ENERGY MANAGEMENT PRACTICES AND IMPLEMENTATION IN CAMPUS BUILDING

NIDZAMUDDEEN BIN ISHAK

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Master of Engineering (Electrical)

Faculty of Engineering Technology
UNIVERSITY MALAYSIA PAHANG

MARCH 2016

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ABSTRACT

Energy management and efficiency in building have attracted lots of attention in recent years. Various findings, products and systems in energy management and efficiency aspect have been produced in order to support the needs for a better and greener environment. New wave of energy management and efficiency programs nowadays not only just merely a product installation or specific system solution, but offer a wider approach like the management system, finding baseline energy use, benchmarking, and then only to provide reasonable return-on-investment solution. Therefore, a proper and right model of implementation should be carefully designed before implementing any energy saving measures in order to get a valid and optimized result. Thus, this research proposed a new model of energy management and efficiency system with the specific target of implementation in university campus. An energy management model is developed and findings of energy saving measures from the proposed model will be discussed. A test-bed model is also being developed in order to simulate the real energy management and efficiency in campus. Based on the energy management model and the test-bed proposed, a better result and method of energy saving implementation in campus building is obtained and proved. Finding, result and solutions based on the new model is also being discussed as to put a clear picture on the sustainable energy management purposes in campus building.

Keywords; Campus Building, Energy Efficiency, Sustainable Energy Management System, Green Technology

ABSTRAK

Pengurusan dan kecekapan tenaga di dalam bangunan telah menarik minat pelbagai pihak sejak beberapa tahun kebelakangan ini. Pelbagai bentuk penemuan, produk dan sistem di dalam bidang pengurusan dan kecekapan tenaga telah dihasilkan sebagai sokongan kepada keperluan untuk membentuk persekitaran yang lebih hijau dan baik. Gelombang baru di dalam pelaksanaan program pengurusan dan kecekapan tenaga kini tidak lagi bergantung kepada pemasangan produk atau sistem yang spesifik sahaja, sebaliknya kini telah ditambahbaik dan dikemaskini dengan pendekatan yang lebih luas seperti sistem pengurusan, penentuan asas penggunaan tenaga, penandaarasan dan lain-lain lagi. Setelah selesai proses-proses yang disebutkan tadi, barulah sesuatu sistem dan produk yang dijamin mempunyai kadar pulangan pelaburan yang baik dipasang dan dilaksanakan. Oleh yang demikian, keperluan kepada model pelaksanaan yang tepat dan jitu adalah sangat mendesak bagi memastikan sesuatu perancangan itu mendapat hasil yang berkesan dan optimum. Oleh itu, kajian ini memberi fokus kepada cadangan model baru pengurusan dan kecekapan tenaga di bangunan-bangunan kampus universiti. Satu model pengurusan tenaga di universiti akan dibangunkan dan langkah-langkah penjimatan yang berkaitan akan dikenalpasti. Sebuah model peranti pengujian juga akan dibangunkan bagi membuat simulasi sebenar berkaitan langkah penjimatan yang telah dicadangkan. Hasil penjiimatan yang diperolehi dapat ditunjukkan dengan jelas berdasarkan model pengurusan tenaga dan model peranti pengujian yang telah dibina. Hasil kajian berkaitan model yang dibina juga dibincangkan secara mendalam bagi memberikan gambaran yang jelas kepada model pengurusan tenaga secara lestari di bangunan universiti

Kata kunci; Bangunan Universiti, Kecekapan Tenaga, Pengurusan tenaga lestari, Teknologi Hijau

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CHAPTER 1

INTRODUCTION

1.1 Energy Issues Overview

The world is facing unprecedented challenge in controlling increased in energy prices. The continuously rising costs and the environmental impact of energy generation, transmission and consumption are a major concern for governments, industry and society alike. Among research in renewable energy sources as well as in energy efficiency of buildings, electrical appliances, and vehicles, a considerable amount of attention has been devoted to effective energy management (Kyusakov, Eliasson, Deventer, Delsing, & Cragie, 2012).

As in Malaysia, it is predicted that the oil reserve is estimated to last for another 19 years and the gas reserve another 33 years (Selamat, Zulzikrami, & Abidin, 2010). Malaysian government also takes several steps in dealing with this energy crisis. In 9th Malaysia Plan, one of the focuses is to design, install and encourage the use of energy efficient features such as energy efficient lighting and air conditioning system especially in government buildings (Greentech Corporation, 2010). As one of the ratified country to Kyoto Protocol, Malaysia government is very committed in targeting to reduce carbon emission by 40% by the year 2020.

