

The main objective is to analyze the overall energy efficiency index (EEI) in FTK building through energy audit. However, there are other objectives must be covered in order to reduce the energy waste and improve the energy efficiency in the building which is:

1) To develop sustainable energy management practices at FTK building.
2) To identify the performance of Energy Efficiency Index (EEI) at FTK building.
3) To analyze energy saving potentials for future improvement
4) To reduce energy consumption in Factory 1.

1.4 Scope of Work

This energy audit will conduct at Factory 1, Faculty of Engineering Technology (FTK), UTeM. This audit are focus on the flow of the energy consumption in the building, Energy Efficiency Index (EEI) and the potential saving that can be applied in the factory. The process of this audit is start from September 2015 until May 2016. The processes of auditing are based on schematic diagrams of Factory 1, area of the building, historical metering bills and electrical and mechanical equipment in the building. In addition, the auditing process for this factory covers only for lighting systems, air-conditioning systems, lab equipment and electrical equipment. Besides, the parameters measures in this project are lux level, temperature, carbon dioxide and humidity. Next, this project also uses simulation which is eQUEST software to identify the performance of the building. This factory is consisting of:

1) 34 Laboratories
2) 9 Corridors
3) 4 Toilets (2 Male, 2 Female)
4) 2 Prayer rooms (Male and Female)

Figure 1.1: Gross floor area for Factory 1, FTK

Figure 1.1 shows the drawing by AutoCAD software for layout Factory 1, FTK. The gross floor area Factory 1 is 11 692 m^2.

CHAPTER 2

LITERATURE REVIEW

In this chapter, there will be insight about theory and essential standard in building up this framework. Moreover, there will be a case study where audit of past related works that comparative with this task and do the summary and discussion of the review.

2.1 Theory and basic principles

2.1.1 Energy Audit

An energy audit can be characterized as a systematic measurement and inspection to assess where the building uses energy and identify energy efficient measures (EEMs) to decrease energy usage. Energy audit is a vital energy management service which applies energy investigation systems to assess the profile of energy usage to expand energy efficiency measures EEMs in building [6]. In addition, energy audit also can be identify as a procedure to identify working issues, enhance inhabitants comfort, and enhance the utilization in the existing buildings. Moreover, it distinguishes the chance for energy conservation. The process is uncommon in nature, and it evaluates changes in building utilize, the state of existing equipment, and the significance of new energy-efficient advances [7].

On the other hand, Green Tech Malaysia define the energy audit as a structured inspection and analysis of energy use and consumption of audited objects to identify energy flows, potential opportunities and monitoring and verification for improving energy performance and reporting them [7].

2.1.1.1 Categories of Energy Audit

a) Preliminary Audit

This process also called as a “brief audit” or “walk through audit”. It is essentially an initial data gathering effort. Quick and fast overview of energy use patterns [8]. At this stage, it gives instruction for energy accounting system and provides staff or helper with perspectives of processes and equipment. Moreover, it‟s commonly uses accessible data and completed data with simple measurement. This preliminary audit involves the simple zero-cost and low-cost measures for energy efficiency [9].

b) Detailed Audit

Detailed audit is an instrumented information gathering of all energy consuming equipment and process in a plant, followed by a detailed energy and cost analysis of the dissimilar processes. This process is focus on budget incentive energy savings opportunities, which have been identified in preliminary audit [9]. In addition, it also identifies the no-cost and low-cost opportunities, and provides energy efficient measure (EEM) recommendations in order to reduce the energy usage. This level of process includes an analysis of energy costs, energy usage and building characteristics [8].

c) Investment Grade Audit

The investment grade audit concentrates on budget intensive measures and involves techno-economic analysis. The practical part consists of the design concept of the proposed measure, a detailed estimation of budget spends and operations and maintenance (O&M) costs. Besides, this level of auditing includes monitoring, data collection and engineering analysis [10].

Table 2.1: Summary of energy audit process [8]

Type	Description
Preliminary Audit	Evaluating energy consumption in general Energy bill analysis and determining Building Energy Index (BEI) Identifying areas for potential savings in general using experience and „rule of thumb". No systematic measurement
Detailed Audit	Using input from preliminary audit Identification of energy sources and end users and apportionment Determination of equipment and system performance Investigation and measurement to identify potential savings Analysis of saving measures using and technical and economic evaluation.
Investment Grade Audit	Input from detail audit Involve high cost, complex system Require financing Longer period for investigation and monitoring

Table 2.1 above shows the summary of energy audit process which are preliminary audit, detailed audit and investment grade audit.

2.1.1.2 Energy Audit Process

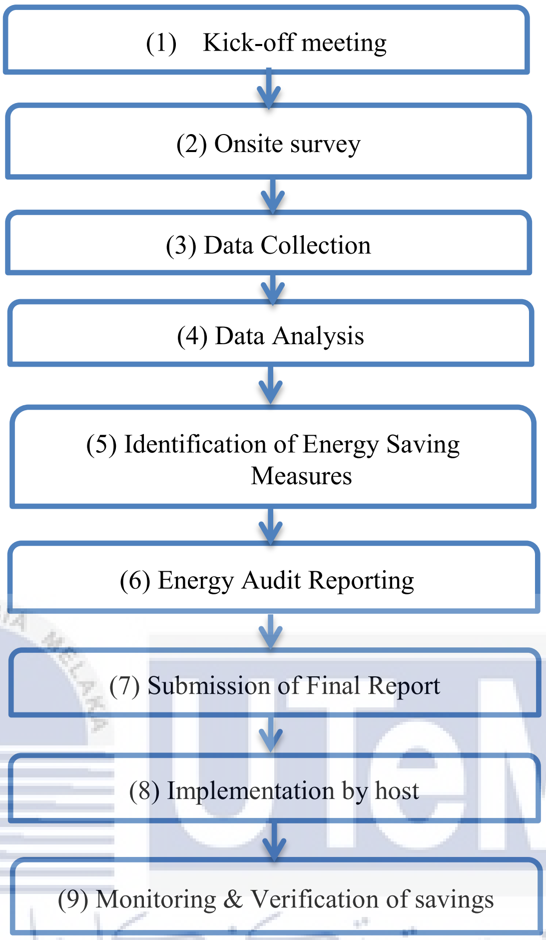


Figure 2.1: Flow Chart of Energy Audit Process [8].

Figure 2.1 above shows the flowchart that commonly used for auditor to plan the energy audit in the buildings. There are nine steps for auditing process which are kick of meeting with the energy management team, do the onsite survey which is to get the gross floor area of the building and collect all the data and make the analysis. Next, identify the potential saving in the building, do the implementation and submit the final report. In addition, to get the consistency of decreasing in energy consumption, the audit team must have schedule to monitor and verification the equipment in the building.

2.1.2 Energy Efficiency

Energy efficiency is identified with accomplishing more work with the same unit of energy and it additionally assumes a part as tool that shows the least level of energy waste to perform related task for a desired final product. Moreover, it additionally characterized as the proportion between the yield of the execution, administration, products or energy, and source of energy [11].

In addition, the energy efficiency is referring to physical performance of particular energy services and production, for example lighting, air conditioning and motor drive. High energy efficiency is accomplished by replacing, improve, or remain the existing equipment to decrease measure of energy usage. The energy efficiency is normally measured by the production quantity per unit of energy input (miles per gallon or lumen per watt). Since energy is one a few variables of production (work, capital and materials are others), energy efficiency upgrades add to more prominent energy productivity and economic efficiency [12].

On the other hand, it likewise assumes an important part in controlling energy use, and additionally lessening cost and keeping up agreeable environment in buildings. Energy efficiency and energy management are firmly related in regarding observing and controlling energy consumptions in buildings. With the present increment in the worldwide energy utilization, the main worry is not just centered on how to deliver the required energy but additionally approaches to enhance energy efficiency to guarantee sustainable energy supply and to be able to meet the required demand. In order to guarantee ideal operations of buildings energy system, energy efficiency activities ought to be done routinely and constantly to check real sample of the energy consumption in the building. The achievement variable for energy efficiency activities enormously relies on upon the strategy or markers used to gauge the energy performance in the buildings [13].

2.1.3 Energy Efficiency Index

Energy Efficiency Index (EEI) is an instrument used to trace the performance of energy consumption. The estimation of EEI relies on upon the utilization of energy in a specific application. Normally, EEI can be characterized as far as an energy component and a factor connected to the energy using component of the association as given in equation (1) underneath [14].

1) Weight of the product produced
2) Number of item produced
3) Weight of raw material used
4) Period of production
5) Period of plant usage
6) Floor area of building
7) Number of in-patient bed per night (hospital building)
8) Number of occupied room per night (hotel building)

$$\mathrm{EEI} = \frac{\text{Energy input}}{\text{Factor related to the energy using component}} \qquad (1.0)$$

This index plans to deliver a quantitative energy efficiency metric, in view of real estimations or appraisals of vitality utilization. In addition, EEI in building s fit for adjusting to new arrangements of information with respect to energy use and future changes in energy efficiency. With a specific end goal to meet these prerequisites, EEI in building uses the connection between the built zone of a building and its energy utilization [15].

Table 2.2: Parameters affecting energy use in building [2]

End- use	Factors
1. Air conditioning and Space Heating	Occupancy and Management
2. Lighting	Environmental Standards
3. Power and Process	Climate Building Design and Construction Mechanical and Electrical Equipment

Table 2.2 above shows the parameters and factors that affecting energy use in buildings. There will be numerous difficulties at diverse levels of building exist when the different parameters included. The difficulties lay in how every one of these parameters influence the span time building's energy usage and how the energy reading can be assessed and measured precisely [15].

2.1.4 Building Efficiency Index

Some researchers carry out the EEI investigation by including independently the different types of buildings to avoid unreasonable correlation and estimation between buildings, because every building does not perform the same capacity. Buildings are utilized for multiple points, for example residential houses or commercial buildings, which are reflected by the distinctive number of occupants and other differences, including the building envelope characteristics, energy consuming equipment or installations and operation hours [15]. Different variables to be considered are topographical area and environment. Every one of these elements should be considered with a specific end goal to keep up the energy utilization performance at the ideal level [14].

A study did by Ahmad Sukri [14] reveal that energy usage in building can be fundamentally enhanced the EEI model in an energy management program. The index is communicated in kWh/m2 which calculated the using formula total energy usage divide by gross floor area of the building in meter square.

$$\text{BEI} = \frac{\text{Energy consumption (kWh)}}{\text{Area }(\text{m}^2)} \tag{1.1}$$

2.1.5 eQUEST Software

The Quick Energy Simulation Tool (eQUEST) software are gives a modern and advance, and yet simple to-use building analysis appliance. With eQUEST, it can give professional measure in a moderate level of effort. It was intended to permit you to perform point by point investigation of today's best in building design technologies using modern building energy use simulation techniques but without need wide experience in the "art" of building performance modeling [16].

Figure 2.2: Logo eQUEST software [16]

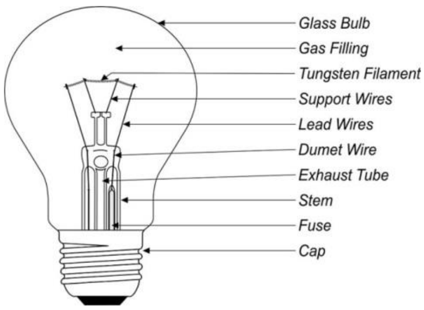
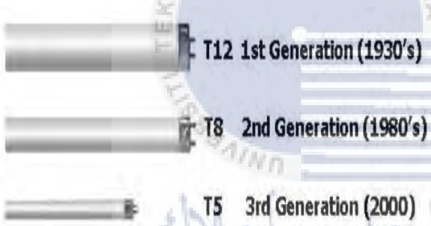
Progresses in computer innovation make it extremely practical as an energy simulation tool. This organized method also makes it practical for prediction of building thermal production. The energy challenges can be recognize by handled with apply new methodologies and brilliant innovation to make better energy efficiency. The implementation of computer technology is extremely successful instrument because elements, for example, usability, easy to understand and cost effective. Computer technology can be utilized to perform manual computations in very precise, fast way and requires shorter time step, which make them generally utilized apparatus as a part of building execution [1].

2.1.6 Lighting System

Lighting is fundamental piece of regular life. Lighting or illumination is the planned utilization of luminosity to accomplish a practical effect. It is indeed a fact that lighting records around 40% of the world‟s total energy consumption. It demonstrates the reliance of human on lighting [17]. Besides, lighting is known as strong causes that increase the energy demand and greenhouse gas emissions [18]. The efficient utilization of manufactured lighting can provide energy and in addition cost funds. There can be a few measures that can be taken for energy investment funds. By controlling the lighting Illuminance level, the energy can be save, increase human comfort and efficiency [19].

2.1.6.1 Types of Lighting

Table 2.3: Description for three types of lamps

Types of Lighting	Description
1) Incandescent lamps  Figure 2.3: Incandescent lamps [20]	1. It is the most seasoned and exceptionally basic light utilized as a part of homes, inside and outside particularly in rural areas. 2. This lamp is the most inefficient. 3. It creates and radiates much heat as compared to the amount of light [19].
2) Fluorescent lamps  Figure 2.4: Classification types of fluorescent lamps [21].	1. This lamps are having more efficiency compare than incandescent lights. 2. Fluorescent lamps have types T5, T8 and T12. 3. T5 are the latest version and the most productive and more compact than others.
3) Light Emitting Diodes (LED)  Figure 2.5: Types of Light Emitted Diode (LED) lamps [23]	1. It is enduring any longer and devouring a great deal less vitality than radiant lights and CFLs. 2. LED lamps are environmental friendly and recyable, unlike the CFLs due to the utilization of mercury inside the CFL. The danger of mercury is surely and creates a serious long-term problem. 3. LED has long term life span and can save cost, save material and production of 25 incandescent light bulbs [22].

2.1.6.2 Comparison performance of lamps

Table 2.4: Comparison performance lamps [24]

	Incandescent lamp	**Fluorescent**	**Compact Fluorescent lamp**	**Metal Halide**	**High Pressure Sodium**
Wattages (lamp only)	15- 15k	15-219	4-40	175-1k	70-1k
Life (hour)	750-12k	7.5k-24k	10k-20k	1.5k-15k	24k
Efficacy(lm/W) Lamp only	15-25	55-100	50-80	80-100	75-140
Lumen maintenance	Fair to excellent	Fair to excellent	Fair	Good	Excellent
Color renditions	Excellent	Good to excellent	Good to excellent	Very good	Fair
Light direction control	Very good	fair	fair	Very good	Very good

Table 2.4 shows the comparison between five types of lamps in term of performance. Based on the table, the most better lamps are Compact fluorescent lamps (CFL) because it used lowest wattages, long span time, fair lumen maintenance and excellent to color rendition index (CRI). CRI define as measurement of how accurately an artificial light source which means the brightness of lamps. The highest of the CRI will give the better artificial light. But, the best lamp is LED and it used the lowest wattages compare to others.

2.1.6.3 Ballast

The fluorescent lamps are using ballast to boost electric current to start the bulb. The ballast are used to limit the current flow, and avoid the fluorescent lamp from directly connect to voltage power source. If this case happens, the lamp would overheat and burn out.

Electronic ballast and magnetic ballast are the two main types of ballasts used in all types of fluorescent lamps. There is a huge difference operation of works and how the ballast affects the lighting in the rooms and buildings [25].

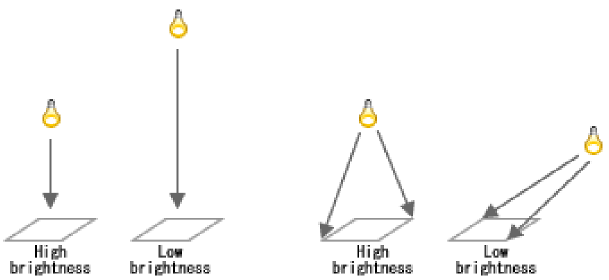
Table 2.5: Comparison between magnetic and electronic ballast [25]

Magnetic Ballast	**Electronic Ballast**
High operation cost	Low operating cost
The price for 1 unit cheaper than electronic ballast	More expensive
Cause the light of the lamp to flicker and creates humming sound	Not humming sound and smooth when switch ON the lamp
Less efficient	More efficient with higher frequency

Table 2.5 are shows the comparison between magnetic and electronic ballast that used in the fluorescent lamps. According to the table, the electronic ballast is better than magnetic ballast because it does not flicker and humming, so it can reduce the startup current.

2.1.6.4 Lighting selection factors

Table 2.6: Definition for factors of lighting

Lighting selection factor	**Definition**
Luminaire	Device that distributes filters or change the light emitted from one or more lamps [26]
Illuminance (brightness)	The total luminous flux touch on surface, per unit area [27]. 

Lumen	Unit of luminous flux One lux is one lumen per square meter. 1 Watt = 683 lumens [26].
Lux	Lux is the SI unit of illuminance and luminous emittance $\text{Lux} = \frac{\text{Total lumen}}{\text{Area m2}}$ (2.1)

2.1.7 Air-conditioning System

Nowadays, almost all new buildings, commercial, residential and industrial buildings use the heating, ventilation and air-conditioning (HVAC) as the main cooling ways at the building. Due to the increasing of the buildings use HVAC, the energy waste also increase. Hence, the level of carbon dioxide emission to the environment also increase and will cause the global warming and climate change.

Building use around one-third of the world"s energy and it is normal that the pattern will become further until the year 2025. Among the buildings in Malaysia, office buildings expend the most energy for air-conditioning system compared to shopping complexes, hotels and residential buildings. Subsequently, the owners of the building should make a move and take action to spare more energy to avoid needless energy wastage. Generally, building air-conditioning system can be classified into the following categories:

Table 2.7: Description for types of air-conditioning

Type of Air-Conditioning	**Description**
Air Handling Unit (AHU)	a) Instrument used to condition and circulate air as part of a heating, ventilating, and air conditioning (HVAC) system. b) Sometimes AHU release (supply) and receive (return) air straight to and from the space served without ventilation work.

