MEASUREMENT AND MANAGEMENT OF ENERGY USAGE IN SCHOOL OF MECHANICAL ENGINEERING USM

By:

AZIZI BIN ARBAIN

(Matrix no.: 123115)

Supervisor:

DR. CHAN KENG WAI

MAY 2018

This dissertation is submitted to
Universiti Sains Malaysia
As partial fulfilment of the requirement to graduate with honors degree in
BACHELOR OF ENGINEERING (MECHANICAL ENGINEERING)

School of Mechanical Engineering
Engineering Campus
Universiti Sains Malaysia

" I declare that this thesis entitled "*Measurement and Management of Energy Usage of School of Mechanical Engineering USM*" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any degree.

Signature	:	……
Name of Supervisor	:	Azizi bin Arbain
Date	:	May 2018

ACKNOWLEDGEMENT

This final year project was carried out during year 2017-2018 at School of Mechanical Engineering USM. I am grateful to the God for the good health and wellbeing which is important to complete this final year project. This thesis could not have been completed without the help and support from others.

Many people have contributed in completing this final year project including lecturers, researchers, academicians, engineers and practitioners. I owe my deepest gratitude to my supervisor, Dr. Chan Keng Wai. Without his continuous optimism and support this study would hardly have been completed. His guidance into the world of energy management has been essential during this work.

I wish to express my sincere thanks to Dean of School of Mechanical Engineering, Prof. Dr. Zainal Alimuddin Zainal Alauddin for providing all the necessary facilities to complete this project. I am also indebted to En. Sohaimi and En Amir for providing relevant materials which is necessary for this project.

I am also wanted to express my gratitude to my fellow mechanical engineering friends for their help and encouragement. I am extremely thankful and indebted to all those involve either directly or indirectly with this project. Thank you so much for sharing expertise, sincere and valuable guidance and encouragement.

Last but not least, my greatest appreciation dedicated to my parents for the continuous encouragement and unceasing support and attention.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ACPU	Air Cooled Packaged Unit
ACSU	Air Conditioning Split Unit
ACV	Air Conditioning Ventilation System
AHRI	American Air-conditioning, Heating and Refrigeration Institute
AHU	Air Handling Unit
AFUE	Annual Fuel Utilization Efficiency
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BEI	Building Energy Index
BEII	Building Energy Intensity Index
BSE	Boiler Seasonal Efficiency
CFR	Council on Foreign Relations
CO_2	Carbon Dioxide
DCS	Detailed Control Strategy
DOE	Department of Energy
ECS	Existing Control Strategy
EEI	Energy Efficiency Indicators
EMS	Energy Management Software
HVAC	Heating, Ventilation and Air Conditioning
IPLV	Integrated Part Load Value

MS	Malaysia Standard
kWh	Kilowatt per hours
PTM	Pusat Tenaga Malaysia
ROI	Return On Investment
SCOP	Seasonal Coefficient of Performance
SCS	Simple Control Strategy
SEER	Seasonal Energy Efficiency Ratio
USM	Universiti Sains Malaysia
VAV	Variable Air Volume
WCPU	Water Cooled Package Unit

ABSTRAK

Seiring dengan perkembangan status Malayia ke arah negara membangun, penggunaan tenaga elektrik memainkan peranan yang penting masa kini dan telah menyebabkan permintaan yang tinggi dalam sektor pembinaan dan tenaga elektrik. Sektor pembinaan adalah penyumbang utama dalam penggunaan tenaga elektrik di Malaysia. Pelbagai kajian dan usaha telah dijalankan untuk mengatasi masalah ini. Polisi penjimatan tenaga adalah salah satu kempen yang telah dijalankan oleh kerajaan sebagai satu inisiatif untuk mengurangkan penggunaan tenaga. Ini akan dengan tidak langsung mengurangkan kos operasi tenaga sesebuah organisasi atau bangunan. Walaubagaimanapun, kebanyakan bangunan menggunakan tenaga di tahap operasi dan pembaikan. Oleh yang demikian, pengiraan dan pengurusan penggunaan tenaga adalah satu langkah yang sedang dikaji untuk mengurangkan penggunaan tenaga. Dalam kajian ini, fokus ditumpukan terhadap penggunaan tenaga di Pusat Pengajian Kejuruteraan Mekanik, USM kerana penggunan tenaga yang tertinggi antara bangunan-bangunan pusat pengajian yang lain. Kerja lapangan dan pemeriksaan telah dijalankan dan melalui audit tenaga, sebab dan punca penggunaan tenaga elektik yang tinggi telah dikenal pasti. Sistem pendingin hawa semasa menyumbang 58% daripada jumlah kesulurahan penggunaan tenaga di bangunan pusat pengajian. Untuk mengatasi masalah ini, sistem pendingin hawa semasa perlulah diubah suai. Sistem pendingin hawa dengan teknologi inverter perlulah digunakan. Pendingin hawa inverter mengubah kelajuan pemampat dan menghantar kuantiti udara yang tepat. Walaupun harganya mahal daripada pendingin hawa semasa, pendingin hawa inverter adalah 30%-50% lebih murah apabila berfungi kerana menggunakan tenaga yang kurang.