The topic of energy efficiency has come to dominate the energy policy world widely. This is set to continue into the future as a result of political requirements and concern about the environment and climate. The opportunity to gain cost and competitive advantages through the more efficient use of energy will also ensure that the topic does not lose its importance. Although efforts have been made in the area of energy efficiency in the past, there is still significant room for improvement (Kim, 2010; Lovins, 2004; Wu, 2009).

1.2 Systematic Energy Management Approach

Famous saying in energy efficiency stated that 'we can't control what we can't measures'. Thus, this project is aimed to measure the energy that been used, especially buildings in University Malaysia Pahang, and the process of controlling the energy level will then be discussed and further elaborated.

With the development of global economy, there are growing literatures that focuses on the issue of energy consumption of office buildings and large-scale public buildings (Ding, Member, Decker, & Vassileva, n.d.), (Kyusakov et al., 2012), (Muller, Rudolf, & Aumayr, n.d.) and (Collins, Mallick, Volpe, & Morsi, 2012). It is necessary to enhance and improve research and develop in building energy management system. The building energy monitoring and management system collects and analyzes the current energy data a building consumed especially in electrical utilities, water and steam. Then the system can effectively control and manage the energy consumption of a building in order to achieve rational and ideal energy consumption. The system should also able to forecast the future energy consumption trend within the building and make a rational proposal to consume energy based on the collected energy baseline data (Bocheng, 2012).

Research in the field of the energy management and efficiency has become a priority since it is crucial to understand where and how to increase efficiency in the building sector. Energy saving implementation in a building requires a lot of attention due to its complexity of purpose, system and equipment varieties. Building types also can be categorized by use, type of construction, size, and thermal characteristic. (Rensburg, Mathews, & Pelzer, n.d.).

This is closely related to new building energy rating methods, which are required for the development of related building policies (Prudenzi, Di Lillo, Silvestri, & Falvo, 2008; W. Wang et al., 2010; Wei & Li, 2011). Thus, a proper energy management planning is very crucial and will be different from one type of building to another.

Different building needs different solution. For example, proposed energy saving measures for shopping complex building will be different with measures for government complex building, so as for university building. All researchers need to understand the process of implementing energy management and efficiency before proposing any measures in order to have the best solution for system.

As an example, proposing a solution for energy efficiency measures which requires a lot of wiring process seems not economically efficient if it is meant for old or existing building. The process of installing sensors and other equipment which require rewiring process will definitely increase the implementation cost, and thus will affect the return-on-investment calculation (Hao et al., 2012; Tao, Yajuan, Deyun, & Hongke, 2010). A lower return on investment value may be achieved if the same proposal be implemented in newly constructed building. Therefore, prior knowledge in the process of energy management and efficiency is a must before proposing any energy saving solutions.

Energy management systems have been in existence in the energy sector for several decades. The key functions of such systems are to monitor, control, and optimize the flow and use of energy. In general, energy management systems have formidable applications in the generation, transmission and distribution systems of the electrical network (Kling & Ribeiro, 2012).

The knowledge gained from the deployment of energy efficiency projects is driving a transition from traditional tactical practices to more comprehensive strategic energy management practices. Like many modern management practices, a strategic energy management approach highlights the need for an information system to set goals, track performance, and communicate results. As the field of energy management matures, the knowledge gained from thousands of energy efficiency projects is driving a transition from traditional tactical practices to more comprehensive best practices (Gorp, 2004).

1.3 Problem Statement

The knowledge gained from the deployment of energy efficiency projects throughout the last several decades is driving a transition from traditional tactical practices to more comprehensive strategic energy management practices. Like many modern management practices, a strategic energy management approach highlights the need for an information system to set goals, track performance and communicate results. An energy efficiency management information system can support strategic energy management by capturing data about current energy performance, assisting in the creation and tracking of energy performance goals and communicating results to managers and energy project participants (Gorp, 2000).

Specific energy efficiency and management system applications that support strategic energy management should include modeling and forecasting, benchmarking, energy use and cost analysis and measurement and verification. These applications can be combined to form powerful information tools that allow organizations to gain a comprehensive understanding of current energy performance, plan and select cost-effective energy conservation measures, track performance of measures that have been implemented and verify the savings realized.

Managing various type of energy in a building requires much effort, attention and expertise. This is due to its complexity and a lot of requirement. Different building will require different setup and configuration. Thus, energy saving devices will help a lot in managing energy in buildings. Despite wide range of energy management and saving product available in market, customers will find it very hard to choose especially due to the price and also the requirement for the system (Han & Lim, 2010; Prudenzi et al., 2008; van Staden, Zhang, & Xia, 2009; W. Wang et al., 2010).

Current developments in energy efficiency products focus on single function, which is using the less amount of energy. The design is lack in determining the surrounding environment and considering the right and comfort amount of energy level for the user (J. Li, Chung, Xiao, Hong, & Boutaba, 2011).