Split/Window units	a) The split unit contain of the indoor unit and outdoor unit. b) The indoor unit is attached inside the area to be cooled. It can be place as ceiling or wall suspended and consists of the evaporator and blower. c) The outdoor unit is attached outside the building and consists of the compressor, condenser and blower [8].
Package units	a) The package units are used for higher capacity air-conditioning loads in the range of 3 to 15 tons. b) They consists of the filtering, cooling and dehumidifying as well as air handling part with water-cooled or air-cooled condensers.
Centralized air-conditioning systems	a) The central air conditioning system is consists of a huge compressor that has the capacity to produce hundreds of tons of air conditioning. b) A chiller is a machine that evacuates heat from a liquid through a vapor-compression or absorption refrigeration cycle. A vapor-compression water chiller consists of four important elements of the vapor-compression refrigeration cycle (compressor, evaporator, condenser, and shape or metering device) [8].

The heat expelled from the cooled space can be dictated by deliberate the chilled water heat dismissal or condenser water heat gain or the heat rejection in the building Air Handling Units (AHU). Thermal comfort is additionally an essential thought in assessing in appraise the performance of an air-conditioning system. The principle considers that influence thermal comforts are air temperature, relative humidity and flow rate. Air cleanliness, odor, noise and radiation effect also influence the comfort level of workers in a conditioned space [28].

2.1.7.1 Standard for Air conditioning system

In order to achieve the thermal comfort for the occupant, the design for the air conditioning must follow the standard. According to the standard MS 1525, the recommended temperature is in the range between 23^{o}C to 26^{o}C. Next, for standard relative humidity are about 55% to 70%. If the relative humidity is higher than the standard, the lower amount of heat the human body will be able to transfer by means of evaporation. Besides, if the temperature and relative humidity is high, the human body will feel uncomfortable [29].

2.2. Review of Previous Related Works

2.2.1 Energy Efficiency Measurements in a Malaysian Public University

Based on this paper [2] discussed about energy management program carried out at Faculty of Electrical Engineering, UTM. There are many activities are initiated and EEI is used as an indicator of building‟s energy consumption performance. Next, it also focused on calculation of EEI for three years and act as baseline for further saving in the future. This paper is only focused on awareness program and use historical billing to know the EEI for the building. However, the study about proper energy audit such as lux level and power are important in order to obtain the energy efficiency in the building.

2.2.2 New Construction for Commercial Building (Restaurant) by Considering the Green Building Strategies

This paper [3] discusses the new construction of commercial building which is design the electrical appliances such as lighting system, air conditioner and others. This paper use DIALux software to analyze the lighting luminaries in the building and AutoCAD to design the building. The building space and room concept will determine the lighting application that appropriate to applied. There are several things to be considered for lightings such as lux, lumen, and room index and every type of lamps have different ballast that must be consider. Then, this paper shows the energy consumption for the lightings, HVAC, SSO and other electrical equipment. However, these papers do not study about energy audit, relative humidity, carbon dioxide and temperature. Based on the energy audit, the relative humidity, carbon dioxide and temperature are needed because it is represent the energy usage of the air conditioning in the building. Next, these studies are important in order to increase the thermal comfort for occupant.

2.2.3 Energy Audit of an Educational Building in a Hot Summer Climate

This paper [7] discusses that process of energy audit at two-story educational building during hot summer climate. Energy audit teams (EAT) are dividing the energy audit process in three levels, Level 1 (walk-through assessment), Level 2 (survey and data analysis) and Level 3 (detailed analysis). Hence, the EAT are define the time frame and budget during auditing process occur for instance, working hours for audit team, operation hours for electrical equipment and certain devices need a longer period to collect the data (air temperature, relative humidity, power consumption, rate air flow and light intensity). The auditors need an instrument to measure important parameters such as temperature, pressure, flow rate, lighting lux level and running current. In addition, the energy audits for this building are based on Heating Ventilation Air Conditioning (HVAC) system, lighting system and plug-in equipment. On the other hand, the auditors studies the pattern of the energy usage in the building, identified the opportunities for energy and cost savings and calculate the payback period of changing to more efficient lighting and properly maintaining the HVAC system. However, this paper do not studies about coefficient of performance (COP) of air conditioning system and carbon dioxide for indoor and outdoor of the building. In order to increase the performance of the air conditioning, the COP is needs to be calculated.

2.2.4 Identification Building Index Saving using Energy Efficiency Index Approach

Based on this paper [15] discusses the way to reduce energy usage without using cost, easy to implement and satisfies comfortable environment. The study for this paper is conducted at Universiti Teknologi Malaysia (UTM) by using Energy Efficiency Index as baseline in determining how much energy is being wasted as well as being saved. The authors state that the number of occupants influenced the energy performance in the buildings. Hence, the authors approach the method called Class Shifting Method which is substitute the students in other class with appropriate class. This is due to the optimum use of energy in a room can be achieved if all electrical appliances are in use with room fully accommodated as per suggested number of occupancy. In addition, this paper shows the step to calculate the Energy Efficiency Index (EEI) based on energy consumed by lightings and air conditioning system and potential savings can be achieved when approach the method of Class Shifting. However, this paper only shows the data for power consumption in kilowatt hour. There are no studies about lux level for lighting system in this paper although the lux measurement is the most important things in order to know the illuminance of lighting and to implement the de-lamping to reduce energy usage.

2.2.5 Performance Evaluation of an Actual Building Air-Conditioning System

According to this paper [28], it discussed about the performance of air-conditioning in commercial buildings. The type of air-conditioning in the building are split unit, package unit and centralized air-conditioning systems. The purpose of this paper are discussed the performance of air-conditioning on actual building with reference to the MS 1525 and thermal comfort analysis among the occupants. These papers are collecting the data about relative humidity, temperature and COP. The recommended COP based on MS 1525 is 3.0. Other than that, this paper do not discussed about carbon dioxide although it is one of the main things to be considered in air-conditioning system.

2.2.6 Electrical Energy Audit in Malaysian University

According to this paper [30] discusses the process of energy audit in the Universiti Teknologi MARA (UiTM) Penang. The energy audit process was carried out only for lighting system and air conditioning system in the university. The energy consumption for the building is calculated depends on electricity utilization for one year. Hence, from the data taken during audit process, the auditors recognize the potential savings that can be implemented for lighting system and air conditioning systems. The auditors do the de-lamping and re-lamping for lighting systems, while the savings from air conditioning systems such as maintenance chiller evaporator and condenser piping and others. Besides, energy audit recognizes a few energy saving measures, capable to reduce energy waste and increase energy efficiency for electric equipment‟s. However, the studies are not cover about power equipment. Therefore, the power equipment is important in the energy audit process in order to know the energy usage and EEI in the building. Power equipment can be socket outlet, lab equipment, projector and monitor in the classroom.

CHAPTER 3

METHODOLOGY

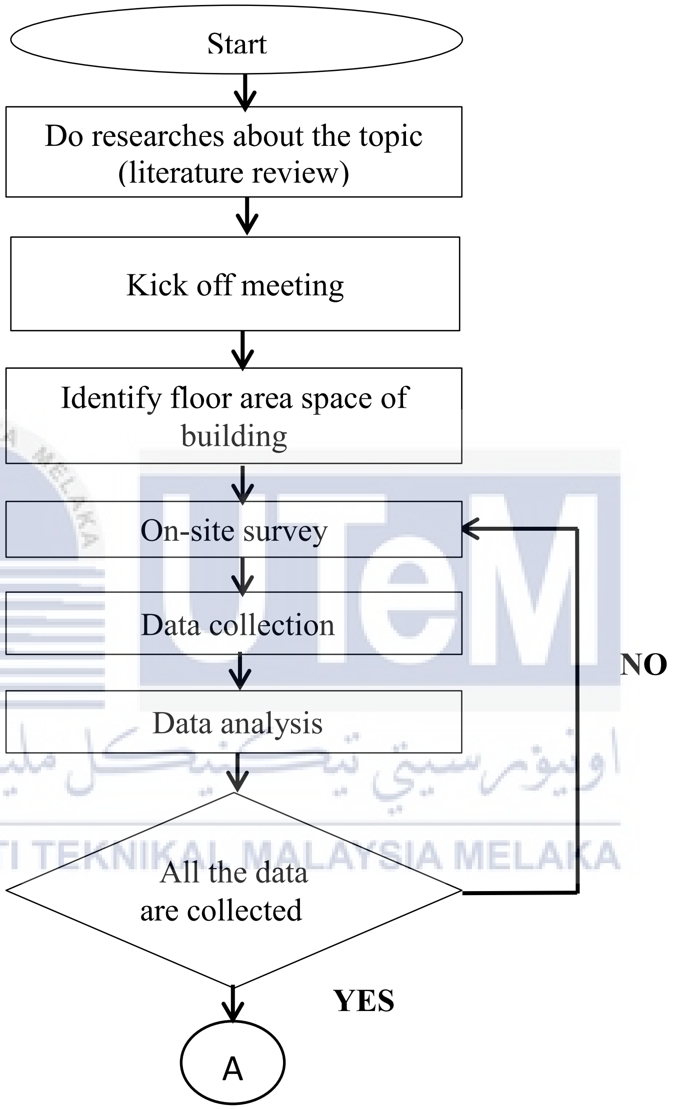
The proper methodology must be taken to make sure the energy audit process is successful. There are a few stages or procedures are used to attain the objectives of the project.

3.1 Introduction

Energy audit is a systematic measurement and practical inspection of energy use in a system or organization. Additionally, it used to recognize the necessary data and make sure that the data collected are dependable. The main data collected through an audit cover the air- conditioning area of the building, lighting, plug-in equipment (power) and energy consumption in the building. Then, the parameters measures for this process are lux level, relative humidity, temperature and carbon dioxide concentration in the building.

3.2 Principles of the methods or techniques used in the previous work

The intent of the project is to use the data collected to calculate potential saving and reduce the energy wastage at Factory 1.



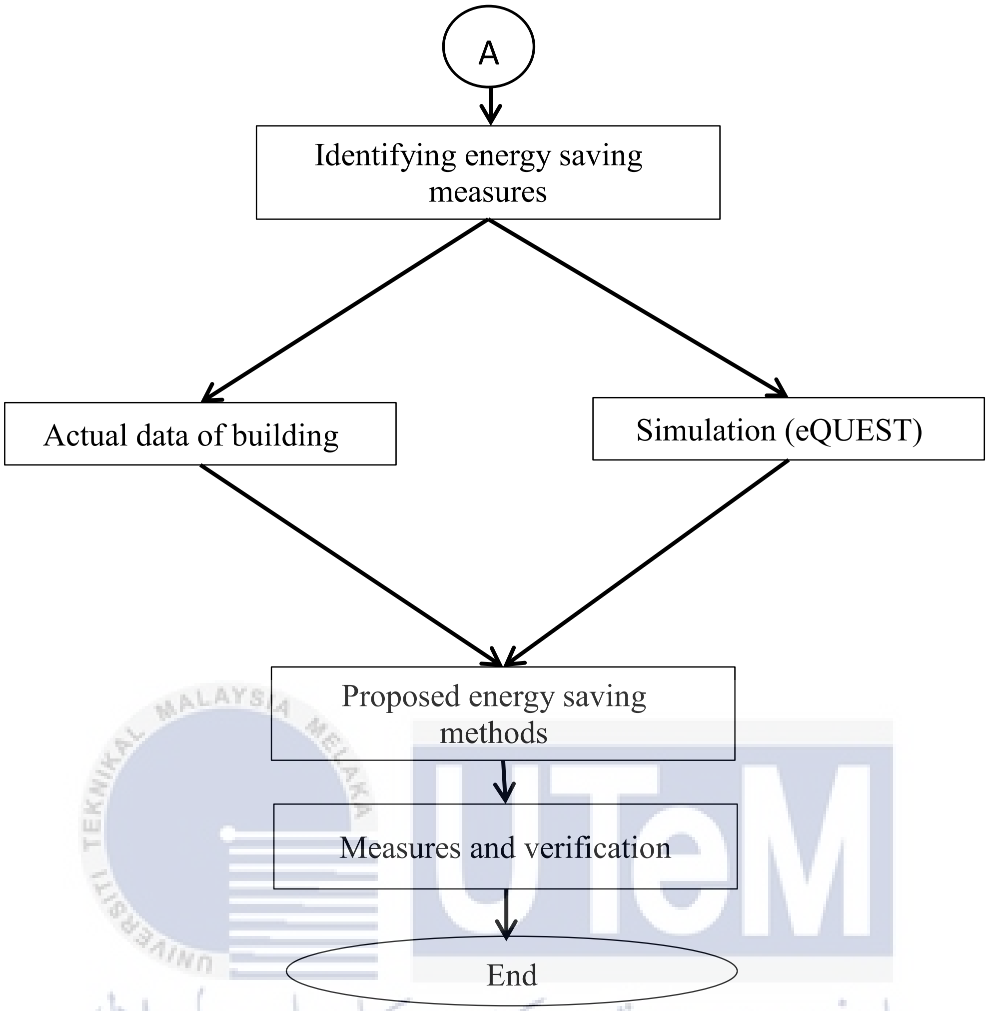


Figure 3.1: Flowchart for overall methodology

3.2.1 Do researches about the topic (Literature Review)

The initial part is accomplished by analyzed the latest finding that has been done by prior researchers which can be a recommendation and guideline in this energy audit process. The best technique or the most convenient method can be study in order to attain the best result. In addition many references are compiled in order to get the important information and fact about the topic. In this part, the focus is about to collect the data from the Factory 1 such as historical metering bills, maximum demand bill, energy consumed by lighting, air-conditioning, lab equipment and electrical equipment.

3.2.2 Kick-off meeting

The meeting with the supervisor and Neraca Niaga Sdn Bhd are held before further the audit process. This meeting purposely to brief about the energy audit process, to know the energy audit objectives and output and to become familiar with the company and the building. On the other hand, this meeting is held to get the confidentiality agreement and data format questionnaire and walk through audit at the Factory 1. The type of energy audit to be performed depends on:

a) Function and type of organization
b) Depth to which a final audit is needed
c) Potential and magnitude of cost reduction desired

3.2.3 Audit plan and schedule

After kick-off meeting, the auditor must plan further step for energy audit process. The things that must be planned such as need to have milestone and checklist for collect data.

Table 3.1: Gantt chart for energy audit planning

Activities	**Semester 1**					**Semester 2**				
	Sept	**Oct**	**Nov**	**Dis**	**Jan**	**Feb**	**Mac**	**April**	**May**	**June**
Literature review										
Kick of meeting										
Onsite survey										
Data Collection										
Data Analysis										
Identification of energy saving measures										
Presentation										
Final report										

Table 3.1 above shows the schedule during energy audit process at Factory 1, FTK. The process for energy audit is within 10 months.

3.2.4 Identify gross floor area space of building

After the planning are done, the next step is to get the layout and plan for the Factory 1 in order to know the types of the building, size of the building, and gross floor area space. To open the layout of the Factory 1, it needs to use the AutoCAD software. Based on this layout, the number of corridors, laboratories, toilets, Air Handling Unit (AHU) rooms and the location of the Main Switch Board (MSB) are recorded. The gross floor area for Factory 1 is 11 692 m^2.

Factory 1 is one of the laboratories used for students from Faculty of Technology Engineering, UTeM. This Factory 1 has one floor building and in rectangle shaped. This faculty consists of full time students in 2015 about 2365 students and 250 occupancy or staff. The operation hours for this building is from Monday to Friday and the class take place from 8.00 am until 6.00 pm while have an off-day at Saturday and Sunday. This faculty offers course in the area of Electricity and Electronic, Manufacturing, Technology and Communication.

3.2.5 On-site survey

According to the definition energy audit it is consists of three levels which are Level 1 (Preliminary audit), Level 2 (Detailed audit), and Level 3 (Investment grade audit). For this on-site survey step in Level 1 of energy audit phase and also called as walk through audit. During this steps, the inspection of the energy and utilities supply system are carry on. Example of the inspection such as note the location of the systems in the layout plan, list the process and utility areas to be checked and audited in detailed audit. There are several steps for walk through audit:

a) Measurement of the selected parameters
b) Data gathering and simple calculation

c) Understanding the process technology and its energy consumption
d) Identify of possible energy saving opportunities
e) Analyzing company records and energy balances

3.2.6 Data collection and analysis

During the site visit, the data are collected. There are many ways to get the data collection such as from desktop or computer, field and cross checking the load demand. There are the important things in the Factory 1 that need to collect and audit to make this process success:

a) Energy consumption by type of energy, by department, by major equipment.
b) Energy cost and tariff data
c) Sources of energy supply
d) Energy management procedures and energy awareness training program within the establishment.
e) Measure the lux level for lighting system, relative humidity, carbon dioxide and temperature.

There are several types of data can be collected at Factory 1, such as energy billing, lux level for lighting, number of lighting, performance of air conditioning and others.

3.2.6.1 Energy records

There are several types of energy records that needed when doing the audit process which are historical bill for past years which is from 2014 and 2015, log-books with daily, weekly or monthly records and maximum demand bill. Based on the on-site survey, this Factory 1 are using tariff E2 from TNB.

TARIFF E2 - MEDIUM VOLTAGE PEAK/OFF-PEAK INDUSTRIAL TARIFF	
For each kilowatt of maximum demand per month during the peak period	37.00 RM/kW
For all kWh during the peak period	35.50 sen/kWh
For all kWh during the off-peak period	21.90 sen/kWh
The minimum monthly charge is RM600.00	

Figure 3.2: Tariff use at Factory 1, FTK [31]

Figure 3.2 shows the Tariff use at Factory 1 which is Tariff E2 for medium voltage peak or off-peak industrial tariff. From TNB, the on peak hour is from 8 am to 10 pm while off-peak period is within 10 pm until 8 am. Below shows the calculation of energy usage:

$$\text{Energy (kWh)} = \text{Appliance Power (kW)} \times \text{Duration (hour)} \qquad (3.1)$$

3.2.6.2 Lighting

The energy audit data collection for lightings systems are measured based on type of lamps, watts and power consumed of the lamps, power and watt of ballast, illuminance of the area using the lux meter and operation time for Factory 1. The measurements for the lightings are taken for each laboratories, corridors, toilets and prayer rooms. On the other hand, the measurements for the lighting systems are done by using a power meter in order to get the load consumption.