ABSTRACT

As Malaysia moves towards the status of developed nation, the consumption of electrical energy has become an important role this day and has causes huge demand of building and electrical energy. Building sector is the major responsible for electrical energy utilization in Malaysia. Numbers of research and efforts have been done in order to cope with this problem. Energy saving policy is one of the campaigns done by the government as an initiative to reduce the energy consumption. This will eventually reduce the energy operating cost of an organization or building. However, most of the buildings used energy within the operation and maintenance stage. Therefore, measurement and management of energy usage is one approach that is being studied to reduce the energy consumption. In this project, the focus is on the energy usage of School of Mechanical Engineering, USM as school building has the highest electricity consumption among other schools building. Field work and inspection had been done and through energy audit, the cause and reason for high electricity consumption had been determined. Existing air conditioning system contributed 58% of total power consumption of school building. To overcome this problem, the current air conditioning system needs to be re-engineered. Inverter ait conditioning system should be used. Inverter air conditioning system varies the speed of the compressors, delivering precise cooling or heating required. Even it is more expensive than the existing ait conditioning system, an inverter air condition is at least 30%-50% cheaper to run as it consumes less power.

CHAPTER 1

INTRODUCTION

The electricity consumption has become an important role in Malaysia, as it is moving toward a developed nation. Huge demand of building and electrical energy is because of the growing population. Demand of energy use by the building's occupant had leads to this phenomenon. In addition, construction sector is one of the fastest growing sector and amongst the main contributor of energy consumption in Malaysia. Development of construction sector in Malaysia not only gives a big impact on country development but also cause energy demand to increase [1].

High economic growth has cause a significant increase in energy sector in Malaysia. The change in policy of the government has leads to this positive connection. Policy change from agricultural based to technological has caused a huge impact in economic growth in the last three decades. The total electricity consumption has increased by 9.2% from 1980 to 2009, whilst domestic product (GDP) has increased by 6.2% from 1980 to 2009 [2].

An energy-efficient building is a building that can maintain the environment and condition of the occupant while reducing the energy consumption as well as the building electricity cost. There are some other methods that can be used in order to optimize the energy consumption. Energy management system and energy efficacy analysis is some example of the methods.

1.1 Project Background

The electricity consumption of School of Mechanical Engineering USM was the highest among all schools building in USM Engineering Campus. For the first half of 2017, electricity consumption of School of Mechanical Engineering USM was 731,911.79 kWh, 17.61 per cent less than 888,391.01 kWh in the same period in 2016. By August 2017, the building had surpassed 940,405.41 kWh of electricity consumption.

Even though the electricity consumption of school has decreased, but the total energy used in building is still high. The efficiency of energy use has improved, but there is still a large potential to save a lot more energy. Energy measurement and management is one of the effective ways to reduce energy consumption and increase energy efficiency simultaneously. This could be done through energy audit and energy management.

The main objective of this project includes finding out problems and caused of excessive energy consumption in School of Mechanical Engineering USM. The relationship between measurement and management of energy usage contribute significantly to the electricity consumption. Most importantly, the reduction in energy usage would indirectly help in the sustainability of our environment.

Energy management is an efficient way to utilize energy effectively. It is one of economic measures in order to improve energy utilization. Energy management could be done through energy auditing. Energy auditing involves evaluation and indication of actual energy consumption. This is important, so that the energy consumption pattern can be analysed and monitored.

Nowadays, efficient and effective ways of energy management is very crucial in order to conserve and optimize energy usage of building. This is to make sure energy cost is reduced. Many studies and research about energy management and energy audit has been done to meet the objective to find ways to reduce energy consumption.

Building Energy Index (BEI) is an indicator to represent the energy usage of a building. It is used to measure specific energy usage of a building. It calculates the ratio of total energy used against the total built-up area to determine the building yearly consumption [3], [4]. The energy index is aimed to show the raise awareness of the building owners so that they can gauge and set target for improvement over time.

1.2 Problem Statement

The main objective of this project is to reduce the energy consumption in which also leads to achieve a low Building Energy Index (BEI) level. Thus, in this project, a solution is going to be determined by measuring and managing energy usage by finding the main problem of the high electricity consumption and how to cope with this problem. Table 1 below shows the total energy usage for all school buildings in USM Engineering Campus in 2016.

