
## Faculty of Mechanical Engineering

# ENERGY AUDIT AND IMPROVEMENT IN THE HUMAN DEVELOPMENT AND LANGUAGE BUILDING

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# ENERGY AUDIT AND IMPROVEMENT IN THE HUMAN DEVELOPMENT AND LANGUAGE BUILDING

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## DECLARATION

I declare that this project entitled "Energy Audit and Improvement in The Human Development and Language Centre Building" is the result of my own research except as cited in the references. The project has not been accepted for any degree and it is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : ABDALRAOUF ABDULSALAM MUSOD

Date : 1/2/2019

## APPROVAL

I hereby declare that I have read this report, and in my opinion, this thesis is sufficient in terms of scope and quality for the award of Master of Engineering in Mechanical Engineering (Energy Engineering).

| | | |
|---|---|---|
| Signature | : | Anuar ..... |
| Supervisor Name | : | DR. SHAMSUL ANUAR BIN SHAMSUDIN |
| Date | : | 25 JANUARY 2019 |

## DEDICATION

I would like to present my work to those who did not stop their daily support since I was born, my dearest father, and my kindest mother, who never hesitate to provide me all the facilities to push me forward as much as they can. This work is a simple and humble reply to their much goodness I have received all this while. I thank them for giving me many chances and I love them so much.

I also dedicate this project to my brothers who have supported me through my life. I always miss them, and I cherish the memories that we have had. I love you all forever.

## ABSTRACT

In this study, attempts were made to measure and evaluate existing internal parameters, which focus on *Pusat Bahasa dan Pembangunan Insan* (PBPI) building located on the UTeM main campus. Physical parameter requirements (energy consumption, air velocity, air flow, operating temperature, relative humidity and lighting intensity) compared to current Malaysian standard (Malaysian Standard 1525: 2014). The results for this project supply a pattern in internal fluctuations and comfort parameters. The project also analyzes the effects of indoor parameters at the comfort level of the occupants and investigates the impact of lighting changes as well as to, analyze and evaluate energy consumption. Based on information and data collection, the total building lighting and total energy consumption of estimated the current energy consumption for all floors. The air conditioning recorded the highest rate consumption was 72% of electricity usage in building, followed by the consumption of lighting was found to be 18% and other equipment 10%. Physical parameter data are collected in three sessions which is from 9:00 am to 11:00 am, 12:00 pm to 2:00 pm and from 3:00 pm to 5:00 pm with an interval of 2 minutes in each reading, the total average air velocity was recorded about 0.1764 m/s. The total average air flow was recorded about 9.8755 CFM. The average operating temperature was recorded (22.758°C) less than that of the Malaysian Standards MS 1525:2014 (24°C – 26°C). The average humidity was recorded 68.306% and average lighting intensity was recorded 461.422 lux. In addition, the Building Energy Index (BEI) for 2016/2017 is 128.53 kWh/m²/year and 137.55 kWh/m²/year for 2017/2018. BEI values in 2017/2018 were higher than that specified in MS 1525:2014 Standards, which is 135 kWh/m²/year. Finally, economic analysis is accompanied by potential alternative measures to achieve optimum building energy utilization.

## *ABSTRAK*

*Permintaan yang semakin meningkat bagi penggunaan tenaga dan kualiti alam sekitar yang lebih baik telah dimotivasi dalam mencari penyelesaian moden untuk kecekapan tenaga, penggunaan elektrik dan pemuliharaan dalaman. Dalam kajian ini, usaha dibuat untuk mengukur dan menilai parameter dalaman yang sedia ada, yang menumpukan kepada bangunan Pusat Bahasa Dan Pembanguan Insan (PBPI) yang terletak di kampus utama UTeM. Keperluan parameter fizikal (penggunaan tenaga, halaju udara, aliran udara, suhu operasi, kelembapan relatif dan intensiti pencahayaan) berbanding dengan piawaian Malaysia semasa (Malaysian Standards 1525:2014). Keputusan dalam projek ini membekalkan corak ilustrasi dalam fluktuasi cuaca dalaman dan parameter keselesaan. Projek ini juga menganalisis kesan parameter dalaman di tahap keselesaan penghuni dan menyiasat kesan perubahan pencahayaan lampu tambahan, menganalisis dan menilai penggunaan tenaga. Berdasarkan maklumat dan pengumpulan data, jumlah pencahayaan bangunan dan jumlah penggunaan tenaga dianggarkan penggunaan tenaga semasa untuk semua tingkat yang penghawa dingin merekodkan penggunaan kadar tertinggi iaitu 72% penggunaan elektrik di bangunan, diikuti dengan penggunaan lampu 18% dan peralatan lain 10%. Data parameter fizikal dikumpulkan dalam tiga sesi iaitu dari 9:00 pagi hingga 11:00 pagi, 12:00 hingga 2:00 petang dan dari 3:00 petang hingga 5:00 petang dengan julat 2 minit dalam setiap bacaan, jumlah purata kelajuan udara dicatatkan kira-kira 0.1764 m / s. Jumlah purata aliran udara dicatatkan kira-kira 9.8755 CFM. Suhu operasi purata direkodkan (22.758℃) kurang daripada Malaysian Standards MS 1525: 2014 (24℃ - 26℃). Kelembapan purata mencatatkan 68.306% dan intensiti pencahayaan purata mencatatkan 461.422 lux. Di samping itu, Indeks Tenaga Bangunan (BEI) untuk 2016/2017 adalah 128.53 kWh / m² / tahun dan 137.55 kWh / m² / tahun untuk 2017/2018. Nilai BEI pada 2017/2018 adalah lebih tinggi daripada piawaian MS 1525:2014 iaitu 135 kWh / m² / tahun. Akhir sekali, analisis ekonomi disertakan dengan langkah-langkah alternatif yang berpotensi untuk mencapai penggunaan tenaga bangunan secara optimum.*