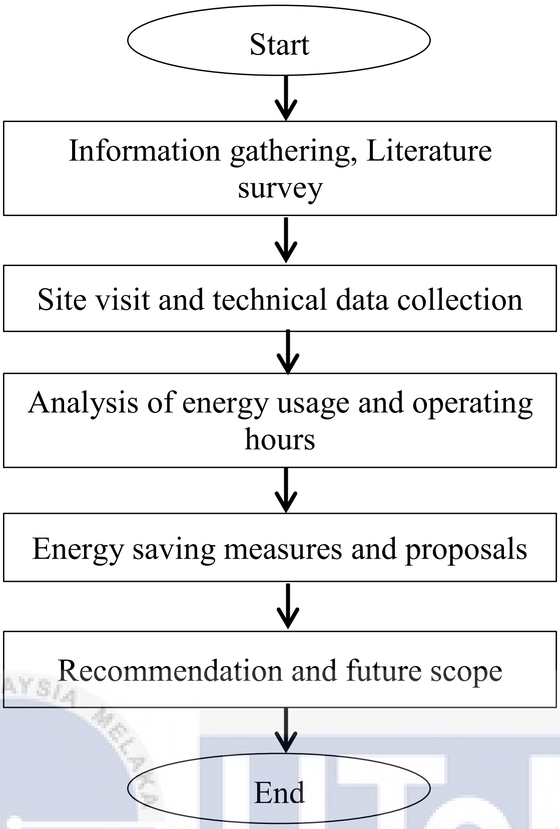


Figure 3.3: Flow chart of lighting for energy audit

Figure 3.3 shows the flows for auditing process for lighting. The information‟s are gathering such as type of lamps, comparison performance of lamps, effect of ballast to lamps and end use of lamps. Next, the site visit are perform at Factory 1 to collect the technical data such as numbers of lamps per laboratories, space of laboratories, type of control system for lamps, number of students used laboratories and illuminance of lighting (lux level). In addition, the number of operating hours and energy usage for lighting will be analyzed. After that, potential saving for lighting can be recognized.

The analysis for existing lighting system is performs at Factory 1 by site visit and technical data collection. Factory 1 consists of laboratories, corridors, toilets and prayers room. The laboratories are examined for work place including physical condition, its process, and occupancy time and energy consumption trend [32].

Figure 3.4: Recessed parabolic fluorescent (T12) with 2‟ fixture [33]

The room is divided by (1m X 1m) grid at height 0.85 m. The illuminance (lux level) is taken by using lux meter at different time of day. The Factory 1 is lit by almost all using recessed parabolic fluorescent (T12) with 2‟ fixture as shown in figure below.

a) Instrument use to measure lux level

In auditing process for lighting, the lux meter is use as an instrument to measure the lux level for the lighting in a specific area.

Figure 3.5: Lux meter [33]

Figure 3.5 above shows the lux meter use for measuring the lux level in the buildings. The lux level in the rooms is taken within three points which is right; center and left with all the lamps are ON condition. The higher of the lux meter during measuring is as higher as table. Then, compare the average of the measure lux level with standard MS 1525 for lighting

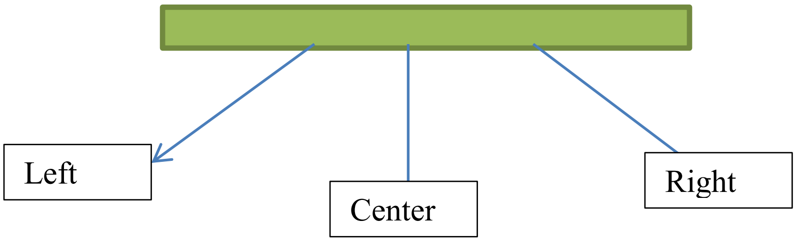


Figure 3.6: Three points for lux measurement

Table 3.2: Standard of lux level using MS 1525 [29]

Task	**Illuminance (Lux)**	**Example of areas**
Lighting for rare used area	100	Interior walkway, car park lift interior, corridor, passageways, stairs, store, locker, and staff changing room
Lighting for working interiors	200	Rare reading and writing
	300- 400	General office
	100	Toilet, bedroom, bathroom
	300-500	Class room, Library

This process is to identify the existing control system used at that factory. Hence, the areas that have very high or very low lighting levels are identified. Besides that, this process also to identify the factors that lead to visual discomfort that may slow down the productivity or compromise safety. In addition, the numbers of students and staff used the buildings and types of work being performed are needed to identify. It is important to know all the size and types of activities in the building in order to know the energy consumption pattern. It also important to check all work surfaces with a lux meter to establish existing lighting levels.

3.2.6.3 Air-conditioning

At the Factory 1, there are consists of three types of air conditioning which are split unit, centralized air conditioning system and Air Handling Unit (AHU). Energy audit process at Factory 1 are measure the energy consumed by the air-conditioning based on type of air conditioning, number of unit air conditioning in the building, operation hour per day, relative humidity and temperature of the rooms. Then, check the leakage and potential savings for the air conditioning. In addition, for relative humidity and temperature measuring it is using the specific meter.

Data gathering from AHU consists of temperature, air velocity and relative humidity for the supply air, return air and mixed air. The sum electrical load of the centralized chiller at building is gotten from considering the electric utilization of the compressor and blower of the refrigeration plant was acquired from the electric usage of the cooling water pumps and cooling tower fan. The electrical power input for the compressor and blower of the refrigeration plant was acquired from the distribution board in the AHU rooms. The electrical power input for the cooling water pumps and cooling tower fans was acquired from the cooling tower building. A comparable figuring and examination were additionally utilized for the individual split units [28].

a) Parameters measure for air-conditioning

Thermal comfort is intent by the room‟s temperature, relative humidity and air velocity. There are numerous extra elements, for example, activity level, clothing, age, gender and health status that influence the comfort. Radiant heat (hot surfaces) or radiant heat loss (cold surfaces) are additionally critical elements for thermal comfort. Basically, the thermal comfort also known as a user or occupier feels satisfied with the thermal environment. People feel uncomfortable when they are too hot or too cold, or when the air is smelly or odorous and old.

i) Relative humidity

Relative humidity (RH) is a measure of the wetness in the air, contrasted with the potential saturation level. Hot air can carry more wetness. If the server room is excessively moist, condensation can build on computer and electric parts and lead them to short out. Likewise, high humidity can produce condensation to form on the coils of a cooling unit, making it to work harder to free itself of the condensation, which in turn can cause to waste cooling, also called latent cooling, and that expenses cost. Meanwhile, if the humidity is too low, server room can encounter electrostatic discharge (ESD). That kind of occasion can make electric tools short and possibly damage it.

ii) Air temperature

The heats are measured by the air temperature. The ambient air heats are measured by thermometers. However, cold surfaces or gain is also essential. Hot surfaces may not be consider in the air temperature, but is the effect of cold or hot objects in the area.

Relative humidity and air temperature are measure because it is relate to thermal comfort at the building. In addition, if the thermal discomfort, the occupier will complaint and this will affect the production at the building. Relative humidity recommended by standard MS 1525 within range 55% -70% while for temperature are within 23 ^{O}C- 26 ^{O}C [31].

In order to increase the thermal comfort for occupants, the standard must be follow to avoid the rooms too hot or too cold. The relative humidity (RH) and temperature can be measure by using Temperature Humidity meter.

Figure 3.7: Temperature Humidity meter [34]

Figure 3.7 shows the one of the instrument use to measure RH and temperature for indoor and outdoor. The meter shows the value of RH in percentage while for temperature is in degree Celsius. The RH and temperature are measure for each laboratories, corridors, toilets and rooms. Then, the average measure value is compare with MS 1525 standard.

3.2.6.4 Carbon dioxide

Carbon dioxide (CO_2) is the major greenhouse gas emitted by human activities. Carbon dioxide is naturally available in the atmosphere as partially of the Earth's carbon cycle (the natural circulation of carbon among the atmosphere, oceans, soil, plants, and animals). While CO_2 emissions come from several of natural sources, human associated emissions are responsible for the rise that has happen in the atmosphere since the industrial revolution. Carbon dioxide emission through electricity used to power homes, business, institutional and industry.

According to the statistic from United States Environmental Protection Agency (US EPA), the combustion of fossil fuels to generate electricity is the largest single source of CO_2 emissions in the country, accounting for about 37% compare in transportation, residential and commercial and industrial [39] . By follow the ASHRAE standard, the carbon dioxide concentrations found in the building is not a direct health risk but it can be used as an indicator of occupants‟ acceptance of the odor. The steady-state CO_2 concentrations for typical office buildings about 700 parts per million (ppm), while for spaces housing within 1000 to 1200 ppm. Besides that, the CO_2 concentrations in outdoor air are usually between 300 to 500 ppm [35].

3.2.7 Identifying energy saving measures

In order to identify energy saving measures in the building, there are two types of methods use to analyze the building‟s performance which is actual data (data collection) of building and simulation using eQUEST software.

The data are analyses in monthly electricity consumption, load apportioning per month, annual specific electricity consumption, annual operational costs distribution in the building and energy efficiency index (EEI) for building. Based on this analysis, the actual data in building are compared with simulation (eQUEST).

3.2.7.1 Actual data of building

For this step, the energy consumption is analyzed using a various method. The data from this building are getting from energy consumption per year for 2014 and 2015. The data for September 2014 until September 2015 are required from Neraca Niaga Sdn Bhd. (NNSB) meanwhile for October 2015 until May 2016 are required from energy meter that installed at Factory 1. Hence, for the data June 2016 until September 2016 is the estimated data after the implementation. This required data can be analyses using monthly time chart. To get the actual data in Factory 1, the energy meter are installed to record the lighting trend and energy consumption of the plug-in equipment. The plug-in equipment is printers, projector and computers.

Next, the collected data will be analyze to identify opportunity manage energy, maintain thermal and lighting comfort and analyze cost. The cost analysis review present energy costs, measure implementation costs and potential savings over time assist to decide practicality and preferences of energy saving suggestions [34].

3.2.7.2 eQUEST software

The main purpose of this method is to develop a base case model that represents the existing energy use and operating conditions in the building. This model is to be used as a reference to estimate the energy savings incurred from appropriately selected energy conservation measures.

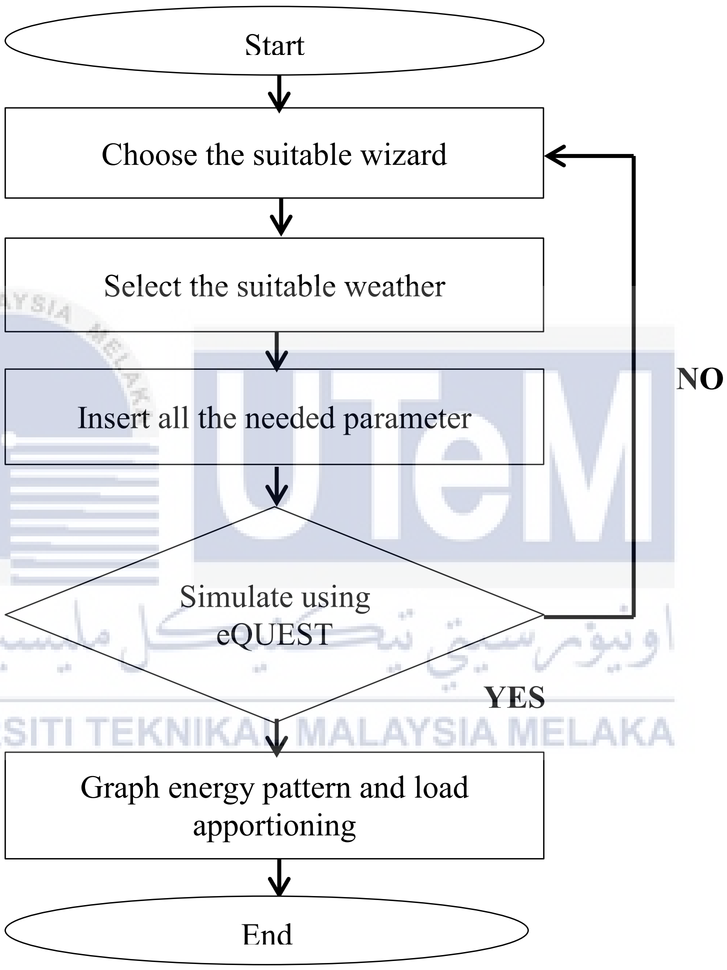


Figure 3.8: Flow chart for eQUEST software

Figure 3.8 above shows the steps for analyze data using Quick Energy Simulation Tools (eQUEST) software. This computer simulation program is used to simulate the building‟s thermal performance. This program helps with analyzing the individual cost of implementation each of the recommendation. The capabilities of this program and simulation tools make this approach very efficient and allow the climate to be considered without any simplification.

Figure 3.9: Types of wizard in eQUEST sofware

To start up using this model, user needs to create a new file and choose the suitable wizard which is Schematic Design Wizard or Design Development Wizard.

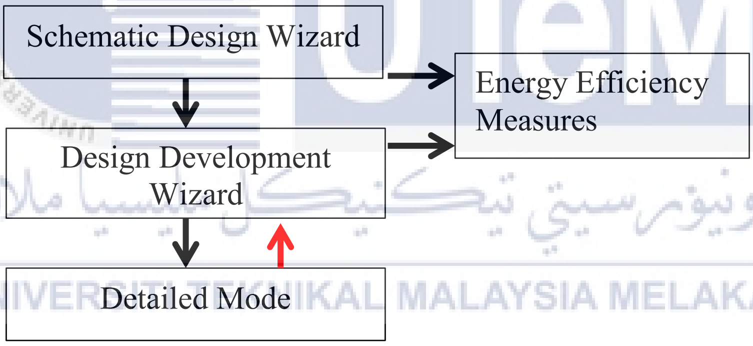


Figure 3.10: Wizards in eQUEST

Figure 3.10 shows the types of operations for wizards in eQUEST. It is possible to convert from wizards with less detail to more detail descriptions of the building. All the available parameters can be defined and changed according to definitions contains in the detailed mode. Once in detail mode of eQUEST, the user can convert back only to Design Development Wizard (DDW) and will lose any detailed information modified within the detailed mode [37]. There are a few differences between Schematic Design Wizard and Design Development Wizard which are as follows:

Table 3.3: Differences between two wizards

Schematic Design Wizard	**Design Development Wizard**
Single shells buildings	Multiple shells buildings
Less options	More options and more inputs

The inputs of this software are divided into 5 sections to make it more friendly used and organized as follows:

a) Building data – Include the project name, building type, location of the building, building area, weather. For the weather, the user needs to download the weather file from EnergyPlus Software and selected the specific weather for the area.

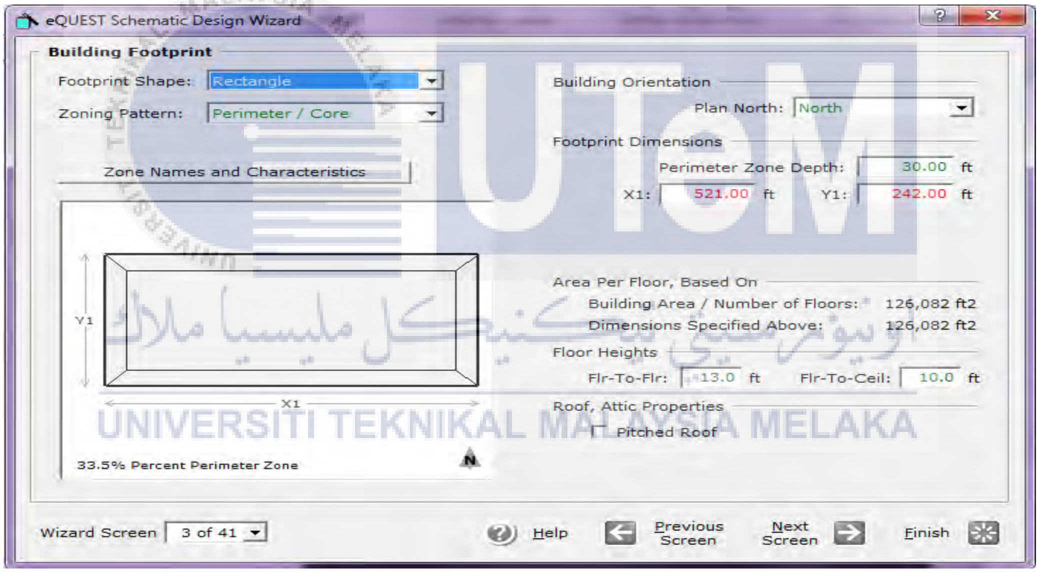


Figure 3.11: Building footprint

Figure 3.11 shows that the types of input need to be filled in the software. In this page, user can load building drawing from AutoCAD software. In the general information, user needs to enter the diameter for building in square feet

b) Building envelope constructions – Include the materials for roof surfaces, ground floor, constructions for above grade walls, exterior door, exterior windows and roof skylights.

c) Activity area allocations – Include area type of buildings such as classroom, laboratories, percent area, design maximum occupation (square feet per person), Design Ventilation, occupied loads by activity area, unoccupied loads by activity area, main schedule information.

d) Thermal Load Consumption data – Include HVAC system definitions, HVAC zones (temperature and air flow), packaged HVAC equipment, HVAC system fans.

e) Electric Utility Charges – Include the custom electric rate which is electric usage and maximum demand. This data can be required from Neraca Niaga Sdn Bhd. The data for electric usage can be analyses for monthly usage and annual.

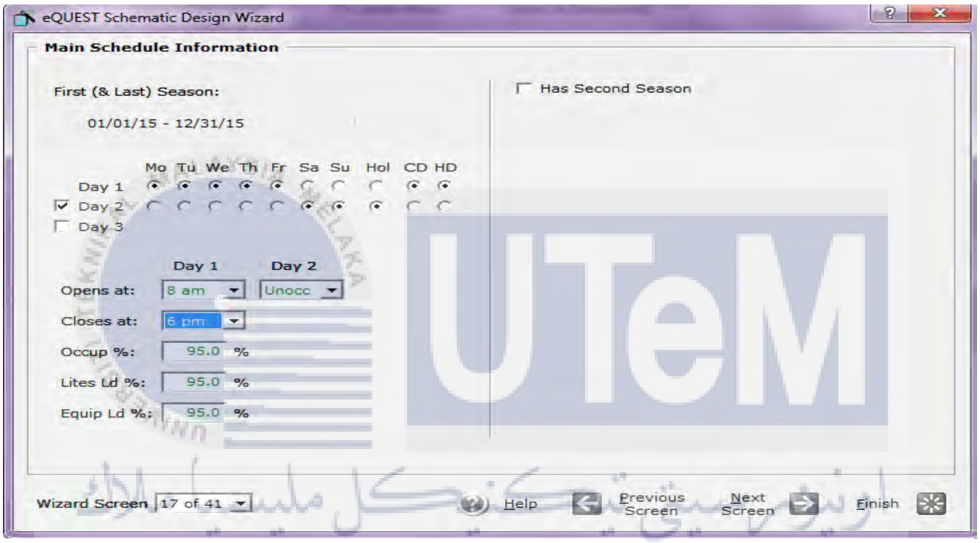


Figure 3.12: The schedule information of the building

Figure 3.12 shows the input need to insert for main schedule information. For Factory 1, it operates on Monday to Friday from 8 am until 6 pm while off day at Saturday and Sunday.