Table 1.1: Total Energy Usage for all USM Engineering Campus school building in 2016

No.	School	Energy Usage (kWh)
1	School of Aerospace Engineering	754,030.51
2	School of Civil Engineering	1,116,947.53
3	School of Electrical & Electronic Engineering	1,603,279.97
4	School of Materials & Mineral Resources Engineering	1,628,322.33
5	School of Chemical Engineering	1,360,513.51
6	School of Mechanical Engineering	1,672,009.43

1.3 Project Objective

The objectives of this project are as follow:

i. To measure the electricity consumption of School of Mechanical Engineering USM
ii. To investigate the root cause of the high energy consumption by school building
iii. To propose efficient and practical solutions to minimize the energy usage

1.4 Scope of the Project

The following scope describes the work that will be completed in order to fulfil the objectives of this project. The scope is organized into the following tasks:

i. Determine the cause and reason by conducting energy audit
ii. Collect data and measure energy consumption
iii. Propose a solution to overcome this problem
iv. Analyse and evaluate energy consumption

1.5 Thesis Outline

This thesis is based on engineering problem existed which need to be solved. The problem is related to electrical energy usage. All approaches and solutions are included in all chapters in this thesis. Chapter one describes an overview about this project as well as objectives and problem statement. Scope of the project and methodology involves are also explained in this chapter. Last but not least, the work schedule for semester one and semester two.

Chapter two discussed on literature review of previous studies. The topic reviewed is basically about energy audit and management. This includes the technology involved such as inverter air conditioner, energy auditor, building automation system and centralised control. At the end of this topic, an efficient cost-effective way to reduce energy usage should be discovered.

Chapter three discussed about the methodology for this project. All the process and method done during the project is revealed in this chapter. Overall step and flow including software and hardware involved are discussed.

Lastly, chapter four discussed about the result obtained. All data collected are compared and analysed to find out the result and find out the best solution in measuring and managing the energy usage of case study building, building of School of Mechanical Engineering USM.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literatures referred for this project were books, articles, publications, research papers and internet. In this chapter, details on theoretical about energy audit and HVAC system will be discussed In addition, the cooling load calculation has been studied and reviewed in this section. Literature scan had been done in order to get a complete understanding about this project.

2.2 Energy Audit

Implementation of energy audit can improve the buildings energy efficiency and reduce the energy wastages [4]. The needs for energy audit are as follow [5]:

a) Energy audit is a way to determine solution to reduce energy consumption per unit of product output or to lower operating costs.
b) Energy audit will provide a reference point for managing energy in the organization.
c) Energy audit will help in planning a more effective use of energy throughout organization.
d) Energy audit will help to understand more about the ways energy and fuel are used in industry**.**
e) Energy audit would give a positive orientation to cost reduction, preventive maintenance and quality control programs.
f) Energy audit will help to keep focus on variations which occur in energy costs.

2.3 Types of Energy Audit

An energy audit is an analysis of energy use and energy consumption within a defined energy audit scope. It is an energy assessment and the level of detail of this assessment determines the type of audit. There are basically three common types of energy auditing [5]:

a) Preliminary audit or walk-through
b) Detailed energy audit
c) Investment-grade audit

2.3.1 Preliminary Audit

The preliminary audit is the simplest and quickest type of audit. It involves going around the plant and identifying visible losses and negligence in operation and maintenance [6]. The result of a preliminary audit include obtain the cumulative energy consumption for the organisation, determine the scope of savings and identify the easiest and immediate ways of energy saving [7].

2.3.2 Detailed Energy Audit

Detailed energy audit is expands from the preliminary audit [5]. It involves collection of basis data, drawings, blue prints as well as visual classification. Utility bills are collected for a 12 to 36 months period to allow evaluation on facility's energy demand rate structures and energy usage profiles. Through this type of energy audit, all energy-conservation measures appropriate for the facility can be identified [8].

2.3.3 Investment-Grade Audit

Investment-grade audit covers estimation of energy input for different processes, collection of past data and specific energy consumption. The scope of this audit is to formulate a detail plan on the basis of quantitative and control evaluation [7]. Both

energy and non-energy investments are rated on a single set of financial criteria that generally stress the expected return on investment (ROI) [5].

2.4 Energy Optimization

Operating energy demands are one of the biggest indicators of building economic operation. Building energy performance can be determined by correct access on a certain areas [9]. These areas are:

a) Description and evaluation of the initial state
b) Energy balance
c) Selection of the energy source
d) The economic assessment

2.4.1 Description and Evaluation of the Initial State [10]

In order to optimize energy and cave the environment, the most important step is to evaluate the possibilities to cut energy usage. Demand response is one of the steps to maintain the balance of energy grid. Demand response is a change in electrical energy by end-use consumers from their usual consumption amount to electricity price over time [11].