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## LIST OF SYMBOLS

| | | |
|---|---|---|
| M/s | - | Meter per second |
| °C | - | Degrees Celsius |
| hr | - | Hour |
| BTU | - | British thermal unit |
| M | - | Meter |
| kW | - | kilowatt |
| Ib | - | Pound |
| W/ $m^2$ | - | Watt per meter square |
| % | - | Percentage |
| TR | - | Tones Refrigerant |
| $CO_2$ | - | Carbon Dioxide |
| Ft | - | Feet |
| Cfm | - | Cubic feet per minute |
| ppm | - | Parts-per Million |

## LIST OF ABBREVIATION

| ABBREVIATIONS | DESCRIPTION |
|---|---|
| PMV | Predicted Mean Vote |
| PPD | Predicted Percentage Dissatisfied |
| ACMV | Air-conditioning & Mechanical Ventilation |
| IEQ | Indoor Environmental Quality |
| BEI | Building Energy Index |
| TNB | Tenaga National Berhad |
| GMT | Greenwich Mean Time |
| GW | Giga Watts |
| GDP | Gross Domestic Product |
| USGBC | Building Council of the United States of America |
| BRE | Building Research Establishment |
| BREEAM | BRE Environmental Assessment Method |
| MRT | Mean Radiant Temperature |
| UTCI | Universal Thermal Climate Index |
| IAQ | Indoor Air Quality |
| LEO | Low Energy Office |
| CO | Carbon Monoxide |
| $CO_2$ | Carbon Dioxide |

| | |
|---|---|
| Rn | Radon |
| VOC | Volatile Organic Compounds |
| RAC™ | Room Acoustic Comfort™ |
| HVAC | Heating, Ventilation and Air-Conditioning |
| GHG | Greenhouse Gas |
| SET | Standard Effective Temperature |
| TAC | Task/Ambient Conditioning Systems |
| RH | Relative Humidity |
| $NO_2$ | Nitrogen Dioxide |
| VOC | Volatile Organic Compound |
| AHU | Air Handling Unit |
| UTeM | Universiti Teknikal Malaysia Melaka |
| UTHM | Universiti Tun Hussein Onn Malaysia |
| MS | Malaysian Standard |
| ISO | International Organization for Standardization |
| EN | European Standard |
| CONS | Consumption |
| ECU | Engine Control Unit |
| SHGC | Solar Heat Gain Coefficient |

# CHAPTER 1

# INTRODUCTION

## 1.1 Research Background

There are a few factors that contribute to the development of countries, such as the growing number of commercial premises and development projects for a residential and non-residential buildings. In directly, these factors impact the demand of energy in the country. Therefore, relevant policies and strategies are adopted to preserve and sustain the environment. Due to the energy crisis occurred in 2006, developers and engineers have become more competent in designing and maintaining buildings, thus, the usage of energy could be monitored in better way to reduce energy waste (Sukri et al., 2015). A wide knowledge of the management issues and an accurate energy audit for buildings represent basic pillars for the critical issues of energy consumption, to support decisions on priority actions and their cost (Magrini, 2016). The process of modelling the transfer of energy between buildings to its surrounding is known as thermal performance. Heating and cooling loads are considered for a conditional building. Therefore, suitable HVAC equipment should be assigned accordingly. On the other hand, non-air-conditioned buildings varied temperatures inside a building can be monitored over a period of time to evaluate the endurance to discomfort. These elements are essential to determine the best designs of a building, and to further devise improved designs that would provide more comfortable indoor conditions (Gulati, 2017).