The output from this software is baseline design, monthly electric consumption, load apportioning, whole building energy efficiency measures, annual energy consumption and monthly peak demand.

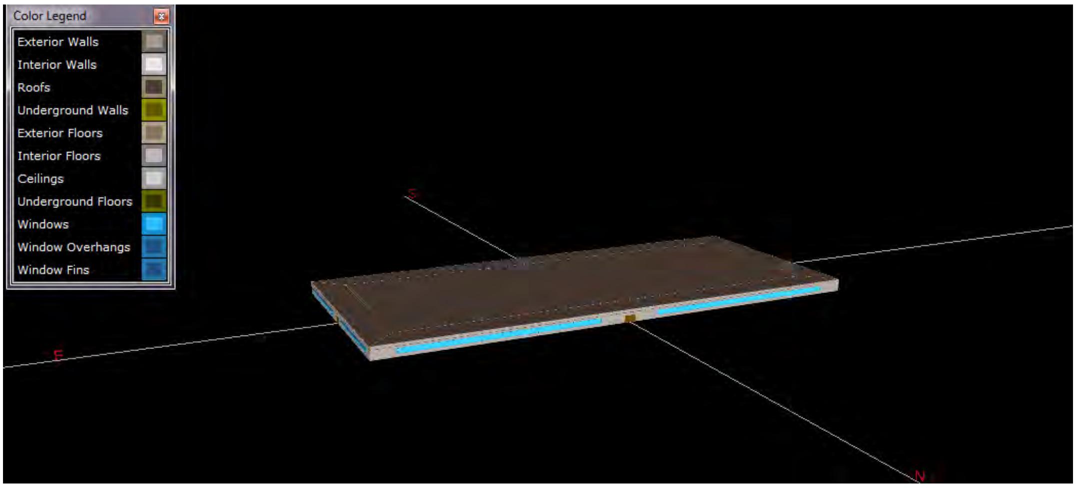


Figure 3.13: The 3D schematic diagram for Factory 1

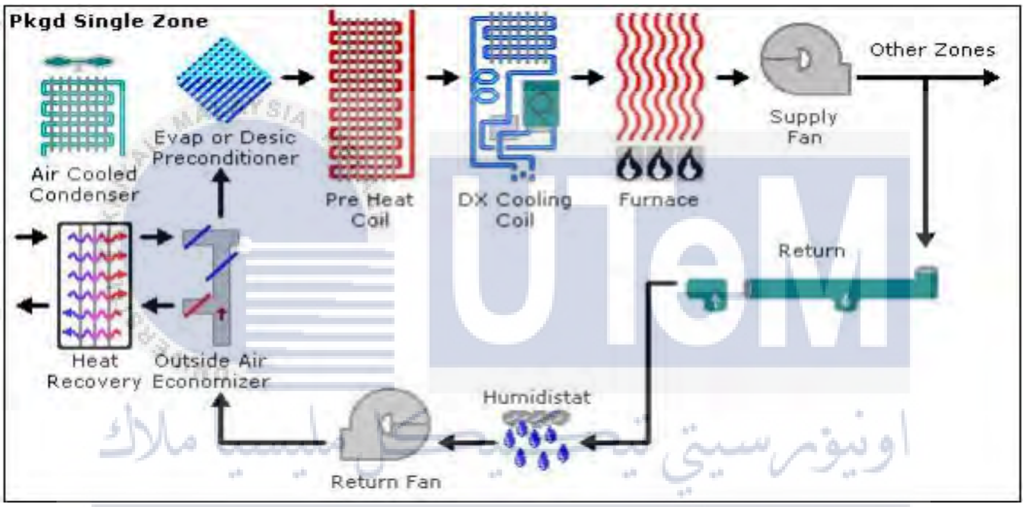


Figure 3.14: Output for air loop in eQUEST simulation

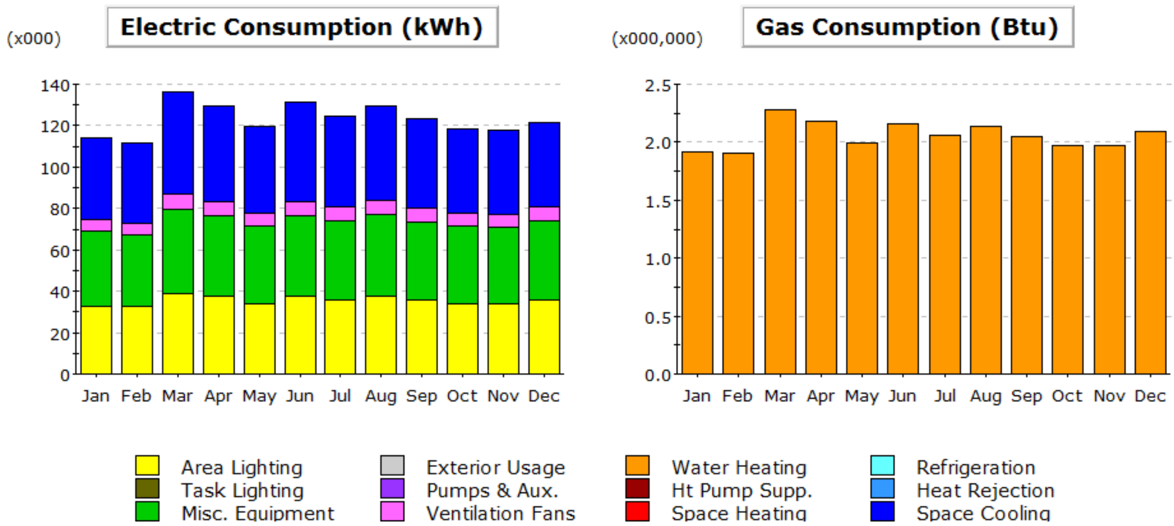


Figure 3.15: Output for baseline design

Figure above shows the example of output produced by the eQUEST simulation. For Figure 3.13 shows the 3D schematic design and For Figure 3.14 about the HVAC system design. Meanwhile for Figure 3.15 shows the baseline design which is electric consumption and gas consumption for 12 month.

3.2.8 Proposed energy saving methods

After identifying the energy saving measures by using two methods which is from actual data and simulation, the energy saving methods are proposed to reduce the energy consumption and increase the potential savings in the buildings.

These steps are divided by three parts of energy saving measures which are no cost, low cost and high cost. For no cost, the energy saving can be saved without using money and budget such as user awareness, repair leaks, fine-tuning of building services and reschedule load or usage. Hence, for low cost measurement it only need low budget such as cooling system improvement, lighting system and technology improvement, monitoring and targeting, housekeeping and insulation. Meanwhile, for high cost energy saving measurement it involves high budget with time such as equipment technology change, system change and cogeneration [8].

3.2.8.1 Propose energy saving method for lighting system

The lighting system used in the buildings mostly use T12 and T8 fluorescent lamp tubes of 36W and 18W and regular inefficient high power magnetic ballast. Next, shortage of energy saving awareness which is the lighting is not turned off when area is over lit and nobody was in public zone and in toilets. Due to these problems, there are ways to increase the lighting system efficiency and decrease the energy consumption.

a) **De-lamping:** Reduce power and luminance. For example to evacuate needless light bulbs/fixtures in areas that are producing greater luminance than standard illumination. At Factory 1, it is using 2 tubes in one reflector so reducing the number of lamps can save up to 50% in lighting energy. The good opportunities for de-lamping are in toilets, kitchen office, corridors and near windows in buildings not used at night.

b) **Re-lamping**: Replacing inefficient type of lamps to high efficient lamps. For example, replacing T8 lamps to T5 lamps or/and LED lamps including electronic ballast.

c) Utilization of signage and automatic lighting control systems, for example, sensors for area where lights were turned off when range is over lit and no students in classrooms, laboratories, rooms and toilets. Thus by attached signage's to create awareness and help change to switch off lights, sensors and automatic control frameworks which consequently switch off lights in unused areas generous electrical energy can be spared [30].

3.2.8.2 Energy saving method for air conditioning system

There are several recommendations to save energy for air conditioning such as maintenance of chiller evaporator and condenser piping, check the air leakage at the tubes or dirty filters which restrain the air flow, replace inefficient compressor with high efficient compressor and retrofitting the chiller if fails to maintenance with high efficient compressor. Next, reset the operation of centralized air-conditioning system to follow the standard (MS 1525 23^{o}C – 26^{o}C) . This step will reduce the energy consumption by air-conditioning.

3.2.9 Measures and verification

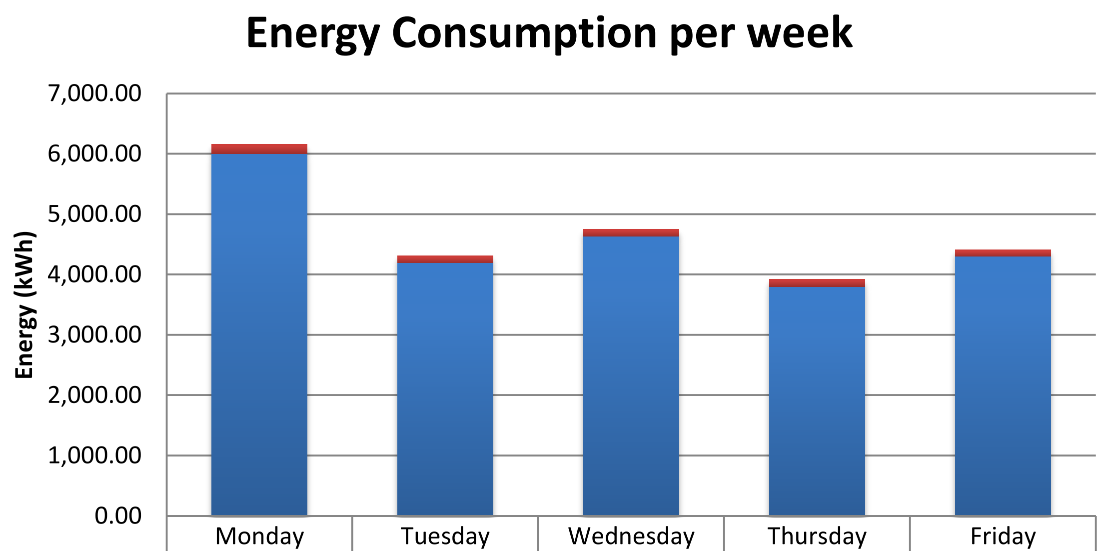
M&V is an objective process for quantifying energy savings achieved through the implementation of Energy Efficiency Measures (EEMs). The process involves measuring and verifying pre - and post-implementation energy use, and adjusting for any salient changes in conditions. The M&V are important to accurately determine how much energy has actually been saved. This can be done in part through metering and sub-metering of facilities and equipment [36].

CHAPTER 4

RESULT & DISCUSSION

4.1 Data collection

The data collection used for analysis performance at Factory 1 such as historical bills (year 2014), schematic diagram for lighting and air conditioning and performance of the lighting, air conditioning, electrical equipment and lab equipment. From the historical bills, the annual energy consumption for Factory 1 is calculated. The collected data are from September 2014 until September 2015 are required from Neraca Niaga Sdn Bhd (NNSB) and data from October 2015 until May 2016 are required by energy meter that installed at Factory 1.



	Monday	Tuesday	Wednesday	Thursday	Friday
Off-peak	156.29	120.43	121.32	118.08	105.26
On-peak	6,003.00	4,192	4,632	3,802	4,302

Figure 4.1: Graph on-peak and off peak energy consumption in one week

Figure 4.1 shows that the graph energy consumption for on-peak and off-peak period in one week. The on peak period start from 8.00 am until 10.00 pm, while the off-peak period from 10.00 pm until 8.00 am. The off-peak period is during at night and it consumes only a small energy usage because there is no machine running, air-conditioning is switch off. But, there are still have energy usage during this time which comes from lighting, emergency exit signage, and miscellaneous equipment. Based on the graph above, Monday is having the highest energy usage during on-peak which is 6,003 kWh.

4.1.1 Trend energy consumption year 2014 and 2015

The historical bills in year 2014 and 2015 are collected from Neraca Niaga Sdn Bhd. The energy billings are collected monthly until one year. Then, the collected data for historical bills are tabulated in Table 4.1 below. The TNB tariff using at this factory is Tariff E2 which is RM 0.355 per kilowatt-hour during peak hour and RM 0.219 during off peak. From TNB, the on peak hour is from 8 am to 10 pm while off-peak period is within 10 pm until 8 am.

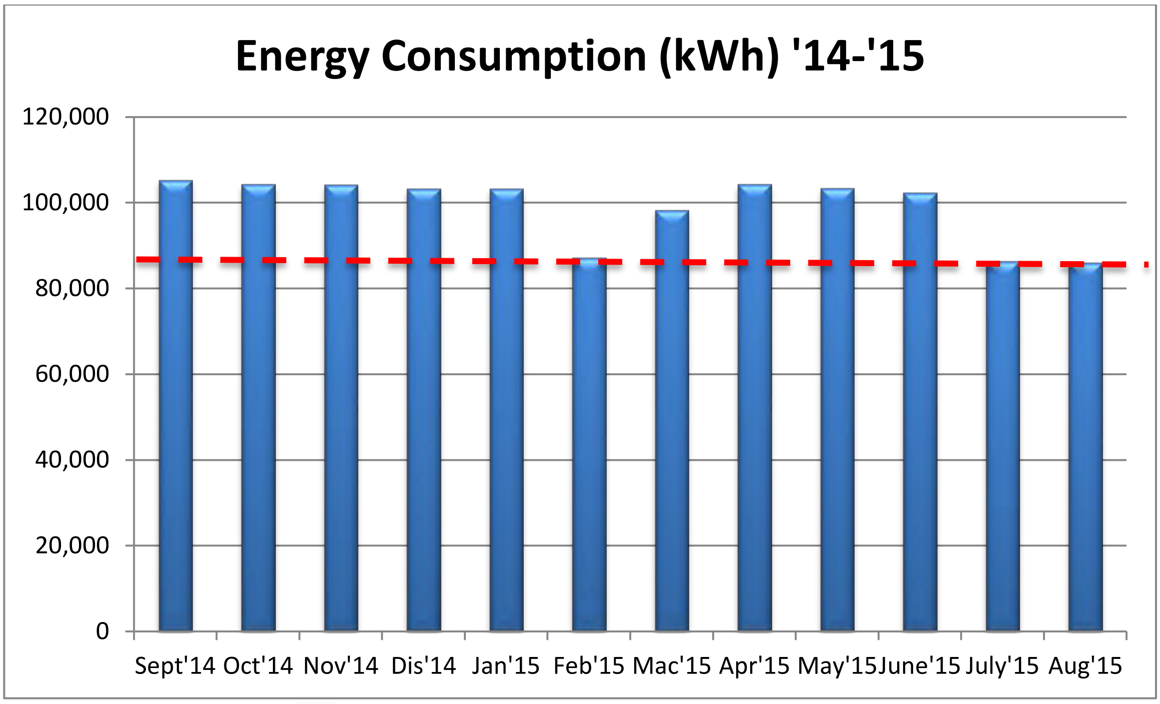


Figure 4.2: Graph for energy consumption year 2014 and 2015

Figure 4.2 shows the graph for monthly energy consumptions in 2014 and 2015. The utility bills are reviewed for 12 month period from September 2014 until August 2015. This collected data are used for all calculations and for purposes of benchmarking the building. The dashed in red are represent the lowest energy consumptions. Besides, the red dashed approximate base load or minimum electric usage required to operate at Factory1.

The total annual energy consumption from September 2014 until August 2015 is 1, 118, 215 kWh with total amounting RM 398 124.10 with average monthly electricity bill RM 33 177.00. From the graph in Figure 4.2, it shows that the monthly electricity usages are reduced at February, July and August but has increment for other month. This is because, during that three month, the faculty are having semester breaks. Besides, for other month it is having an academic session.

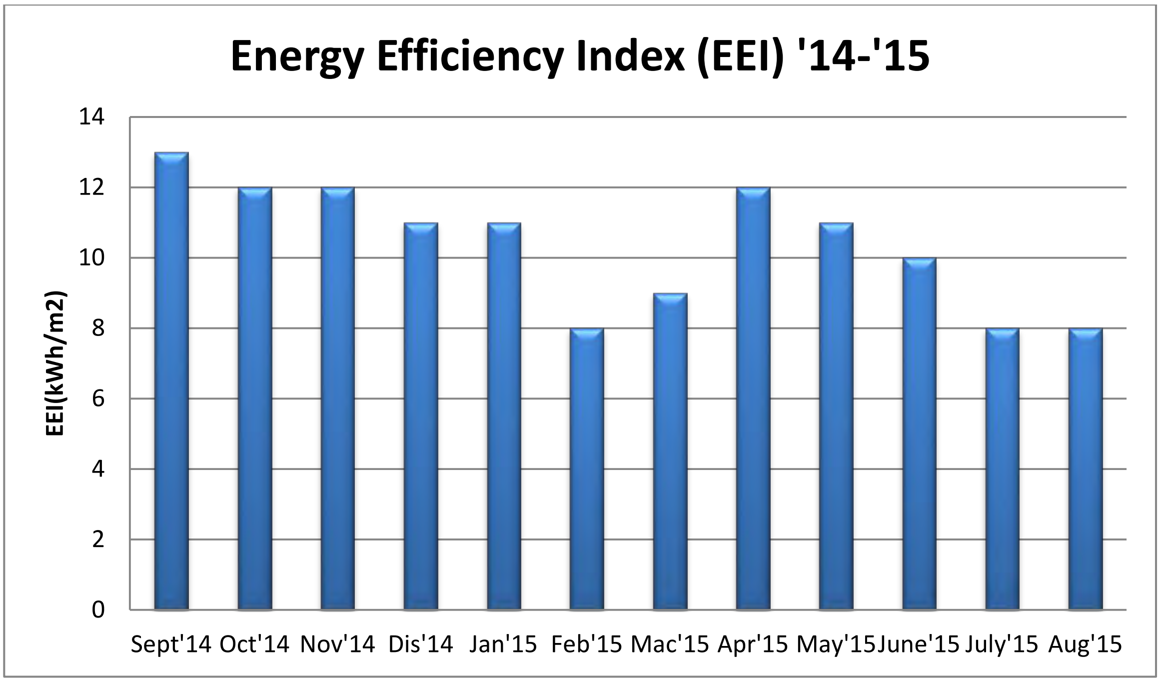


Figure 4.3: Graph for Energy Efficiency Index (EEI) year 2014 and 2015

Calculation of Energy Efficiency Index (EEI):

Average of Energy (kWh) in 1 year = 99 017.92 kWh

Estimated total Energy (kWh) for 1 year

= 99 017.92 x 12

= 1 188 215 kWh

Total Energy (kWh) ÷ gross floor area

= 1 188 215 ÷ 11 692 m²

= 125 kWh/ m2/year

Energy Efficiency Index (EEI) for 2014 and 2015

= 125 kWh/ m²/year

Figure 4.3 show the Energy Efficiency Index (EEI) for Factory 1 in September 2014 until August 2015. The data are collected in monthly for a year. From the graph, it shows that February, July and August have the lowest EEI than other month due to the semester break. From the calculation of Energy Efficiency Index (EEI) for Factory 1 in 2014 are 125 kWh/ m²/year. The best EEI practice and recommended by Malaysian

Standard is 135 kWh/m^2/year. The building of Factory 1 is still in the recommended standard by Malaysian Standard.