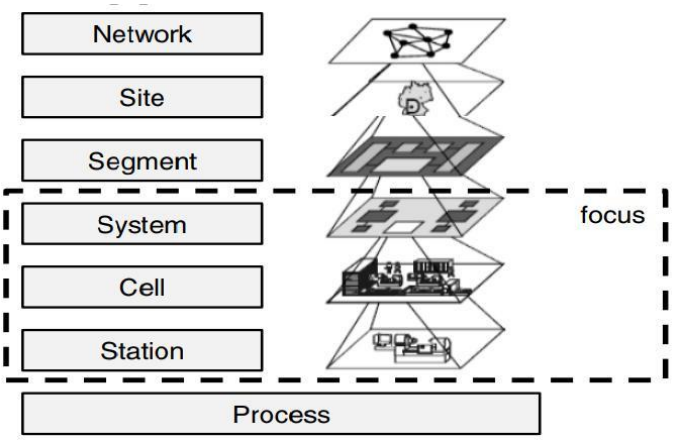

Figure 2.1 Levels of a production [10]

Based on figure 2.1, it is shown that the energy demand can be adapted by changing the energy demand from several sectors. This can be done when a production system has the ability to adapt without remarkable costs that can change energy markets.

2.4.2 Energy Balance

Type of energy as well as its amount and purpose need to balance to determine the energy intensity of a building. The thermal loss calculation method is based on the technical standard STN EN 12831. Assumptions are as follow [11]:

a) air temperature and designed temperature are equally distributed
b) temperature and other properties values are assumed constant and steady state
c) building height must be lower than 5m
d) buildings are heated to a specified temperature interval
e) temperature and resulting temperature of the air must assume the same

Total design heat loss of heated area formula is as follows:

( ) (W) (2.1)

– designed thermal loss in the transition of heat in the heated space (W)

– designed heat loss caused by ventilation in the heated space (W)

– temperature correction factor (-)

2.4.3 Selection of the Energy Source

Selection of energy source should be done separately for each building. Some consideration should be done in choosing energy source, mainly on the building technical characteristics, building location site, purpose of the building, operation time and so on [12]. There are three approaches in the nature of temporary modular buildings, which are [9]:

a) The first approach focused on easy access to the local energy and local renewable energy sources.

b) Second approach is to exclude the installation of the heat pump water which is expensive to install.
c) Third approach is by choosing a renewable resources is simple to install and easy to operate.

2.4.2 The Economic Assessment [11]

This assessment will be evaluated in terms of economic efficiency. This includes the use of investment funds and the saving effect achieved. The economic assessment is based on the building value before and after the implementation of austerity measures and the determination of the rate of return.

2.5 HVAC System

HVAC system is the technology for indoor environmental comfort. Its purposes are to optimize the building's energy consumption, ensuring the occupant's comfort, and preserving air quality [13]. Due to its huge impact on environmental factor, HVAC system is the most energy consuming device and its usage has been a problem on electricity demand. High power needed to operate it has resulted in increases of electricity cost. The total electric peak load induced by air-conditioning is estimated to be equal to 38 percent of the non-coincident peak load [14].

In [13], the proposed technology is computationally simple and requires access to some data. Most of the data exist in building energy management and control systems. A cost-effective building operating strategy is needed to reduce energy costs associated with the operation of the HVAC system. Three methods is used to determine the most significant energy savings method. There are simple control strategy (SCS), detailed control strategy (DCS) and existing control strategy (ECS). The idea of this journal is to find the controller set point of supply air temperature and chilled water temperature that has the minimum total energy use. These strategies are done by respecting the thermal comfort in the zone. In order to do that, the set points for chilled water supply temperature and ducts static pressure were determined.

In [15], HVAC prescriptive requirements in energy regulations has been classified into six categories; equipment minimum efficiencies, fluid distribution systems, HVAC control, ventilation, heat recovery and free cooling.

2.5.1 Equipment Minimum Efficiencies

Energy efficiency indicates equipment efficiency for a given time at a certain load state and operating condition. It also expresses the average efficiency during a typical operation period. There are four steps in the development of equipment energy efficiency; construction of energy efficiency, definition of standard procedures for their assessment, certification of performance by an independent organization or laboratory, and setting minimum efficiency figures [16].

Table 2.1: Average energy efficiency indicators for HVAC equipment [16]

Equipment type	**EEI**	**Rating standard**
Unitary air conditioners and heat pumps	SEER SCOP IPLV	AHRI 210/240 AHRI 210/240 AHRI 340/360
Boilers and furnaces	AFUE BSE	DOE 10 CFR Part 430 Part L: Second tier document
Chillers	IPLV	AHRI 550/590 AHRI 560

2.5.2 Fluid Distribution Systems

A fluid transportation system is energy-efficient when distribution losses and energy use of fluid movers are reduced [16].