There are two main characters of the current practice in energy management and efficiency implementation. The first character is to focus on developing a system as a whole rather than installation of specific product or solution. Secondly, different area or building function will require different method of energy management models. Therefore, it is unavoidable for energy manager and practitioners to take in account these two characters while formulating any energy management and efficiency model.

As to ensure the valid and optimized result, this research will proposed an energy management and efficiency model to be implemented in campus building. By designing this model, a more comprehensive result on energy saving measures can be obtained and a test-rig hardware mode can be precisely design in order to simulate the required energy savings. Besides that, this research will propose a smarter controller and system that take into consideration the surrounding amount of energy and then control it to the right and comfort energy level is significant. The process of designing this smart controller system will cover the use of sensors in determining surrounding energy level, verifying the standards and comfort energy level and then using appropriate method to control the output.

Combination of both the energy management and the test-bed hardware model developed in this research will demonstrate a valid and optimized result of efficient campus energy efficiency program.

1.4 Objectives

The main objectives if this research is do a comparison study about the different methods in implementing energy management and efficiency program for various areas. By comparing different method, a new and complete energy management model for campus building can be formulated correctly.

The second objective is to produce comprehensive lists of energy saving results based of the proposed energy saving models. These lists may then be arranged based on areas, cost and practicality in implementation. By having these lists, a proper result simulation can be prepared in order to prove the effectiveness of the proposed energy management and efficiency model.

Lastly, the objectives is to run the simulation on the test-rig in order to prove certain percentage of energy saving could be obtain by implementing the new energy management and efficiency model for campus buildings. The result can be used as the reference for further project implementation and improvement.

1.5 Project Scope

This research will explore various option of energy saving devices and then to propose the best characteristic needed to be combined together in order to get the best product with the balance of cost and function. In general, this research may focus on designing and developing of a controller for managing the utility energy, in this case, the electrical energy.

By using university campus as the project area, the project starts with studying the need of energy efficiency program. The research started with gathering knowledge and information about the process of implementing energy efficiency project. Researcher needs to understand the different between saving verses efficient. Furthermore, understanding on the correct policies and procedures regarding energy efficiency project implementation is crucial to make sure that the project will give full benefits.

The next process is to get the baseline data. These data can be obtained through electricity bills, studying the electrical single line diagrams and also occupancy data for each building in the university area. Data logging process is also being included as to get the real and current electrical energy usage data. Implementation of any energy saving project should also consider these factors to make sure no side effect or post-project problem.

Based on observation, survey and discussion with the management, there is a need in implementing energy efficiency program due to high bills for utilities especially electricity and water. After conforming the right and appropriate process of energy efficiency project, further studies need to be done by searching on academics writings and practical proof.

After completing the process of simple energy audit, a target area is selected. The loads and configuration of this target area will be reviewed. A test-rig will be developed as to represent the target area. This need to be done since the research areas are still under vendor's warranty and difficult to interrupt the running system. A controller is then being developed to simulate the test configuration. All data from different configuration is then being analyzed to prove the efficiency results.

1.6 Thesis Organization

This thesis consists of five chapters. Chapter 1 of the thesis discusses on the brief introduction on energy management and also the importance of energy management nowadays. It will also focus on the problem statements, objectives of the project and also scope of work.

Chapter 2 reviews the basic of energy management process and procedures. It will also discuss the history of energy management in Malaysia and the current practice of energy management. Laws and policies regarding the energy management in Malaysia will also be discussed. This chapter will also discuss about energy audit, one of the main tools in energy management process. This chapter will also contain the brief study on current methodologies in energy management implementation especially in buildings. A few examples on energy management implementation in other areas will also be briefly discussed.

Chapter 3 discusses the proposed methodology of implementing energy management, specifically in university building. Based on literature study, a set of procedures is proposed as to improve current energy management implementation. The proposed new methodology will be discussed in details and a simple model is shown to properly present the methodology. Drawbacks of current energy management implementation will also discussed and advantages of newly proposed methodology will also be presented.

Chapter 4 discusses all the data and results from the energy management process and implementation based on the newly proposed methodology. Examples of energy management and saving project will be shown by the category of no cost, low cost and high cost measures. Simple calculations on return-on-investment for each project will also be discussed. The result from three testing configuration is also presented and analyzed.

Chapter 5 presents the conclusion of this project and will also propose further works that can be done in future. Some barriers and obstacles faced during this project will also briefly note in this chapter.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss various method of implementing energy management and efficiency program in different places. Procedures and steps in implementing energy audit will also being discussed here. A review on energy management and efficiency system implementation in Malaysia and also the related rules and regulation will also briefly stated in this chapter.