4.1.2 Trend energy consumption year 2015 and 2016

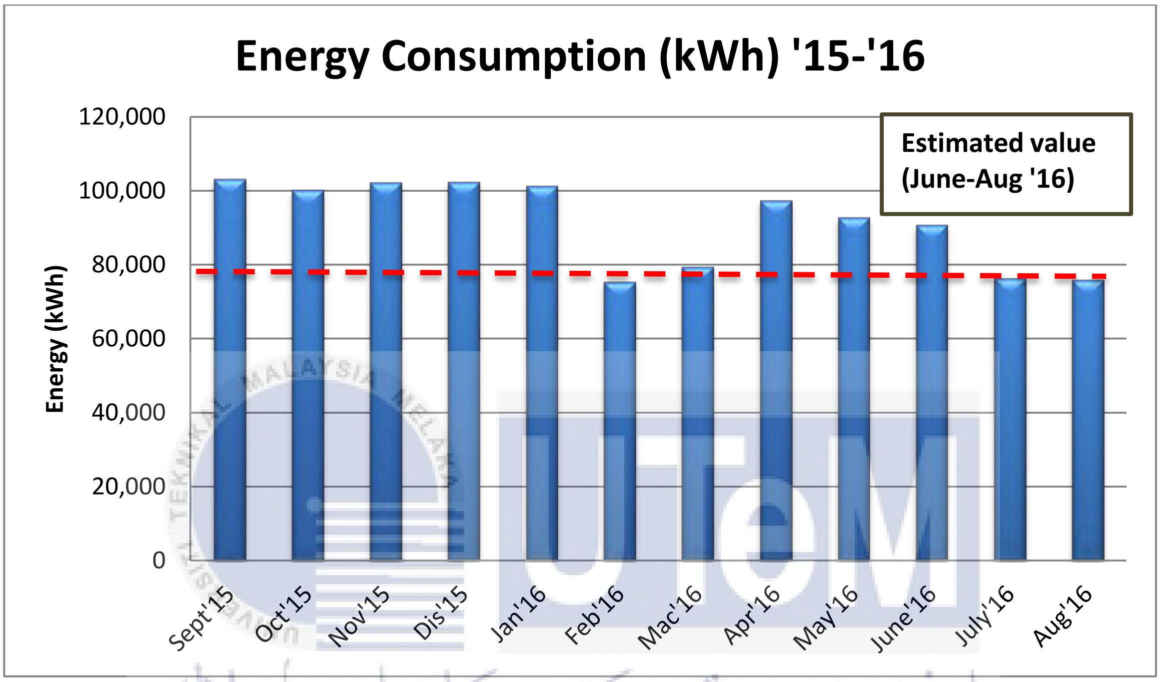


Figure 4.4: Graph for energy consumption year 2015 and 2016

Figure 4.4 shows the graph for energy consumption in 2015 and 2016. The analysis of electricity consumption is based on monthly summary report in one year which is from September 2015 until August 2016. According to the figure above, the total annual energy consumption for Factory 1 are 1,097,704 kWh with amount of total cost RM 371 561.70 with average monthly electricity bill is RM 30 963.48. It was observed that the monthly energy usage in February 2016, July 2016 and August 2016 have the lowest energy usage among another month. This is because, at February, July and August the faculty are having the semester break. For other month, the energy consumption is slightly decreasing until the end of August 2016 due to effect of implementation Energy Efficiency practices in the Factory 1. The implementation period is from November 2015 until May 2016. Next, in June 2016 until August 2016 is estimated value of energy consumption per month. This is because, the data collected only at May 2016. For the next three month, it is estimated that the energy consumption is still decreasing because of semester break at July and August and also effect of implementation energy practices. The highest energy usage is in September 2015 with 103 212 kWh which it was the beginning of the new academic session.

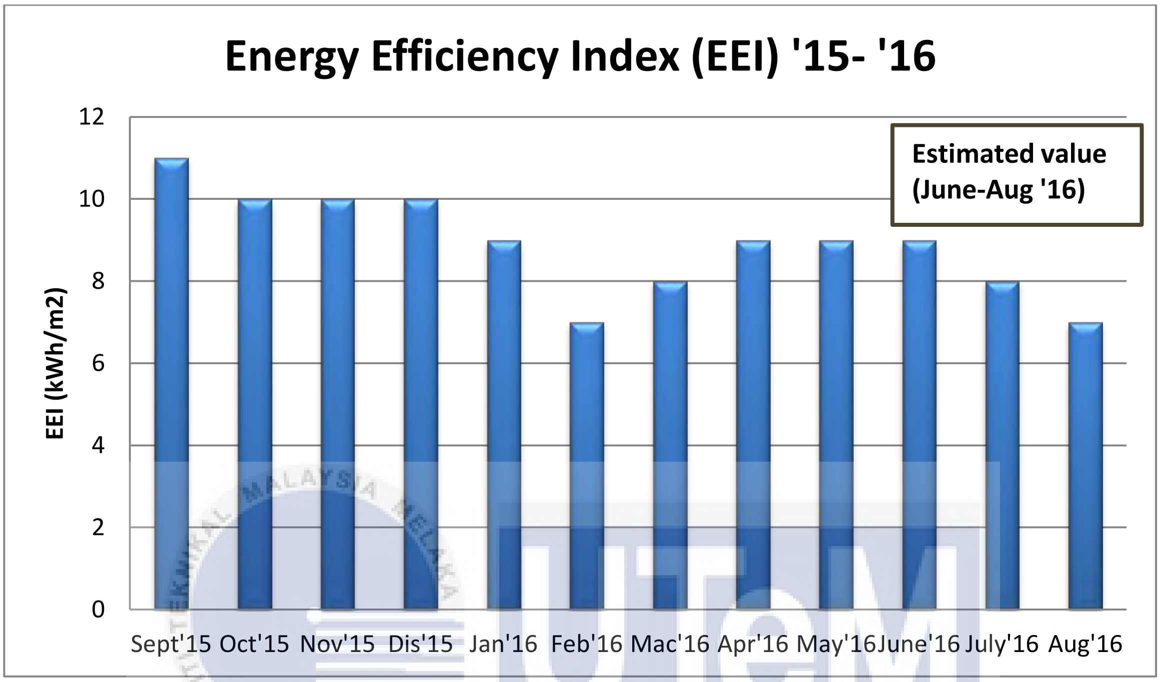


Figure 4.5: Graph for monthly Energy Efficiency Index (EEI) for 2015 and 2016

Calculation of Energy Efficiency Index (EEI):

Average of Energy (kWh) in 1 year = 91 475.33 kWh

Estimated total Energy (kWh) for 1 year

= 91 475.33 x 12

= 1 097 704 kWh

Total Energy (kWh) ÷ gross floor area

= 1 097 704 ÷ 11 692 m²

= 110 kWh/ m2/year

Energy Efficiency Index (EEI) for 2015 and 2016

= 110 kWh/ m²/year

Figure 4.5 shows the graph for Energy Efficiency Index (EEI) for year 2015 and 2016. The data are calculated for 12 month in one year. Based on the graph above, it shows that February, July and August are have the lowest EEI due to the semester break meanwhile, for other month are also having deficit in EEI due to implementation of Energy Efficiency strategies at the Factory 1 start from November 2015 until May 2016. For the rest three months, which is June, July and August 2016 are estimated EEI value based on the percentage of decreasing of energy consumption per month after implementation period. The total annual EEI for 2015 are 110 kWh/ m^2/year lower than EEI in 2014 which is 125 kWh/ m^2/year. The EEI for 2015 are in best practice and below from the EEI Malaysia Standard which is 135 kWh/ m^2/year. EEI is currently used as indicator in the building for measuring energy performance. EEI is important to determine the specific building"s energy performance in term of energy efficiency. By referring to Malaysia Standard, the lower the EEI value, the building is in the best performance.

4.1.3 Energy consumption patterns in 2015

Table 4.1: Energy Usage in Factory 1 (FTK) in one month

Parameters	Total Energy Usage per month (kWh)
Lighting	10456
Electrical Equipment	11950
Lab Equipment	21724
Air Conditioner	52716.8
Others	1799.2
Total :	**98646**

Table 4.1 shows average energy consumption for Factory 1 in one month. This data are collected from September 2015 until May 2016. The data are collected using the power meter and based on the capacity per unit watt for the equipment. The audit process at this building is focus on performance and energy usage for lighting, electrical equipment, air conditioning and lab equipment. Meanwhile for others equipment are stands for plug in equipment such as personal laptop, charger hand phone, water cooler and etc. The measurements of this load are by using the power meter, number of equipment use, operation hours, and capacity per unit watt of the equipment.

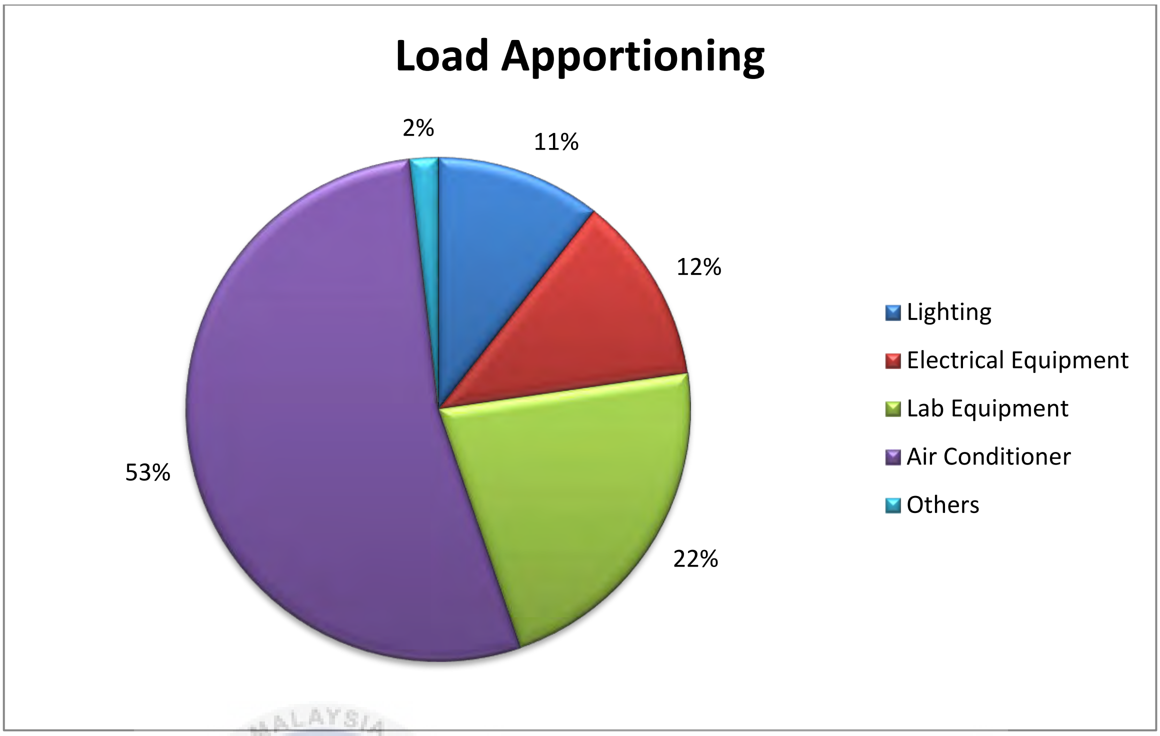


Figure 4.6: Load apportioning for equipment in Factory 1

Figure 4.6 about percentage load apportioning used by the equipment in Factory 1. From the figure above, the largest amount of energy (53%) is consumed by the air conditioning while the lab equipment in second place with 22%. Next, the third largest amount energy consumes is from electrical equipment with 12 %, then follows by lighting (11%) and others (2%).

The air conditioning systems consumes the highest energy due to the consistency of operating hours. Besides that, Factory 1 using one chiller, 15 split unit air conditioner and Air Handling Unit to serving the whole building for 8 hours in a day. The cooling of the building provided by chilled water from the plant and use high of energy. Besides, the centralized air conditioning is running without stopping for 8 hours a day. Moreover, another factor that draw the higher energy consumes by air conditioning is number of occupants who are number of students and staffs. This occupants behavior play an important role in specify the energy consumption for air conditioning. For example, too many students used the room and laboratories at one time (exceed daily activity per day) and make the students not having a thermal comfort. These situations can be overcome by lower the temperature in the rooms and it will increase the energy consumptions for air conditioning.

Second highest energy consumption is lab equipment. Lab equipment consumes high energy due to large power equipment used in the laboratory such as wire cut machine (3000W capacity per unit), plastic injection moulding machine (3000W capacity per unit) and Robotic Arm Kits (5000W capacity per unit). This factory has 34 laboratories which consist of mechanical, electrical, manufacturing, technology and telecommunications lab. On the other hand, the operation hours for laboratories are not fixed. The usages of laboratories are according to the student‟s schedule.

Next, energy consumes by lighting and electrical equipment is almost the same which are 11% and 12% respectively. Although the Factory 1 are using hundreds of light with recessed parabolic 2‟‟ fixture (T 12 fluorescent lamps), the whole lighting systems still consumed least amount of energy compare to air conditioning systems, lab equipment and electrical equipment. This is because the lights only consume a small energy (capacity per unit). On the other hand, the energy consumes by electrical equipment come from projector, printer and PC Computer in every laboratory.

Energy utilization for lab equipment and air conditioning account for a larger proportion of building energy consumption, thus having high potential of energy saving. Thus, the energy saving methods are proposed for air conditioning systems to be implemented aimed at reducing energy utilization and energy cost in buildings. For example, windows and exterior doors should not be left open while the air-conditioning is running and increase the temperature of the air-conditioning based on the thermal comfort which is not too low and not too high.

4.1.4 Parameter measure

There are four parameter measures in Factory 1 by using specific meter. These parameters are measures for 34 laboratories, 9 corridors, toilets and other rooms. This parameter measures to identify the condition of the building and determine the potential savings. Next, the proposed methods for increase the thermal comforts in the building are discussed below.

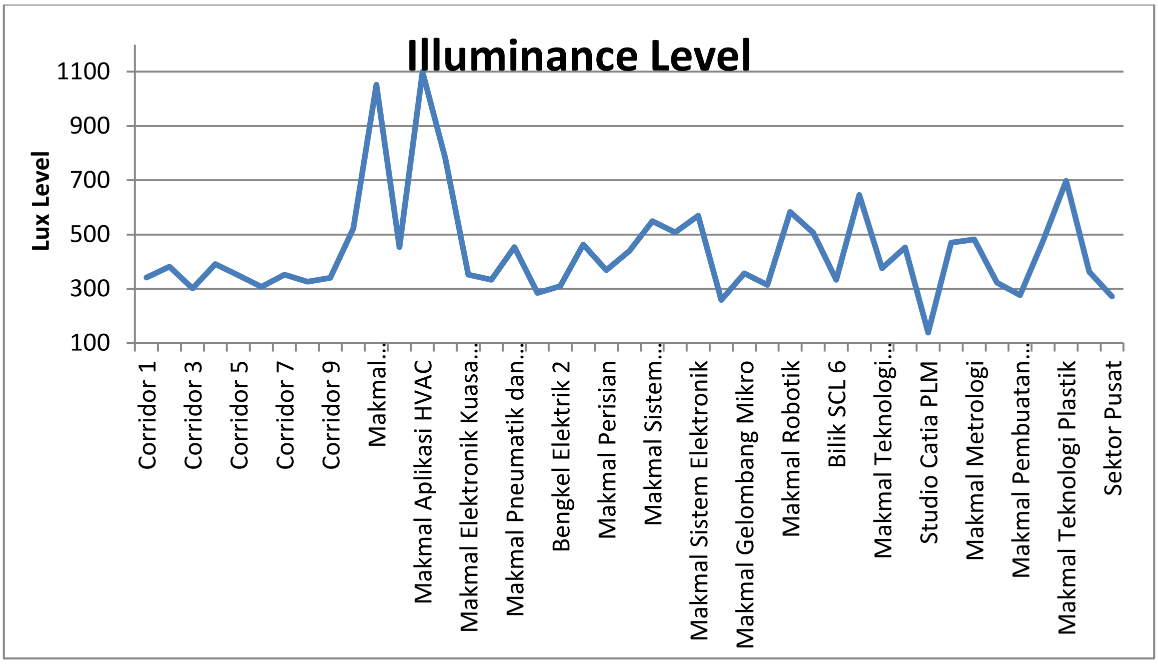


Figure 4.7: Graph for Illuminance Level (lux) at Factory 1

Figure 4.7 shows the graph for lux level for Factory 1, FTK. This Factory 1 is using the T12 fluorescent lamps with 36 W and ceiling recessed 2" fixture also have an emergency lights with 18 W per unit capacity. The lux level is measure based on three points, which are right, center and left. Then, the average of the measure lux level is compare with standard lux level (MS 1525). The average measure lux levels for nine corridors are between 300 to 400 lux. On the other hand, the standard for the lightings for corridor are between 100-150 lux, and for laboratory are between 300-500 lux. Besides that, the average lux (measure) for laboratories is between 300 to 700 lux but there are two labs achieve the highest lux level with 900-1000 lux.