Table 2.2: HVAC systems requirements for fluid distribution systems [16]

Type	**Requirements**
Insulation requirements	Minimum insulation thickness Minimum thermal resistance Maximum thermal losses per unit length or area Thermal losses to delivered energy limitation
Sealing requirements	Maximum leakage rate Duct leakage tests
Specific consumption	Fan power limitation Pump power limitation
Load calculations	Load calculation procedures Design criteria for load calculations
Design temperature rise	Air supply to room temperature difference Water supply to return temp. difference at coils
Pressure losses	Pressure drop limits for some devices Maximum pressure loss per unit length

2.5.3 HVAC Control Requirements

Regarding to [16], HVAC control requirements can be organized in five categories; zone controls, air handling unit (AHU) controls, water loop controls, primary equipment controls and energy metering.

Table 2.3: Requirements of HVAC control systems [16]

Component	**Requirement**
Zone controls	Thermal zoning Zone isolation Temperature controls Humidity controls Simultaneous heating and cooling VAV boxes
AHU controls	Variable air volume Variable air temperature

Water loops controls	Variable water flow Variable water temperature Pump isolation Heat pump loops
Primary equipment controls	Load management Equipment controls Cooling towers Heat pumps
Energy metering	Metering and monitoring

2.5.4 Ventilation Requirements

Ventilation is the process of replacing contaminated indoor air with fresh air from outside the building. In mechanical ventilation, the airflow is distributed by means of fans and ductwork arrangement throughout the building [17]. Then, the air is distributed through diffuser. The ventilation component of energy usage in buildings has increased relative to the total energy consumption [18]. However, air flow recirculation and room pressurization requirements can increase minimum outdoor air requirements above labels required by indirect methods [16].

2.5.5 Heat Recovery Requirements

Technologies to recover waste energy are energy-efficient measures and are widely implemented in industrial and building sector. The main recoverable thermal energy flows in HVAC facilities are flue losses recovery, exhaust air heat recovery, condenser heat recovery, air economizer and water economizer [16].

Table 2.4: Requirements for heat recovery and economizer in HVAC systems [16]

Requirement	**Description**
Flue losses recovery	External recovery devices to preheat air Use of condensing boilers to recover latent heat

Exhaust air heat recovery	Installation of minimum efficient heat recovery devices Bypass to allow effective economiser operation
Condenser heat recovery	To meet sanitary water heating demand To meet simultaneous heating and cooling loads
Air economizer	Increasing outdoor air volume to reduce cooling coil loads Simultaneous operation of economizers and cool generators
Water economizer	Use of water from rowers to reduce cooling primary loads

2.5.6 Free Cooling Requirements

Free cooling is a method to lower the air temperature in a building by using low external air temperature instead of mechanical refrigeration to assist in chilling water. When free cooling, it is possible to save about 15% of the delivered energy compared with the standard beam system [19]. The idea of the free cooling is to eliminate cooling loads when outdoor condition permit, using evaporative cooled water from a cooling tower to either:

a) Cool supply air in cooling coils
b) Precool return water in hydronic systems
c) Precool supply air in water-cooled unitary air conditioners

The saving potential of free cooling is significantly decreased if the economizer control is only activated in place of mechanical cooling [16].

2.6 Inverter Air Conditioner System

The conventional air conditioner system uses a compressor that switch on/off periodically in regulating the temperature of a zone. The basic diagram showing the

process is shown in Figure 2.2. A thermostat is usually used to determine the ambient temperature and switch the compressor on when the ambient temperature is higher and off when the ambient temperature is lower than desired temperature. This will caused a large variation in room temperature and also high energy consumption owing to frequent on-off cycle [20].

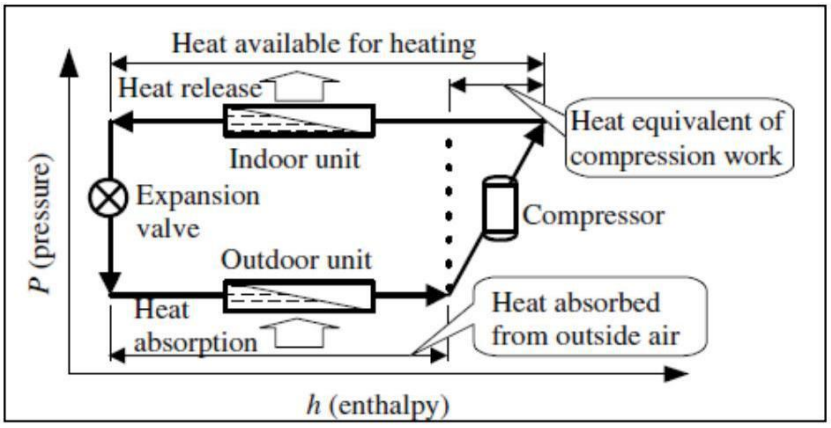

Figure 2.2: Diagram of heat pump cycle in heating [20]

Whilst, for inverter air conditioner system, it uses a variable frequency drive to control the speed of moot and compressor. The compressor is driven at variable speed and will contribute to comfort as a result of the stable room temperature. Thus, result in reduction of energy consumption as input power to the compressor is reduced and efficiency of heat exchange improved.