Energy audit is an important method or a systematic process of energy evaluation to reduce energy consumption by identifying electrical energy efficient measures (EEMs). It applies certain methods for analysis to evaluate the records of energy utilized in order to develop EEMs in buildings (Lee et al., 2015). An energy audit established in UTeM in 2018 is an energy utilization profile of electrical devices in terms of kWh consumption, cost and the operating hours, such as air–conditions, lights and other electrical equipment. It was concluded that a large amount of energy was consumed for the purpose of air–conditioning and lighting systems, having high potential of energy saving. Therefore, EEMs were developed and implemented to reduce energy utilization and the cost for the lighting and air–conditioning systems. Building managements should fully cooperate and embrace the importance of an audit since it is impossible to perform an audit without the involvement of the top management and the entire staff (Muhammad, 2017).

As mentioned earlier, lightings and air–conditioning systems consume the most energy in a building. Approximately 25% of the total energy is consumed by the lighting system alone. This energy waste is caused by the irresponsible behavior of staff that failed to switch off the lights before they leave their premise of work. The management could install efficiently designed lightings with improved and qualify lights to reduce energy waste (Sarsour, 2017). On the other hand, air–conditioning consumes approximately 56% of the total energy. Hence, it is the highest energy utilized in a building. Energy waste occurs when the air–conditioning system are not switched off accordingly when it is not needed and also the behavior of staff who would leave the doors and windows open. An improvised system control of equipment losses be achieved by using an efficient air–conditioning system (Hua et al., 2011). Energy audit identifies energy waste and develops EEMs. Hence, energy recorders are used to determine the real energy utilization of the

lighting and air–conditioning systems. There are two methods of electrical energy audit that can be conducted i.e. simple audit and detailed audit. A simple audit is a low cost audit that develops low cost measures, whereas a detailed audit develops medium or high cost EEMs that are expensive and also time consuming to execute (Wang and Huang, 2017).

According to the previous works, a significant portion in the range of 20% - 60% energy consumed in a building is due to the energy used to run the fans and pumps in chiller. Not to forget, the energy used in heating or cooling is transferred from central system to cooling plants. Humidity of air is controlled by air–conditioning system by increasing or decreasing the moisture content in the air. Other portions of air-conditioningsystem are such as the heating and cooling of air by controlling the temperature, washing and filtering that purifies the air and the control of air motion and ventilation. The process of suppling and removing air by natural or mechanical means, to and from any space is known as ventilation. The air from ventilation may or not may be conditioned (Hordeski, 2011).

A new and existing building must comply with Malaysia Standard policies which are required to meet MS 1525:2014 while undergoing the design, construction, operation and maintenance. Energy is mostly consumed by air-conditioning systems in offices, educational premises, commercial buildings and homes to provide comfort to the occupants. As a result, the Department of Standards Malaysia (DSM) published the Code of Practice for Energy Efficiency and Use of Renewable Energy for Non-Residential Building, with the purpose to mainly outline installation. It also requires managements to minimize the usage of energy without compromising the design, the function of the building, the comfort or the productivity of the residents (Malaysian Standards, 2014).

The concept of energy efficiency and developing sustainable buildings have become popular in both developed and developing countries, yet it is not attainable due to the gap between the real situation and the ultimate objectives. Even though current energy systems are improving, they still fall disappointingly short of meeting desirable values for good efficiency. Hence, well-trained energy auditors are important to guarantee the success of constructing energy efficient buildings. The energy audit results in government buildings as published by *Pusat Tenaga Malaysia* in 2014 refers to major commercial buildings in tropical climate such as in Malaysia are shown in Figure 1.1 (GTM, 2015).