This statement shows that, all 9 corridors and there are a few laboratories are in over lit and need to do the de-lamping and re-lamping to decrease the energy wastage. Besides, the de-lamping is reducing the illuminance and the power usage. For example, reduce the number of lamps that place near the windows because it has daylight that act as natural lamps and having a timer or light sensor at the corridor. Besides that, change the T 12 to T8 or T5 fluorescent lamps which are more efficient and low energy usage than T12.

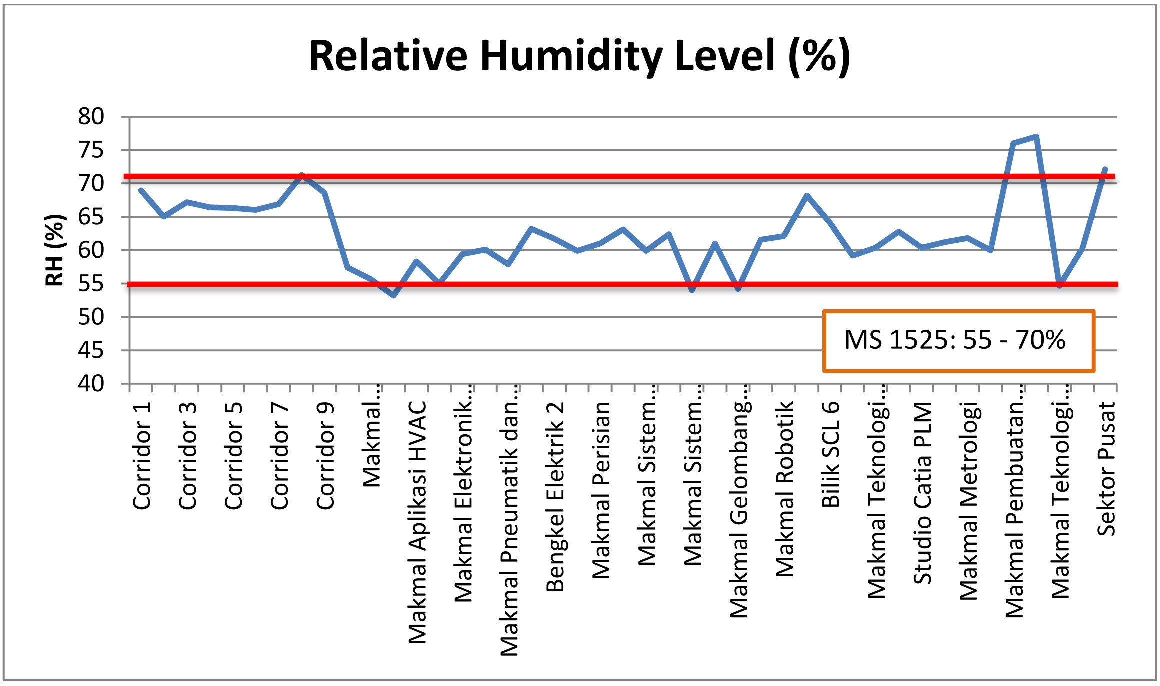


Figure 4.8: Graph for Relative Humidity level in Factory 1

Figure 4.8 shows the graph for relative humidity at Factory 1. The relative humidity is measure by using humidity meter at three points same as method for lux level and the average are compare with the standard MS 1525. Based on the graph above, the relative humidity for Factory 1 are in a best practice and still in recommended range by MS 1525 which is between 50% – 70%. But, there are two laboratories are exceeding the standards which are Manufacturing Lab and Plastic Technology Lab.

The relative humidity needs to follows the standard to make the occupant and student comfortable. This is because, when the relative humidity is higher, the lower the amount of heat the human body will be able to transfer by evaporation and make the human body feel uncomfortable.

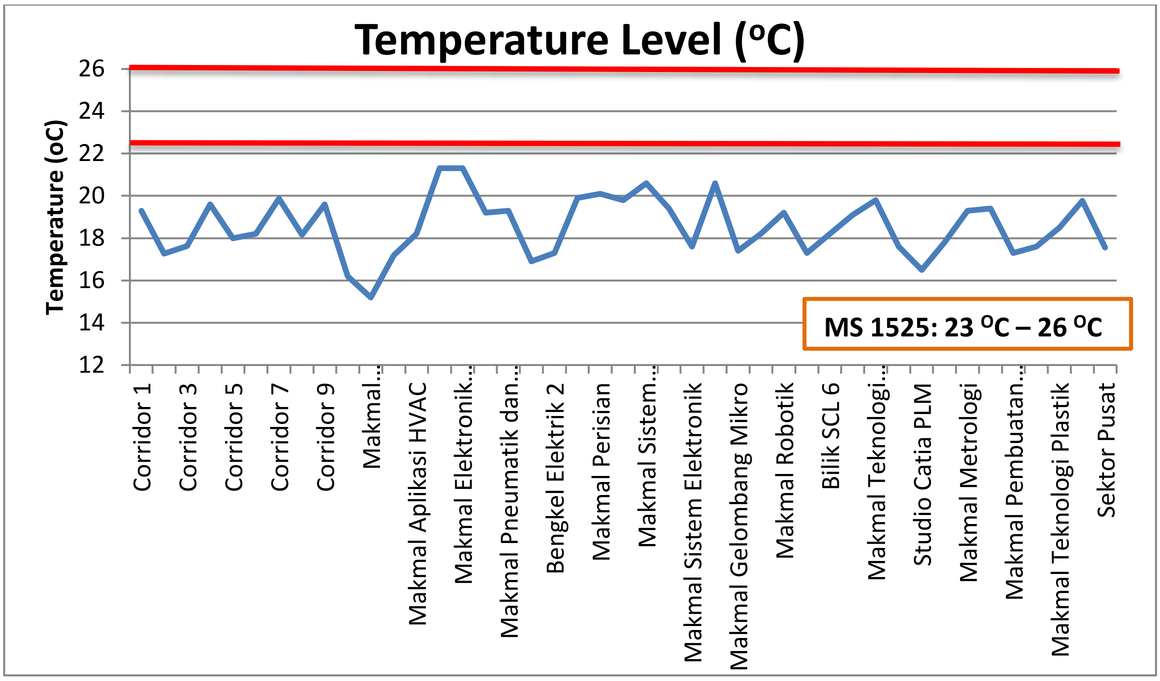


Figure 4.9: Graph for temperature level at Factory 1, FTK.

Figure 4.9 are about the graph temperature level at Factory 1. The temperature is measure using humidity meter and in unit degree Celsius. The recommendation temperatures are from standard MS 1525 between 23 ^{O}C – 26 ^{O}C. Based on the graph above, the temperatures for 9 corridors and 34 laboratories are too lower which in range between 19 ^{O}C – 17 ^{O}C. Thus, the thermal comfort at this place is lower and too cold. The occupant and students might feel uncomfortable due to the extreme cold environment.

Hence, the temperature at Factory 1 needs to arise to achieve the thermal comfort and make the students more comfortable with the environment. This step can reduce the energy usage. Next, to prevent the unnecessary electrical wastage when no one"s around, the air conditioning can be built with single start button switches and can be turned on manually or timer.

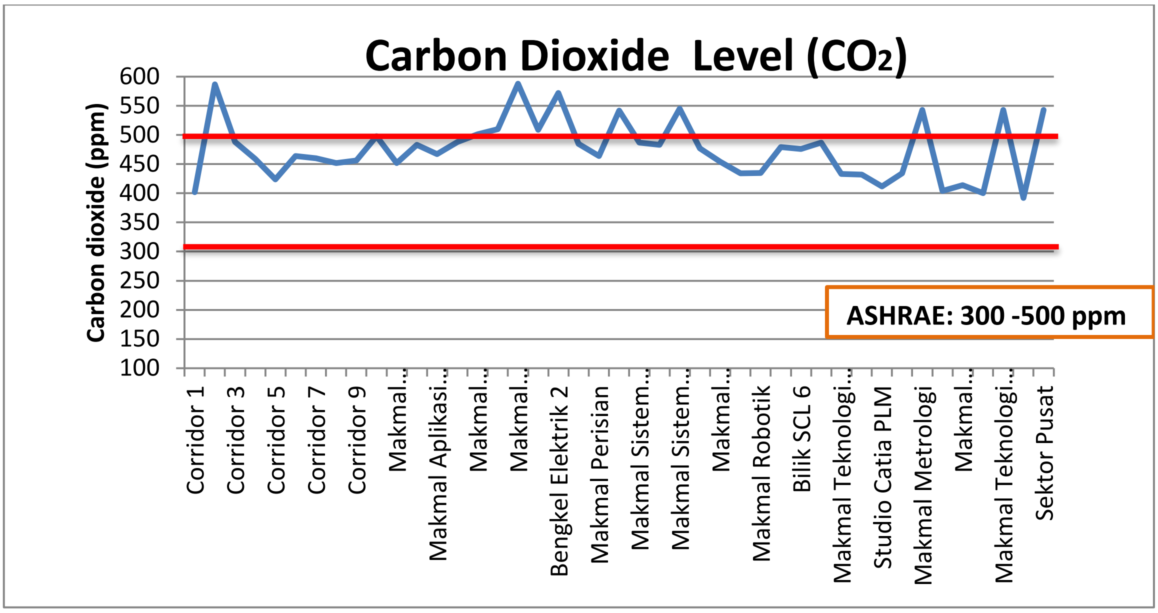


Figure 4.10: Graph for carbon dioxide level at Factory 1, FTK

Figure 4.10 shows that the graph for carbon dioxide (CO_2) level for Factory 1. This data are measure using Bacharach Analyzer meter to determine the level of CO_2 for every laboratories and corridors. The standards for CO_2 that recommended by ASHRAE standard are from 300-500 parts per million (ppm). Based on the graph above, there are several laboratories and corridor that exceeding the recommended standard while the other lab are in a good thermal comfort.

Emission of CO_2 arises from energy consumption activities including heating, cooling, ventilation and lighting of the building. According to the ASHRAE standard, the CO_2 concentrations found in the building is not a direct health risk but it can be used as an indicator of occupants‟ acceptance of the odor. The concentrations of CO_2 must be reducing in order to decrease the global warming effect and climate change. The carbon dioxide emissions can be reduced by decreasing of energy consumption and increase the energy efficiency in the building.

4.1.5 Implementation of energy efficiency practices at Factory 1

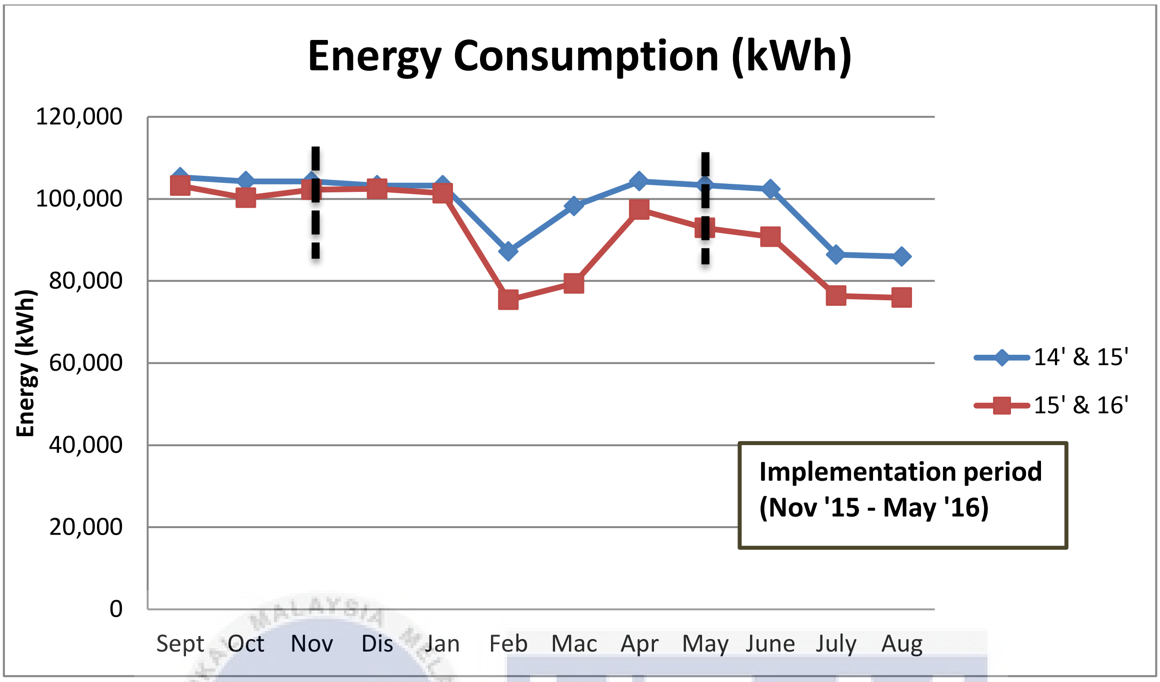


Figure 4.11: Graph energy consumption for 2014 and 2015 after implementation

Figure 4.11 shows the comparison in energy consumption from 2014 and 2015 to 2015 and 2016. These comparisons have made to determine the potential saving in 2015and 2016 after implementation of Energy Efficiency Practices at Factory 1 from November 2015 until May 2016. Based on the observation, there are slightly reductions in energy consumption from December 2015 until August 2016. As already know, Feb, July and August are the semester break. Meanwhile, for other months also having deficit due to the implementation energy practices periods which is until May 2016. However, for the rest months which are June, July and August 2016, the data for energy consumption is the estimated value based on the percentage of decreasing of energy usage after implementation. The implementations of Energy Efficiency Practices are based on the result on site observation, data collection, historical energy consumption and operating hours.

By site observation, the conditions of Factory 1 **before** the implementation are:

1. The lighting at the corridor is not switch off even the environment is too bright.
2. All the lightings are „ON" whether there is natural lighting from surrounding.

3. The rooms seem extremely colder to the students and even though the weather is rainy outside.
4. Lack of awareness – do not switch off the lamps and air conditioning after using the laboratories.
5. The lamps in laboratories still ON even there are no students around.
6. The lamps at toilets are not turn OFF even though there is no person around.

Next, the conditions of Factory 1 from view of data collected. The data such as lux level, temperature, relative humidity, and carbon dioxide are taken in order to determine the performance of the whole Factory 1. The conditions of Factory 1 **before** implementation are:

1. Lux level – All the laboratories and corridors are exceed the MS 1525 standard. This is because there are too many numbers of lamps in every rooms and all of it are switch ON for a long times. For example, lux level for one corridor and HVAC Application Lab are exceeding until 1000 lux.
2. Temperature – The average temperature for the whole building are extremely low which is from $17^{o}C$ – 20 ^{o}C and not follow the MS 1525 standard. Many students have complaints the rooms are very colder and make them uncomfortable.
3. Relative Humidity – Almost all corridors and laboratories in best practice and in recommended standard.
4. Carbon dioxide – There are a few laboratories exceeding the ASHRAE standard which is from 300-500 ppm. But, it better to reduce more carbon dioxide to avoid the global effect.

After the implementation of EE practices at Factory 1 from November 2015, the monthly energy consumption for the next month are having a slightly decreasing from 2014. The annual energy consumes at 2015 is 1,188,215 kWh and reduce to 1,097,704 kWh which is more than 10% decreasing from 2014. The annual cost also decrease from RM 398 124.10 to RM 371 561.70 in 2015 and 2016. From Sept 15 until Aug 16, the annual potential saving is RM 26 562.40 which is can save more than 10% cost. On the other hand, the annual Energy Efficiency Index (EEI) for 2016 is having slightly decreasing from 125 kWh/ m²/year to 110 kWh/ m²/year which in a recommended standard (MS 1525:135 kWh/ m²/year).

Type of implementation EE Practices done at Factory 1:

1. Awareness stickers for saving energy at the classrooms and laboratories.
2. Switch off the light while using the board and open the curtains instead, so that the daylight luminates the room.
3. Increase the room‟s temperature until it achieves the thermal comfort.
4. Switch of the lamps and computers when leaving the laboratory.
5. Lit up small area only
6. Make a schedule to preventive maintenance for air conditioning and other equipment.
7. Repairing the leakage of the air conditioning and increase the efficiency of lab equipment.
8. Improving human behavior by training, guideline and monitoring to energy saving.

4.2 Comparison of measurement and simulation method

In energy audit, energy management tool such as is needed to calculate and analyse the baseline energy parameters. The audit included a site visit, data collected, survey of the building envelope, observation for plant system at the building and simulation of the building‟s energy use. The processes for actual energy audit are taking time too long and use more money. But, by using eQUEST software it help to improve and reduce time consumed from conventional energy audit procedure. This software is also useful for building management to perform analysis to monitor the energy performance in the building. The purpose using this simulation is to determine the potential of these programs to perform whole building energy analysis, and compare the results with the actual building energy performance

The simulation process started with the Schematic Development Wizard and then chooses the whether specifically for Malaysia and selects the place nearest to Malacca. In this phase, eQUEST software defaults in occupancy, scheduling, internal loads, and HVAC system were replaced with more accurate survey data. This included developing detailed schedules for typical spaces within the building and assigning more accurate occupancy and load data. HVAC system details were also modified to reflect the existing situation. The simulation model was calibrated using monthly and hourly utility data obtained from the local utility for each of the buildings. The results of the calibration are compared with the monthly utility data which is actual data.