2.7 Building Energy Index

Building Energy Index is used for comparing energy use in buildings [4]. It is usually expressed as kWh/m^2/year. In this study, the researchers focused on investigating the energy consumption for three selected government office building in Malaysia and to identify BEI for each building. The calculation for Building Energy Index (BEI) is as follows:

$$\text{BEI} = \text{Total Energy Used (kWh/year)} \; / \; \text{Gross Floor Area (m}^2\text{)} \qquad (2.2)$$

The energy consumption of the three buildings is calculated based on the monthly electricity consumption history and as expected, the most electricity consumption was from air-conditioning, ventilation and electrical lighting [4]. The distribution of energy consumption of the building office is summarized in Figure 1.

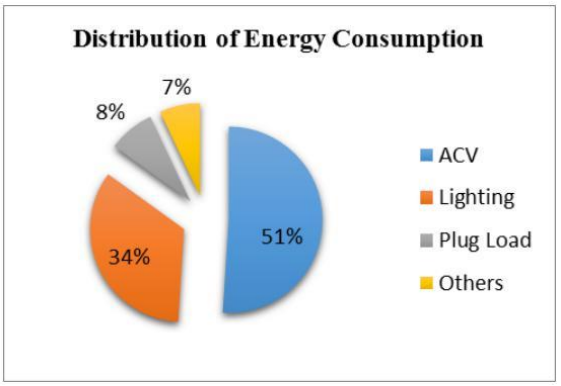

Figure 2.3: Average distribution of energy consumption of the building office [4]

Overall, the Air Conditioning Ventilation System (ACV) has the highest consumption of energy but, the average distribution of energy consumption of building might be different as building of School of Mechanical Engineering has plenty of equipment and machines that use large amount of electricity when operating.

2.8 Wireless Sensor Network

Integration of wireless sensor network with internet communications into a platform is to support energy management. Energy information is collected using wireless devices operating with various communication standards. It is found that it is possible to remotely control an electrical appliance through wireless but still there is still lack of understanding on why there is still different even the same direct energy feedback in the same format has been given [21].

2.9 Energy Management Study Case by Previous Researchers

Several thesis and journal have been reviewed in order to get some idea and information about the energy management done by other researchers. The results from the literature review are as follow:

2.9.1 Electrical Energy Audit in Residential House by Awanish Kumar, Shashi Ranjan, M. Bharath Kumar Singh, Priyanka Kumari, and L. Ramesh

The purpose of the energy audit of this case study is to save electricity as well as other resources. In this case study, historical data on energy consumption is reviewed based on electricity bills. Based on one of the researcher, it is better to look for other renewable resources present and find out a better energy audit approach and more efficient energy technology. Through this study, consumer will get to know the procedure for residential energy audit. Some of the procedure that have been implemented in the case study is as follows [22]:

- Calculation of load usage
- Plot electric usage graph
- Data collection of all major equipment

The audit process has been conducted at 29 buildings consist of 25 houses, 2 industrial buildings and 2 commercial buildings. Based on the result obtained from the case study, the energy consumption is mainly from the air conditioner and other major equipment such as fridge and fans. From the case study, it is also found that manufacturing year influenced appliance performance. This is due to the difference in technology existed.