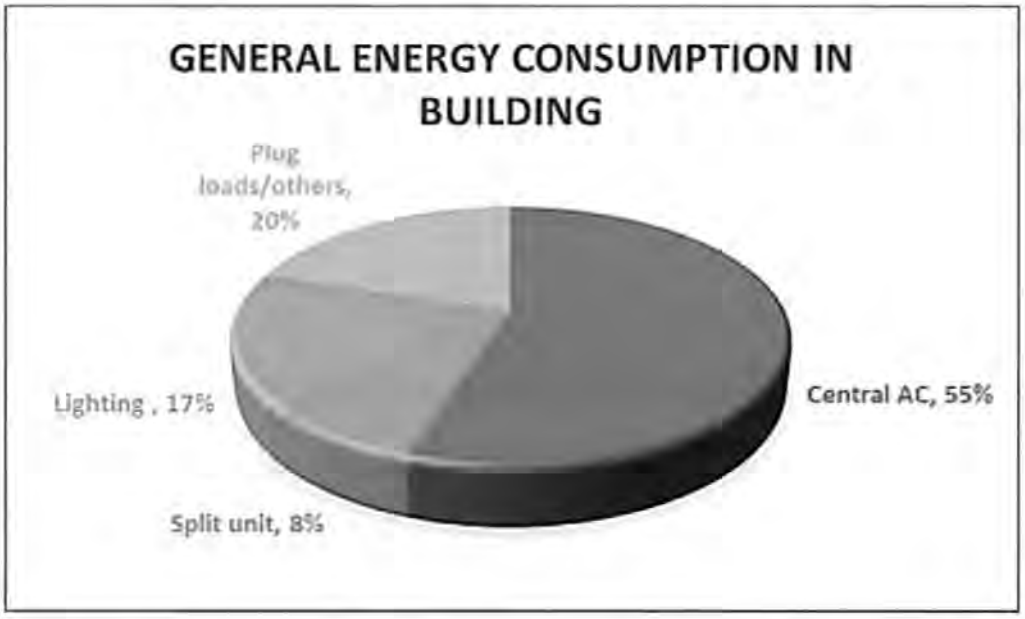


Figure 1.1: Energy Audit in Government Buildings (GTM, 2015)

It reveals that the commercial building programs should give importance to the air-conditioning system, lighting system and plug loads. The audit also classified energy wastes in to three categories:

- Inefficient buildings and equipment design and retrofit.
- Poor building commissioning practices.

• Inadequate maintenance and operations in the buildings.

Energy efficiency programs in commercial building should be implemented to bring comfort to occupants by maintaining Indoor Air Quality (IAQ), and at the same time, ensure financial profit to the owners. Many office buildings exceed the level of energy index by 250 kWh/m²/year, although the standard index given by MS 1525:2014 for air-conditioned offices. According to the Malaysian Standards MS1525:2014, it is recommended that commercial building energy index (BEI) in Malaysia is 135kWh/m²/year. (Noranai et al., 2011).

In this present work, Detailed Energy Audit has been conducted at the selected building and all related data about that building was collected in order to get overall picture of the building energy consumption. From this data, potential energy saving measures that can be implemented in the building are discussed.

## 1.2 Problem Statement

It is evident that electrical energy utilized in buildings continues to increase and will continue to grow in demand, utilized by the advanced technology used in electrical equipment (Singh et al., 2012). An energy audit is crucial to obtain an optimal energy performance by reducing the energy waste and improve the efficiency of air-conditioning and lighting systems. Critical evaluation and advanced study are required in order to achieve measures that would maximize building energy efficiency.

This project aims to conduct building energy performance analysis for the academic building in the university (the Centre for Languages and Human Development PBPI) and also to provide possible energy-consumption improvement of the building. In doing so, it also boosts and supports UTeM energy policy.

## 1.3 Research Objectives

I- To evaluate the efficiency of energy used in selected academic building (Center for Languages and Human Development, PBPI) at Universiti Teknikal Malaysia Melaka.

II- To compare the analysis between the actual and theoretical building suggested by MS1525:2014 and Green Building Index specifications.

III- To investigate possible energy-consumption improvement options.

## 1.4 Project Scope

This research explores various options in energy saving devices and then to propose the best characteristic needed to combine together in order to get the optimal product with the balance of cost and function. In general, this research may focus on designing and developing of a "controller" for managing the electrical energy. By using the university campus as the project area, the project starts with studying the need of energy efficiency. The research knowledge and information about the energy efficiency project implementation is crucial to make sure that the project will give full benefits.

Moreover, this study involves gathering of data such as area of the building, electricity bills, lighting system, air-condition and measuring indoor air physical parameters, such as humidity, temperature and airflow in the building of the Centre for Languages and Human Development (PBPI), which consists of three levels. The selected location is on UTeM main campus. It determines the current indoor air-condition of non-equipped building to evaluate requirements to reach the comfortable and acceptable indoor condition of each type of rooms, since, this building have been used as educational

purposed functionally and classified as office, classroom and laboratory. Finally, it aims to propose cost saving methods for auditing building.

## 1.5 Significance of the Study

An evaluation of energy conservation and its flow in a building, with a system to reduce energy waste is defined as energy audit. A methodology is a theoretical analysis of the methods applied in this project in reducing present time energy usage as much as possible while improving the condition and comfort using relevant equipment. Hence, actual results and database of energy utilized and the consumption of energy for air-conditioning and lighting system in PBPI building will be discussed in the following chapters.

Justifications of the research are as listed below.

I- Analysis energy consumption at PBPI building using measured data for electricity.

II- Provide data for the consumption of energy for air-conditioning and lighting system also physical Parameter measurements consist of lighting intensity, air velocity, operating temperature, humidity, and air flow.

III- To support and promote government energy efficiency policy that aims to minimize nations energy consumption, and thus, decreases energy waste.

IV- Significant public health benefits should surface when the electrical energy consumption decreases. In contrast, the increasing consumption of electric power leads to the increment of used fuel, and consequently leading to air and water pollution, which is associated with many health problems such as breathing problems, heart attacks, neurological damage, and cancer.