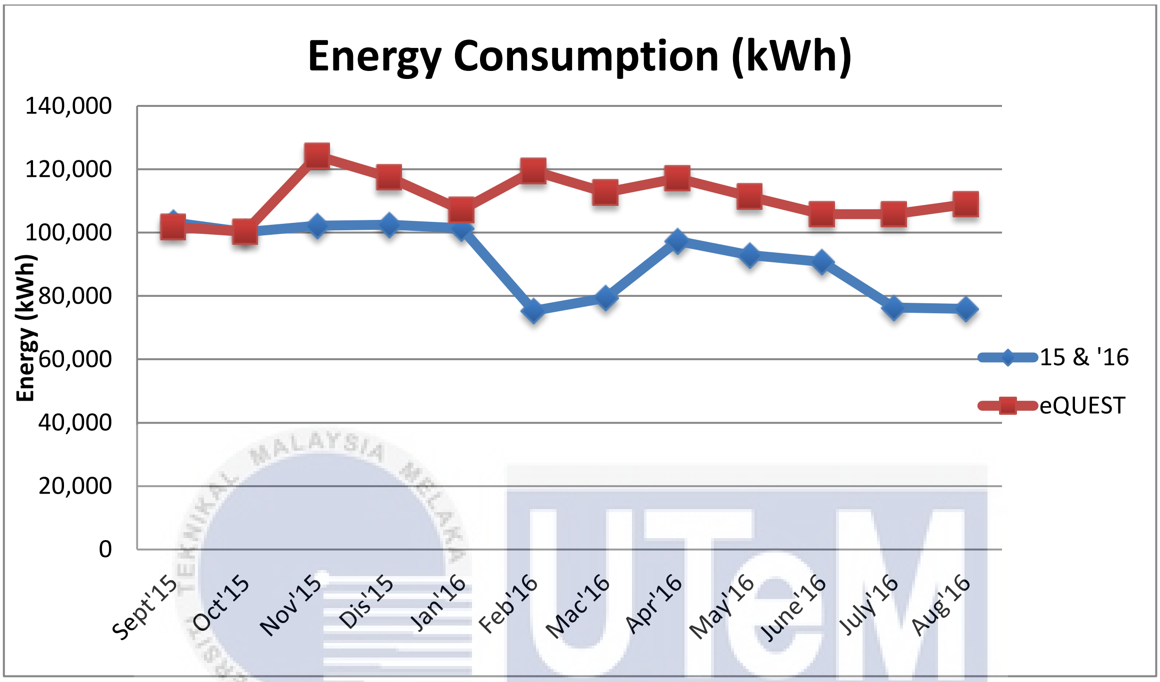


Figure 4.12: Graph comparison between simulation and actual data in 2015 and 2016

Figure 4.12 shows that the graph for energy consumption between simulation using eQUEST software and actual data in 2015 and 2016. The comparison for data simulation and actual energy usage in the building are been made in order to determine their degree of closeness. The results indicate that the energy modeling from eQUEST is much higher than the actual data usage in 2015 and 2016. By comparing the total energy usage to the actual performance data, it is evident that simulation is significantly higher than the actual energy usage. The annual energy usage shows by simulation is 1, 332, 400 kWh while the annual energy usage for actual data is 1,097,704 kWh. Specifically, the simulation results are 15% higher than the actual data.

The largest performance gap between these two methods is within February until April. This is due to the semester break during this season and close attention should be given to these months in future simulations. In addition, when evaluating building"s actual energy consumption with predicted simulation it is hard to find the root cause of the difference because all possible errors within the program are occurring simultaneously. This includes occupancy load, scheduling, lighting schedule, temperature set points and HVAC design. To increase the accuracy data in the eQUEST simulation, using onsite weather data would be recommended. By installing an onsite weather data, collecting temperature, relative humidity, solar radiation, wind direction and wind speed will help create the most accurate custom weather file.

4.3 Discussion

This energy audit project are determine several energy saving measures which can be undertaken within an organization to reduce electrical energy usage by reducing wastage and improve the energy efficiency. From this audit project, the annual energy consumption for year 2014 and 2015 can be reducing from 1,188,215 kWh to 1,097,704 kWh. Meanwhile the Energy Efficiency Index for the Factory 1 also decreases from 125 to110 kWh/m^2/yr. On the other hand, after the implementation of energy efficiency practices at November 2015, the annual saving is RM 26 562.40 which is more than 10%. In addition, the decreasing of energy consumption will lower the emissions of Carbon Dioxide to the atmosphere. From this project, the annual energy consumption is decrease until 90511 kWh and will reduce the emissions of carbon dioxide as much as 68.8 tons per year. This situation will reduce the global effect and climate change.

CHAPTER 5

CONCLUSION & RECOMMENDATION

This chapter are discussing about summary and conclusion for this energy audit project. The conclusion made is based on the analysis performance for the entire Factory 1. Then, the recommendation will be suggested based on this project outcome for future research and development.

5.1 Conclusion

The energy audit process at Factory 1, FTK have been presented and discussed in this report. The objectives of this project are to decrease energy usage and start the benchmark of the Energy Efficiency Index (EEI) baseline. This is because; electrical energy usage in buildings is constantly increasing and will keep on growing in the future due to more high power electrical equipment will be introduced. From this energy audit project, it is able to distinguish energy saving measures, reduce electrical energy usage, reduce the carbon dioxide emissions, energy bill and increase the energy efficiency. Next, energy audit is conducted at Factory 1 to identify the energy efficient measures that can be implementing in order to reduce the energy consumption. The data collections from this building are historical energy consumption, lux level, relative humidity, and temperature and carbon dioxide concentrations. This audit based on focus on loads such as lighting, air conditioning, lab equipment and electrical equipment. Based on the site observation and data collected, the Energy Efficiency Practices has been implemented at Factory 1 start from September 2015. The implementation has been done at Factory 1 because there are several corridors and laboratories are exceeding the range for recommended standard (according to MS 1525 and ASHRAE). After the implementation of EE practices at

Factory 1 from November 2015, the monthly energy consumption for the next month are having a slightly decreasing from 2014. The annual energy consumes at 2014 is 1,188,215 kWh and reduce to 1,097,704 kWh which is more than 10% decreasing from 2014. The annual cost also decrease from RM 398 124.10 to RM 371 561.70 in 2015 and 2016. From Sept 15 until Aug 16, the annual potential saving is RM 26 562.40which is can save more than 10% cost. On the other hand, the annual Energy Efficiency Index (EEI) for 2016 is having slightly decreasing from 125 kWh/ m^2/year to 110 kWh/ m^2/year which in a recommended standard (MS 1525:135 kWh/ m^2/year).

On the other hand, this project also includes a comparison between eQUEST and actual data in 2015. The simulation is used to identify the performance and thermal comforts of the buildings. The energy consumption for simulation is a bit higher than actual data in 2015 and 2016 this is because there are with 15 % performance gap. This is due to the error in occupants load, scheduling and lighting schedule.

5.2 Recommendations

Energy audit can properly handle and manage only when there are the data such as energy bills, schematic diagram for single line diagram, drawing of building and drawing for electrical and air conditioning plant. For future work, it more precise to install the metering and sub-metering in every building to make easier to collected the data directly to know the energy consumes by the building. Besides, it is easier to do energy saving measurement and retrofitting in the building. The other recommendations are built a sensor based switching system that can switch on the air conditioner automatically when the students around and switch off when no students. This system can reduce the energy wastage and energy bills. Next, the further study in relationship of levels of occupant comforts with thermal comfort in the building.

REFERENCES

[1] Bakar NNA, Hassan MY, Abdullah H, Rahman HA, Abdullah FM,Hussin F, Bandi M. Energy Efficiency Index as an Indicator for Measuring Building Energy Performance: A Review. *Renewable and Sustainable Energy Reviews*, 1-11, 2015.

[2] Ahmad AS, Hassan MY, Abdullah H, Rahman HA, Majid MS, Bandi M. Energy Efficiency Measurements in Malaysian Public University. *IEEE International Conference Power and Energy*, 582-587, 2012.

[3] MF Baharom, K.Ahmad, M.N.M Nasir, W.M Bukhari, H.I Jaafar. New Construction for Commercial Building (Restaurant) by Considering the Green Building Strategies.*International Journal of Engineering and Technology (IJET)*, *7*(4), 1329-1342, 2015.

[4] *Energy Policy UTeM*. Malacca, 2015.

[5] Suruhanjaya Tenaga. *Malaysia Energy Statistics Handbook 2014*. [Online]Available at from www.st.gov.my, 2014.

[6] J.Randolph and G.M. Masters, "Energy for Sustainability: Technology, Planning, Policy," 165-212, 2008.

[7] Ali Alajmi. Energy audit of an educational building in a hot summer climate.*Energy and Buildings*, (47), 122-130, 2011.

[8] GreenTech Malaysia. *Energy Auditor Training Course*. 2015.

[9] Michael Baechler. *A Guide to Energy Audits*. Pacific Northwest National Laboratory, 2011.

[10] MK.Zamri, BEKP 4763, Lecture 4: Energy Audit, Universiti Teknikal Malaysia Melaka (UTeM), 2015.

[11] Julian DS.Energy efficiency and the environment: The potential for energy efficient lighting to save energy and reduce carbon dioxide emissions at Melbourne University,Australia.Energy;25(9):823–39, 2000.

[12] Maheswaran D, Rangaraj, K.K. Jembu Kailas, Kumar A. Energy Efficiency in Electrical Systems. *IEEE International Conference on Power Electronics, Drives and Energy Systems*, 1-6, 2012.

[13] Parameshwaran R, Kalaiselvam S,Harikrishnan S, Elayaperumal A.Sustainable thermal energy storage technologies for buildings: a review Renew Sustain Energy Rev;16(5):2394–433, 2012

[14] Bakar NNA, Hassan MY, Abdullah H, Rahman HA, Abdullah MP, Hussin F, Bandi M. Identification Building Energy Saving using Energy Efficiency Index Approach. *IEEE International Conference Power & Energy*, 366-370, 2014.

[15] González, A. B. Díaz, J. J., Caamaño, A. J., & Wilby, M. R. Towards a universal energy efficiency index for buildings. *Energy and Buildings*, (43), 980-987. 2011.

[16] Guideline for Energy Efficiency Label. [Online]Available at: http://www.st.gov.my/index.php/consumer/electricity/efficient-use-of-electricity/energy-efficient-appliances.html, 2013.

[17] Dixit A, Pathak G, Sudhakar K. Comparative Study of Life Cycle Cost of Modern Light Sources used in Domestic Lighting. *International Journal of Science, Environment and Technology*, *4*(2), 364-370, 2015.

[18] Ramya LN. A Case Study on Effective Consumption of Energy using Sensor Based Switching System. *IEEE Sponsored 2nd International Conference on Innovations in Information Embedded and Communication Systems*, 1-4, 2015.

[19] Martirano L. Lighting systems to save energy in educational classrooms, 2011.

[20] The Incandescent Lamp. [Online]Available at: http://www.lamptech.co.uk/Documents/IN%20Introduction.htm, 2011.

[21] Energy Efficiency in fluorescent lighting: T12, T8 & T5 lamps. [Online]Available at: http://www.luxadd.com/index.php/energy-efficient-use-of-lighting.html

[22] Uddin S, Shareef H, Mohamed A, Hannan MA, Mohamed K. LEDs as Energy Efficient Lighting Systems: A Detail Review. *IEEE Student Conference on Research and Development*, 468-472, 2011.

[23] LED lights could save up to 80 percent of your power bill, Capital Business. [Online]Available at: http://www.capitalfm.co.ke/business/2015/08/led-lights-could-save-up-to-80-percent-of-your-power-bill/

[24] Rensselaer Polytechnic Institute. What is ballast [Online] Available at: http://www.lrc.rpi.edu/programs/nlpip/lightinganswers/adaptableballasts/ballast.asp, 2003

[25] What's the Difference between Electronic Ballast and Magnetic Ballast? [Online]Available at: http://www.doityourself.com/stry/whats-the-difference-between-an-electronic-ballast-and-a-magnetic-ballast

[26] Electrical Energy Equipment: Lighting. [Online]Available at: www.energyeefficiencyasia.org

[27] What is luminance? Technical Information, Apiste Corporation. [Online]Available at: http://www.apiste-global.com/fsv/technology_fsv/detail/id=1182

[28] Othman MF, Abdullah H, Sulaiman NA, Hassan MY. Performance evaluation of an actual building air-conditioning system. *International Conference on Mechanical Engineering Research*, 1-8, 2013.

[29] Malaysia Standard 1525:2007, "Code of Practice on Energy Efficiency and use of Renewable Energy for Non-Residential or Commercial Building".

[30] Electrical Energy Audit in a Malaysian University - A Case Study. *IEEE International Conference on Power and Energy*, 616-619, 2012

[31] Pricing & Tariffs - Tenaga Nasional Berhad. [Online]Available at: https://www.tnb.com.my/commercial-industrial/pricing-tariffs1/#industrial-tariffs ,2015

[32] K.R. Shailesh, S. Tanuja, Manish Kumar, Rai Aseem Krishna. Energy Consumption Optimisation in Classrooms using Lighting Energy Audit.

[33] Old News 2012. [Online]Available at: http://www.mikesflightdeck.com/oldnews/oldnews_2012.html

[34] Fluke 971 Temperature Humidity Meter, helping you maintain good indoor air quality (IAQ). [Online]Available at: http://en-us.fluke.com/products/hvac-iaq-tools/fluke-971-hvac-iaq.html

[35] Stephen C. Turner. What‟s New in ASHRAE‟s Standard on Comfort. *ASHRAE Journal*, 42-48, 2011

[36] Measurement & Verification [Online] Available at: http://www.energy-efficiency.com/measurement-and-verification/

[37] Tobias Maile, Martin Fischer, Vladimir Bazjanac. Center for Integrated Facility Engineering. *Building Energy Performance Simulation Tools - A Life-Cycle and Interoperable Perspective*, 1-49. [Online] Available at: http://cife.stanford.edu/sites/default/files/WP107.pdf, 2007.

[38] Greenhouse Gas Equivalencies Calculator | Energy and the Environment | US EPA. [Online] Available at: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator, 2015.

APPENDICES

Appendix A: Corridor at Factory 1 during site visit

Appendix B: Corridor and entrance door at Factory 1 during site visit

Appendix C: Server room Factory 1

Appendix D: Server room Factory 1

Appendix E: Split unit used at Factory 1

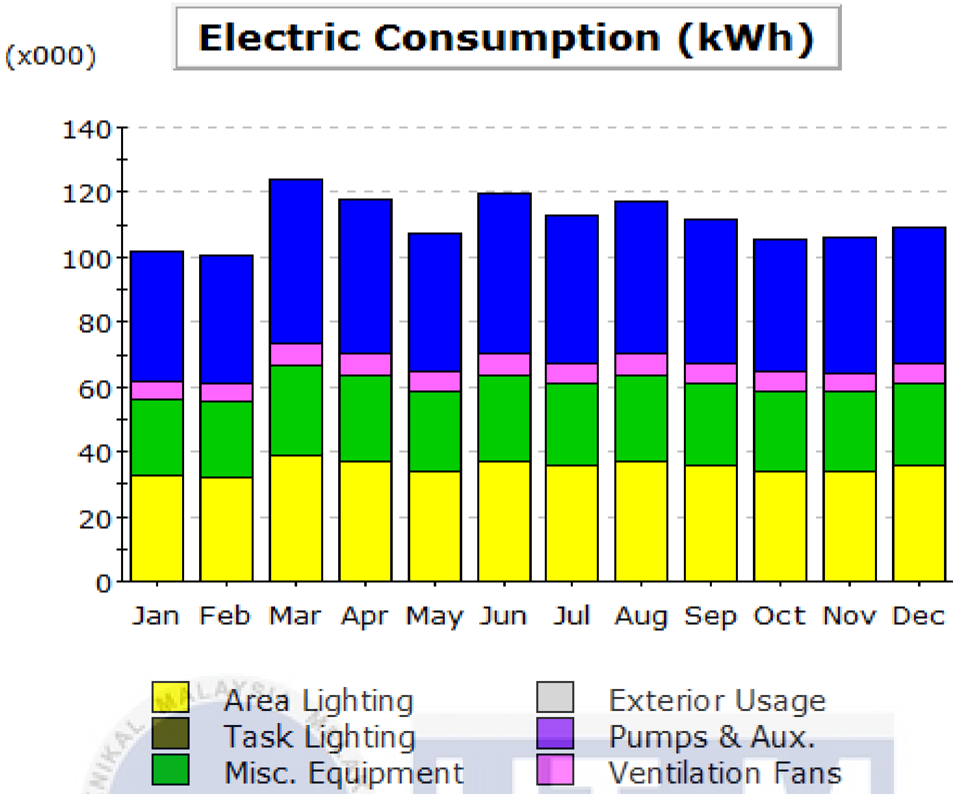
Appendix F: Energy consumptions year 2014 and 2015

Month	Energy Consume On-Peak (kWh)	Energy Consume Off-Peak (kWh)	Total Energy Consumption (kWh)	Cost Consume On-Peak (RM)	Cost Consume Off Peak (RM)	Total Cost (RM)	EEI
Sept'14	89,759	15,524	105,283	31864.45	3399.75	35264.2	13
Oct'14	87,009	14,283	104,292	30888.2	3127.97	34016.17	12
Nov'14	86,990	17,283	104,273	30881.45	3784.97	34666.43	12
Dec'14	87,998	15,283	103,281	31239.29	3346.97	34586.27	11
Jan'15	86,896	16,384	103,280	30848.08	3588.09	34436.18	11
Feb'15	77,919	9,273	87,192	27661.25	2030.78	29692.03	8
Mac'15	88,003	10,236	98,239	31241.07	2241.68	33482.75	9
Apr'15	89,020	15,263	104,283	31602.1	3342.59	34944.7	12
May'15	87,099	16,283	103,382	30920.15	3565.97	34486.12	11
June'15	84,010	18,374	102,384	29823.55	4023.90	33847.46	10
July'15	77,131	9,263	86,394	27381.51	2028.59	29410.1	8
Aug'15	77,004	8,928	85,932	27336.42	1955.23	29291.65	8
Total	**1,018,838**	**166,377**	**1,188,215**	**361687.5**	**36436.56**	**398124.1**	**125**