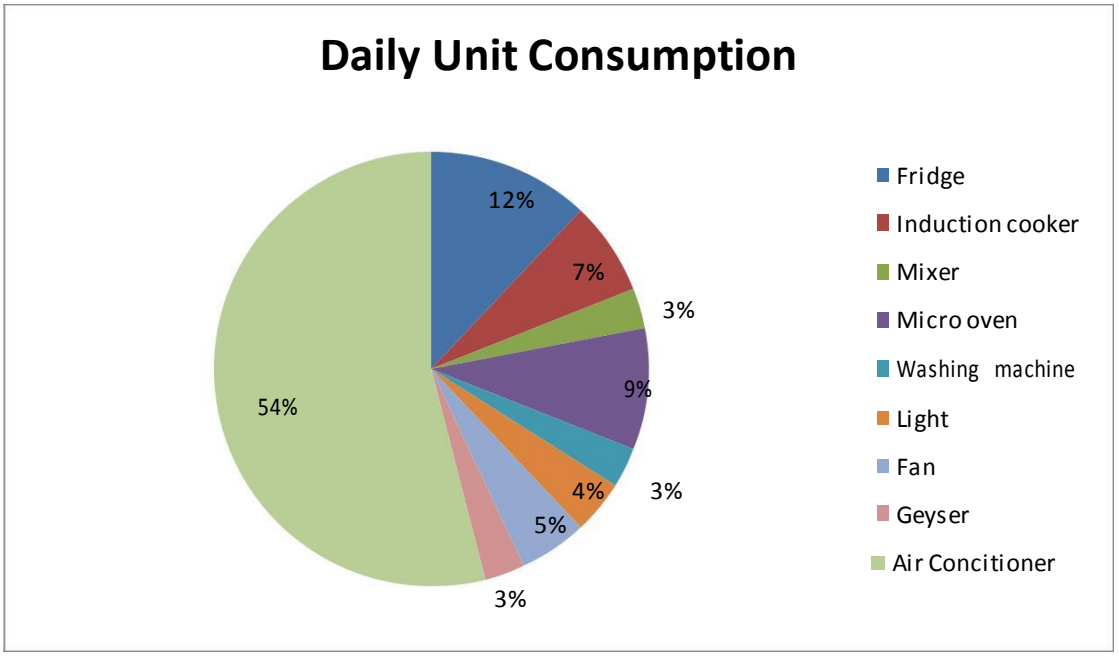

Figure 2.4: Daily power utilization [22]

2.9.2 Energy Audit of an Industrial Site by Matteo Dongellini, Casiomo Marinosci, and Gian Luca Morini

8 large industrial buildings have been inspected to get a preliminary energy audit. The researchers chose to conduct the energy audit in industrial site because as compared to non-residential buildings, industrial building are usually characterized by larger thermal loads, ventilation losses and pollution control requirements. Industrial site is needed to the energy audits to monitor energy consumption as well as to save energy. The energy audit is done according to Italian standard. The procedure is as follows [23]:

- Complete energy analysis of the whole system
- Energy waste identification
- Retrofitting plan definition is needed to reduce energy consumption
- Implementation of a systematic plan
- Monitor the results

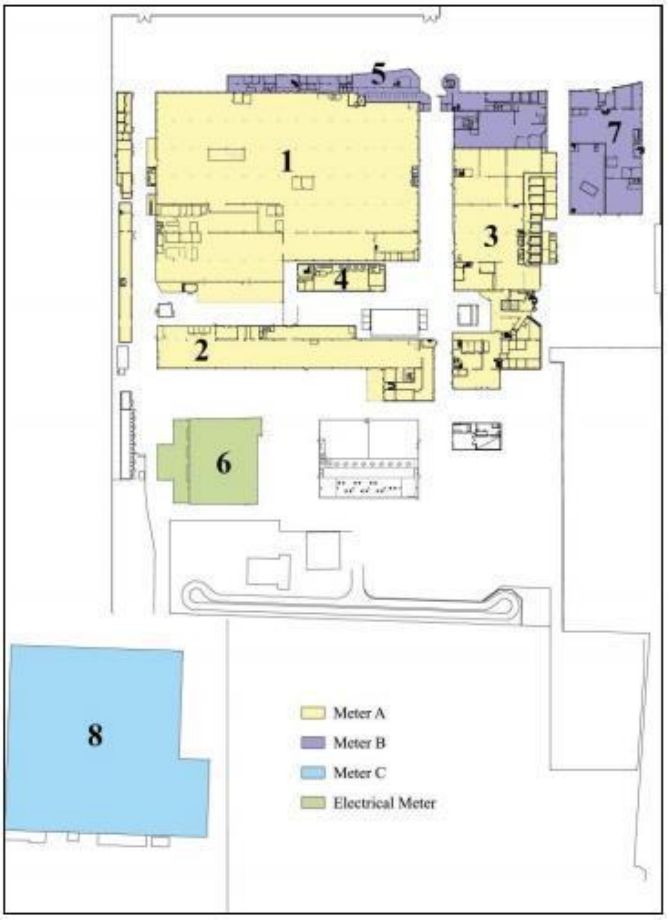

Figure 2.5: Layout of the factory [23]

The factory is divided into several parts and every part is occupied with different envelops and heating system. Unfortunately, the thermal layout is complex. There is no correlation between buildings and thermal plants as each part is occupied with different systems and manufactured different items. However, the result obtained could be considered for each building standard condition.

2.9.3 Energy Audit A Case Study of University by Lakshminarayana and Jayatheertha [24]

In India, the educational institutions are mainly equipped by ceiling fan and lighting. Energy efficient technology such as super fan and light emitting diode tube light can save a lot of energy. Through this case study, the researchers aimed to evaluate the energy audit if super fan and light emitting diode tube light are used.

According to the researchers, the advantages of energy management measures in university are [24]:

- Reduce load on generating station
- Save environment as an environment- friendly technology is used
- Give knowledge to students and staff so that they can implement at their houses.

2.10 Summary

The literature review is done to collect as much as possible information needed for this final year project. Journal and other reading materials have been reviewed in order to get idea to conduct this case study. This chapter provides the summary of literature reviews on topic related to energy audit, energy management, energy saving and technology involved.

CHAPTER 3

METHODOLOGY

In this section, whole method and step done during the project will be explained. The research is basically based on field work energy audit and computer software. The main tasks of this project are as follow:

i. Collect data and information about energy consumption of case study building which is School of Mechanical Engineering USM building
ii. Study all electricity sources and building parameters of school building in order to get idea how the system woks
iii. Develop methodology for energy auditing

Instruments involved in this research are personal computer and measurement apparatus; air velocity meter, relative humidity meter and thermometer.