Appendix G: Energy consumptions for year 2015 and 2016

Month	Energy Consume On-Peak	Energy Consume Off-Peak	Total Energy Consumption (kWh)	Cost Consume On-Peak	Cost Consume Off Peak	Total Cost (RM)	EEI
Sept'15	88,939	14,273	103,212	31573.35	3125.787	34699.13	13
Oct'15	85,309	14,923	100,232	30284.7	3268.137	33552.83	12
Nov'15	88,290	13,942	102,232	31342.95	3053.298	34396.25	12
Dec'15	88,580	13,902	102,482	31445.9	3044.538	34490.44	11
Jan'16	89,190	12,192	101,382	31662.45	2670.048	34332.5	11
Feb'16	66,121	9,273	75,394	23472.96	2030.787	25503.74	8
Mac'16	70,482	8,902	79,384	25021.11	1949.538	26970.65	9
Apr'16	88,453	8,921	97,374	31400.82	1953.699	33354.51	12
May'16	82,639	10,273	92,912	29336.85	2249.787	31586.63	11
June'16	79,561	11,223	90,784	28244.16	2457.837	30701.99	10
July'16	68,481	7,903	76,384	24310.76	1730.757	26041.51	8
Aug'16	68,400	7,532	75,932	24282	1649.508	25931.51	8
Total	**964,445**	**133,259**	**1,097,704**	**342378**	**29,184**	**371561.7**	**110**

Appendix H: Factory 1 using simulation eQUEST



Appendix I: Graph for energy consumption using eQuest software

Appendix J: Table for energy consumption using eQuest software

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	40.1	39.3	51.0	47.4	42.6	49.4	45.2	46.9	44.2	41.2	41.5	41.6	530.4
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	5.7	5.7	6.9	6.6	6.0	6.6	6.3	6.6	6.3	6.0	6.0	6.3	75.0
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	23.6	23.0	27.4	26.3	24.5	26.3	25.5	26.4	25.3	24.5	24.4	25.5	302.7
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	32.4	32.3	38.9	37.2	34.0	37.2	35.7	37.3	35.6	34.0	34.0	35.7	424.3
Total	101.8	100.3	124.2	117.5	107.2	119.5	112.7	117.2	111.4	105.8	105.8	109.0	1,332.4

Appendix K: Collected data Factory 1 (Lighting)

LEVEL	ROOM N0/DESCRIPTION	Illuminance (Lux)				CO_2	RH	Temp.	Type	Type of fittings	No of Lamps	emergency lamps	Energy Usage per day (kWh)
		R	C	L	AVE								
1	Corridor 1	442	326	257	341.66	402	68.96	19.3	FLUO	2 X 36	98	12	28.992
	Corridor 2	251	241	654	382	587	65.03	17.26	FLUO	2 X 36	30	8	9.152
	Corridor 3	338	280	285	301	488	67.16	17.633	FLUO	2 X 36	26	7	7.936
	Corridor 4	341	417	414	390.6	459	66.4	19.6	FLUO	2 X 36	34	9	10.368
	Corridor 5	313	323	414	350	424	66.33	18	FLUO	2 X 36	10	3	3.072
	Corridor 6	296	414	211	307	464	66.03	18.2	FLUO	2 X 36	26	7	7.936
	Corridor 7	315	354	388	352.33	460	66.9	19.86	FLUO	2 X 36	24	4	7.168
	Corridor 8	298	312	367	325.66	452	71.26	18.16	FLUO	2 X 36	32	4	9.472
	Corridor 9	343	299	377	339.66	456	68.56	19.6	FLUO	2 X 36	36	4	10.624
LANE 1	Makmal Diagnostik dan Getaran Mesin	369	128	1069	522	498	57.4	16.2	FLUO	2 X 36	72	5	13.16
	Makmal Penyelenggaraan Mesin	1054	1046	1057	1052.3	452	55.7	15.2	FLUO	2 X 36	54	6	9.96
	Makmal Pengagihan Udara	777	351	233	453.66	483	53.2	17.2	FLUO	2 X 36	72	4	13.12
	Makmal Aplikasi HVAC	1030	941	1326	1099	467	58.3	18.2	FLUO	2 X 36	72	8	13.28
	Makmal Teknologi Industri HVAC	756	856	734	782	488	55	21.3	FLUO	2 X 36	72	5	13.16

LANE 2	Makmal Elektronik Kuasa dan Pemacu	337	340	380	352.33	501	59.4	21.3	FLUO	2 X 36	72	7	13.24
	Makmal Sistem Kuasa	399	149	453	333.66	510	60.1	19.2	FLUO	2 X 36	72	3	13.08
	Makmal Pneumatik dan Hidraulik	412	435	512	453	588	57.9	19.3	FLUO	2 X 36	64	5	11.72
	Makmal FMS	183	240	431	284.66	509	63.2	16.9	FLUO	2 X 36	72	6	13.2
	Bengkel Elektrik 2	322	263	342	309	572	61.7	17.3	FLUO	2 X 36	72	3	13.08
LANE 3	Makmal Pengaturcaraan Komputer II	604	328	456	462.66	485	59.9	19.9	FLUO	2 X 36	64	4	11.68
	Makmal Perisian	281	319	506	368.66	464	61	20.1	FLUO	2 X 36	72	4	13.12
	Makmal Sistem Pengoperasian	345	435	537	439	542	63.1	19.8	FLUO	2 X 36	64	3	11.68
	Makmal Sistem Telekomunikasi	516	457	673	548.66	487	59.9	20.6	FLUO	2 X 36	72	3	13.08
	Makmal Frekuensi Radio	419	420	683	507.33	483	62.4	19.4	FLUO	2 X 36	72	4	13.12
	Makmal Sistem Elektronik	512	593	602	569	545	54	17.6	FLUO	2 X 36	64	6	11.76
	Bengkel Elektronik	221	240	314	258.33	477	61	20.6	FLUO	2 X 36	72	4	13.12

LANE 4	Makmal Gelombang Mikro	321	424	324	356.33	454	54.2	17.4	FLUO	2 X 36	72	4	13.12
	Makmal Antenna	341	146	456	314.33	434	61.6	18.2	FLUO	2 X 36	54	4	9.84
	Makmal Robotik	889	424	437	583.3	435	62.1	19.2	FLUO	2 X 36	72	7	13.24
	Makmal Projek 1	230	1073	218	507	479	68.2	17.3	FLUO	2 X 36	72	6	13.2
	Bilik SCL 6	240	346	413	333	476	64.1	18.2	FLUO	2 X 36	72	4	13.12
	Makmal Pengujian Bahan	356	871	712	646.3	487	59.2	19.1	FLUO	2 X 36	64	6	11.76
	Makmal Teknologi Pencantuman Termaju	468	299	360	375.66	433	60.4	19.8	FLUO	2 X 36	74	2	13.4
LANE 5	Makmal Rekabentuk Ergonomik & OSHE	342	412	602	452	432	62.8	17.6	FLUO	2 X 36	72	4	13.12
	Studio Catia PLM	93	218	105	138.66	412	60.4	16.5	FLUO	2 X 36	64	6	11.76
	Makmal Kejuruteraan Industri Kawalan Kualiti	315	421	673	469.66	434	61.2	17.8	FLUO	2 X 36	72	4	13.12
	Makmal Metrologi	345	564	537	482	543	61.8	19.3	FLUO	2 X 36	64	5	11.72
	Bilik EFGO	243	235	489	322.33	404	60	19.4	FLUO	2 X 36	76	3	13.8
	Makmal Pembuatan Termaju	150	361	317	276	414	76	17.3	FLUO	2 X 36	72	2	13.04
	Studio CNC	369	849	213	477	400	77	17.6	FLUO	2 X 36	72	3	13.08
	Makmal Teknologi Plastik	734	738	623	698.3	543	54.7	18.5	FLUO	2 X 36	72	6	13.2
	Makmal Teknologi Pembentukan Termaju	232	432	423	362.33	392	60.3	19.763	FLUO	2 X 36	54	4	9.88
	Sektor Pusat	343	234	237	271	543	72.1	17.56	FLUO	2 X 36	72	4	13.12
												TOTAL	**522.8**

Appendix L: Collected data Factory 1 (Air Conditioning)

NO	CODE	ITEM	STATUS	VOLT	TONS	KW		
CHILLER FACTORY 1								
1	W35-01162	Screw Chiller York 1	Active	415	300	201		
						201		
NO	**CODE**	**ITEM**	**STATUS**	**VOLT**	**HP**	**KW**	**AMP**	**P/FACTOR**
COOLING TOWER								
1	W35-01164	Cooling Tower	Active	415	4	5.5	21	0.9
2	W35-M0101	Cooling Tower	Active	415	4	5.5	21.5	0.9
						11		
CONDENSER PUMP								
1	W35-01167	Condenser Water Pump	Active	415	10	17.07	25	0.95
2	W35-01168	Condenser Water Pump	Active	415	10	17.34	25.4	0.95
						34.42		
CHILLED WATER PUMP								
1	W35-01165	Chilled Water Pump	Active	415	15	26.49	38.8	0.95
2	W35-01166	Chilled Water Pump	Active	415	15	26.56	38.9	0.95
						53.06		

Equipment	Detail of Appliance	Quantity	Total Power (kW)	Operating Hours per day	Energy (kWh)
Split Unit	2kW	15	30	8	240

Appendix M: Collected data Factory 1 (Lab Equipment)

Lab	Detail of Appliance	Quantity	Capacity per Unit (Watt)	Operating Hours per 5 days	Energy Usage per 5 days (kWh)
Makmal Diagnostik & Getaran Mesin	Machinery Diagnostic System	2	2000	27	202.5
	Vibration Analyser	2	1000		
	Break and Load	2	250		
	Crack Shaft Detection	2	1000		
	VRF System	2	500		
	Multiple Compressor	2	4000		
Makmal Aplikasi HVAC	HVAC Electrical & Control Component Modular Training KIT	3	1500	18	513
	Double Stage Compression	3	2000		
	Wirecut machine	2	3000		
	die sinking machine	2	3000		
Studio CNC	surface grinding machine	2	1500	21	504
	cylindrical grinding machine	2	1500		
	EDM drilling machine	2	1500		
	Plastic injection molding machine	3	3000		
	blow molding machine	3	3000		
Makmal Teknologi Plastik	Computer HP	30	250	18	138.6
	Wall Scree	1	200		
Makmal Pengaturcaraan Komputer II	LCD Panasonic	1	200	21	140.7
	Motor Starter Training Bench	4	500		
	Power and Energy Quality Analyzer	30	150		
Bengkel Elektrik 2	3-Phase Induction Motor	10	1100	18	503.1
	Earth Tester	10	300		
	Power Analyzer	10	250		
	Industrial Vacuum Cleaner	2	500		

	Benchtop Drill	5	450		
	Cable Tracer Kits	5	250		
	FMS	2	1500		
	DC Servo Motor For Position	2	1100		
	Water Tank System For Flow & Level Control Plant	2	500		
	Heat Transfer System For Temperature Control Plant	2	500		
	Dual Mode Controller Sorting	3	250		
Makmal FMS	Stamping Pneumatic Plant	4	1000	27	108
Makmal Kejuruteraan Industri Kawalan Kualiti	Advance hydraulic training set	5	1000	18	535.5
	Advance Electro-hydraulic training set	5	250		
	Co-ordinate measuring machine	1	1000		
	Workstation PC	30	250		
	Milling machine	2	2000		
	lathe machine	2	2000		
	UTS machine	2	1000		
	Robot welding	1	3000		
	CNC bending	2	1000		
Makmal Pneumatik dan Hidraulik	CNC rolling	2	1000	21	210
	Wirecut machine	2	1000		
	die sinking machine	2	3000		
Makmal Metrologi	surface grinding machine	2	3000	21	126
Makmal Rekabentuk Ergonomik & OSHE	cylindrical grinding machine,	2	3000	18	108
Makmal Projek 1	EDM drilling machine	2	3500	18	216
	Digital Oscilloscope	20	250		
Bilik EFGO	Function Generator	10	350	21	73.5
Makmal Teknologi Pencantuman Termaju	DC Power Supply	10	350	21	73.5

Makmal Teknologi Pembentukan Termaju	Electronic Single Phase Energy Meter	5	500	18	42.75
	Benchtop Drill	5	450		
Makmal Pembuatan Termaju	Cable Tracer Kits	5	200	18	18
Bengkel Elektronik	DC Servo Motor For Position	5	1100	21	244.65
	Speed & Inverted Pendulum Control Plant	2	500		
	Water Tank System For Flow & Level Control Plant	2	500		
	Heat Transfer System For Temperature Control Plant	3	150		
	Dual Mode Controller Sorting	4	750		
	Stamping Pneumatic Plant	4	300		
	Pneumatic Application Station	2	250		
Makmal Teknologi Pencantuman Termaju	DC Power Supply	10	350	18	63
Makmal Teknologi Pembentukan Termaju	Six(6) Dof Industrial Robot Training Station System Integrated With Vision System	3	3000	21	294
	Robotics Arm Kits System	1	5000		
Makmal Pembuatan Termaju	Machine Vision System	2	2000	18	180
	Services Robot (Mobile Robot) 1	2	3000		

Energy usage per 5 day = 5431.2 kWh

Energy usage per 20 day = 21 724kWh

Appendix N: Collected data Factory 1 (Electrical equipment)

Equipment	**Quantity**	**Capacity per Unit (Watt)**	**Operating Hours per day**	**Energy Usage per day (kWh)**
Computer	400	250	5	500
Projector	36	250	8	72
Printer	34	250	3	25.5
				597.5

Total energy usage per day = 597.5 kWh

Total energy usage per month = 597.5 kWh X 20 day = 11 950 kWh

Cost per month (RM) = 11 950 kWh X 0.355 RM/kWh = RM 4242.25

Mohamad Faizal b. Baharom
Faculty of Electrical Engineering,
Universiti Teknikal Malaysia Melaka,
76100 Ayer Keroh,
Melaka

20 November 2015

To,
Dean,
Faculty of Technology Engineering,
Universiti Teknikal Malaysia Melaka,
76100 Ayer Keroh,
Melaka

Permission to use Equipment in Laboratory for Energy Audit

Respected Sir,

For our Projek Sarjana Muda (PSM) that will be supervised by Mr. Mohamad Faizal b. Baharom, we will conduct the Energy Audit at FTK building. We are looking ahead for your permission to allow us to use the equipment or parameter measurement in FTK laboratories such as meter for measure carbon dioxide, Lux meter (*Amprobe Lm-120*), Humidity meter and power meter. Next, we also need a permission to enter the substation to analyse the major load flows at your faculty.

We will use to visit your faculty for the end of the next semester (June 2016) until the project is done. So, we are looking ahead your approval to use that equipment until the auditing process is done. There are two student involve in this visit, which is Azma Niza Laila bt Zakaria and Muhammad Farhan b. Rasdi. We concede that the visit will be totally upon our personal responsibility and will be visiting on our personal risk. Our main motive behind this visit is do the survey and walk through audit, then getting the actual data for our Energy Audit project. We also need a permission to use the data such as monthly bills, maximum demand bills, schematic diagram and others.
Kindly looking ahead for your positive response

Thank You,
Sincerely,

……………………………
Name:
Date:

Approved by,

…………………………
Name:
Date:

Mohamad Faizal b. Baharom
Faculty Kejuruteraan Elektrik,
Universiti Teknikal Malaysia Melaka,
76100 Ayer Keroh,
Melaka

20 November 2015

Kepada,
Dekan,
Fakulti Teknologi Kejuruteraan ,
Universiti Teknikal Malaysia Melaka,
76100 Ayer Keroh,
Melaka

Tuan,

Memohon Kebenaran Memasuki Makmal di FTK bagi Tugasan 'Energy Audit'

Berhubung perkara di atas, saya Mohamad Faizal b. Baharom, pensyarah Fakulti Kejuruteraan Elektrik UTeM, ingin memohon kebenaran daripada pihak tuan untuk memasuki makmal-makmal di FTK bagi menjalankan tugasan Projek Sarjana Muda (PSM) bersama dua orang pelajar saya iaitu Azma Niza Laila bt Zakaria dan Muhamad Farhan b. Rasdi.

Bagi tugasan „Energy Audit‟ ini, kami perlu memasuki makmal di fakulti tuan bagi mendapatkan data untuk kecerahan lampu, suhu bilik, kadar kelembapan dan penggunaan elektrik lain. Selain itu, kami juga perlu memasuki makmal untuk mendapatkan data penggunaan tenaga daripada „Sub Switch Board‟.

Jadual 1. Antara makmal yang terlibat dalam proses „Energy Audit‟

Makmal Diagnostik dan Getaran Mesin	Makmal Pengaturcaraan Komputer II
Makmal Penyelenggaraan Mesin	Makmal Perisian
Makmal Pengagihan Udara	Makmal Sistem Pengoperasian
Makmal Aplikasi HVAC	Makmal Sistem Telekomunikasi
Makmal Teknologi Industri HVAC	Makmal Frekuensi Radio
Makmal Elektronik Kuasa dan Pemacu	Makmal Sistem Elektronik
Makmal Sistem Kuasa	Bengkel Elektronik
Makmal Pneumatik dan Hidraulik	Makmal Rekabentuk Ergonomik & OSHE
Makmal FMS	Studio Catia PLM
Bengkel Elektrik 2	Makmal Kejuruteraan Industri Kawalan Kualiti
Makmal Gelombang Mikro	Makmal Metrologi
Makmal Antenna	Bilik EFGO
Makmal Robotik	Makmal Pembuatan Termaju
Makmal Projek 1	Studio CNC
Bilik SCL 6	Makmal Teknologi Plastik
Makmal Pengujian Bahan	Makmal Teknologi Pembentukan Termaju
Makmal Teknologi Pencantuman Termaju	Sektor Pusat

Diharapkan permohonan saya akan dipertimbangkan oleh pihak Tuan. Saya berjanji akan mematuhi peraturan yang telah ditetapkan dan akan bertanggungjawab terhadap segala kerosakkan yang berlaku.

Perhatian dan kerjasama daripada pihak Tuan amatlah dihargai.

Sekian, terima kasih.

Yang Benar,	Diluluskan oleh,
…………………………….	…………………………….
Nama:	Nama:
Jawatan:	Jawatan:
Tarikh:	Tarikh:

Energy Audit in Lighting System Form

LEVEL	ROOM NO/DESCRIPTION	LIGHTING EQUIPMENT	NO. OF LAMPS	TYPE OF LAMPS	WATTS (LAMPS + BALLAST)	NO. OF FAULTY LAMPS	TYPE OF CONTROL	OPERATING HOURS	LUX		
									Right	Center	Left

Lighting equipment
CR-ceiling recessed
SM-surface mounted
BC- bare channel
SP-spotlight

Relative humidity and temperature form

LEVEL	ROOM NO/DESCRIPTION	HUMIDITY (%)				TEMPERATURE (^{O}C)		
		RIGHT	CENTER	LEFT	AVE	MAX	MIN	AVE