3.1 Introduction

This chapter will focus on methodology and process flow that has been conducted. The methodology that has been done throughout this project will be elaborated. The data collection stage consists of two categories; desktop data collection and field data collection. These data are needed to calculate the Building Energy Index (BEI) of school building.

After the BEI is determined, an overall picture of potential solution to manage and reduce the energy usage will be established. All the consideration and potential solution are determined. The final process is to analyse and compare all the field data taken with standard measurement. The detail results will be discussed in next chapter.

The methodology carried out is summarized in the chart shown in figure 3.

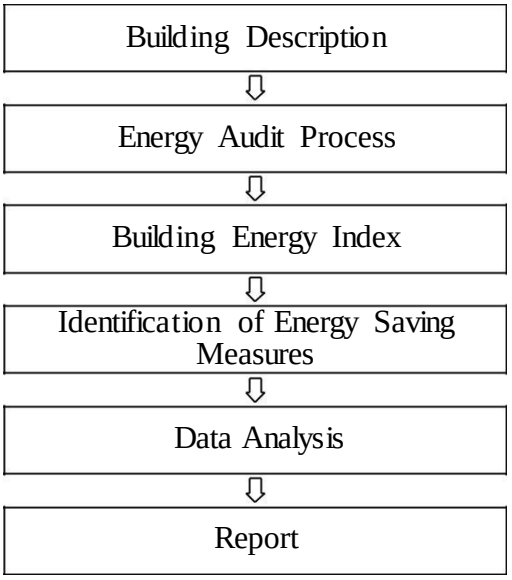

Figure 3.1: Overall project methodology

3.2 Building Description

The building involved for this project is building of School of Mechanical Engineering, USM Engineering Campus located in Nibong Tebal, Pulau Pinang. The building consists of four storeys. The building is divided into many areas such as lecture hall, tutor room, laboratory, library, meeting room, lecture room and office. The building floor area is about 12820 m^2. The building is furnished and most areas are occupied with air-conditioning. The operating hours of the air conditioning system is from 8.00 a.m. to 5.00 p.m. every day except weekend.

Figure 3.2: The case study building

3.3 Energy Audit Process

The energy audit is the primary step in conducting this project. This is important as through energy audit, where, when and how energy is being used is studied and the best solution to reduce the energy usage can be determined. There are two stages in conducting the energy audit process, which are:

i. Preliminary Audit

Through visual inspection of building air conditioning system, lighting, metering, building automation, building maintenance and other factors affecting energy consumption of school building, an overall picture of the potential of energy saving of school building is determined.

ii. Detailed Energy Audit

Detailed analysis of how the energy is being used and potential of energy is estimated. This includes saving method, technology that will be used and cost and payback period of all identified energy saving measures. A physical parameters measurement is done as well.

3.3.1 Preliminary Audit

This process involved analysis of floor plan, air conditioner system drawing, electrical plan and list of assets in order to identify the existing energy usage of school building. A field work has been done to inspect the operational and equipment features in school building. The main purpose of the field work is to obtain general information and understanding about the systems; air conditioning system, lighting system, socket outlet system, of the school building. All data taken has been recorded in Appendix A.

3.3.2 Detailed Energy Audit

The second step is the detailed energy audit. Some measurement has been conducted during the energy audit process. This is to obtain the best information for successful energy cost control program. The physical parameters that were measured are air velocity, air temperature and relative humidity. The measurement shall be taken in locations where the extreme values of the physical parameters are estimated to occur [25].

3.3.2.1 Physical Parameter Measurement

When performing a physical parameter measurement, the following procedures shall be followed [25]:

i. Location for taking the measurement shall be the center of the room.
ii. Measurement intervals for air temperature and humidity shall be five minutes or less, and for air speed shall be three minutes or less.
iii. Height above floor for air temperature and average air speed measurement shall be taken at the 0.1, 0.6 and 1.1m for seated position while and 0.1, 1.1 and 1.7 m for standing position.

Physical parameters measurement is conducted to obtain the best information for successful energy cost control. All the data collected is then compared with standard measurement as described in Malaysian Standard MS1525:2014 [26]. This is to

determine whether existing HVAC system in school building satisfied the comfort level as outlined in the MS1525 [26] or not.

The physical parameters that have been measured are air velocity, air temperature and relative humidity. Apparatus used to take the reading are anemometer, digital thermometer and digital hygrometer. All the apparatus has been calibrated first before measuring the physical parameters.

Figure 3.3: Anemometer

Figure 3.4: Hygrometer

The physical parameter measurement is conducted at lecture room and workshop at ground floor, laboratory and tutor room at first floor, office at second floor and lecturer room at third floor.