2.2 Energy Overview in Malaysia

One of the most important driving factors for a nation to develop is the source of energy. With a population about 28 million, Malaysia is blessed with natural gas and petroleum resources and the growing industrialization and increasing standard of living has considerably increased the usage of energy. Malaysian energy consumption has risen dramatically over the past 20 years due to the combined demands of industrialization and urbanization (US Energy Information Administration, 2013).

Based on the National Energy Balance report from Malaysia Energy Commission, it is stated that the Malaysian total primary energy supply in 2011 was recorded a growth at 3.2 percent compared to the previous year, which is at 3 percent (Malaysia Energy Commission, 2011). The growth was attributed to the higher imports of energy in order to meet local demand. The highest increase of imports was observed for natural gas as it recorded an increase of 26.3 percent to settle at 6,979 ktoe. In 2011, the total crude oil and condensates production posted a decrease of 1.8 percent from that of 2010 to 28,325 ktoe or 569.8 thousand barrels per day. This was due to major scheduled maintenance and shutdown programs that were carried out during this period, involving over 70 fields and 10 pipelines (Energy Commission of Malaysia, 2012; Oh, Pang, & Chua, 2010).

The primary supply of crude oil increase mainly due to higher imports and lower exports up to 9.7 percent compared to the previous year of 2010. The primary supply of natural gas also shows an increase of 0.8 percent from the 2010, mainly due to the higher imports of natural gas in 2010. The primary supply of coal and coke in the country was stable and almost the same as the year 2010.

Figure 2.1 below shows the detail trending of primary energy supply in Malaysia from the year 1990 to 2010.

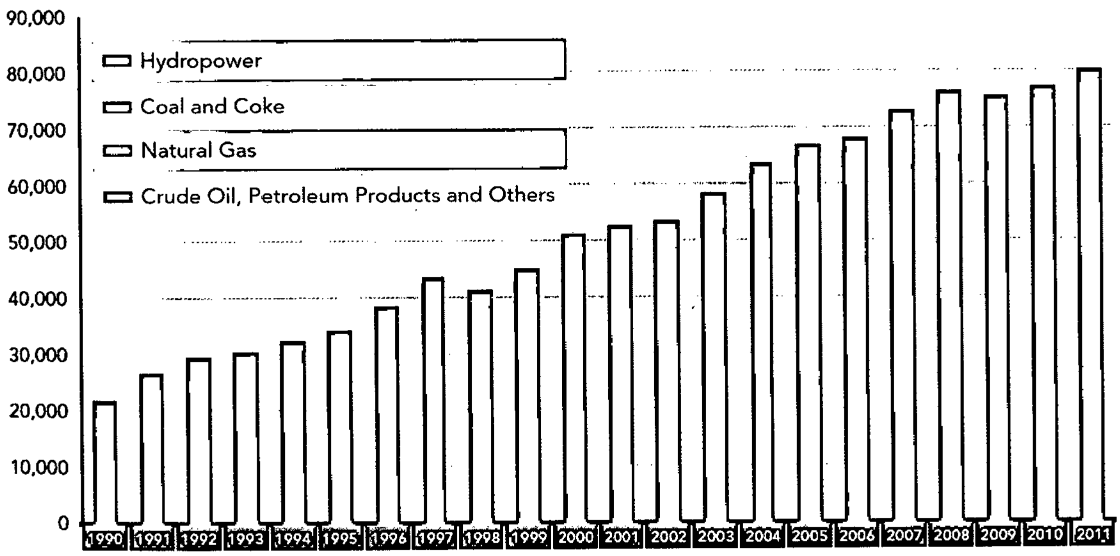

Figure 2.1: Primary Energy Supply in Malaysia

(Source: Malaysia Energy Commission)

As of October 2010, Malaysia was an energy self-sufficient country and a net energy exporter. Oil and natural gas exports accounted for about 30 percent of its total exports in 2010.62. However, because domestic energy demand has escalated sharply in recent years, Malaysia is expected to become a net oil importer after 2015 (Bower, Pumphrey, Poling, & Walton, 2012; Ong, Mahlia, & Masjuki, 2011).

For the electricity generation in Malaysia, based on report produced by the Energy Commission, the total installed electricity generation capacity as of December 2011 was at 28,749 MW, with Peninsular Malaysia had about 84.3 percent of the total, followed by Sarawak at 9.0 percent and Sabah at 6.7 percent. The growth rate for the total electricity consumption is at 2.7 percent. The agriculture sector showed the highest growth with 9.6 percent, followed by commercial at 4.8 percent and the remaining residential and industrial sectors both grew at 1.7 percent. The industrial sector was the main consumer of electricity in Malaysia with its share of 43.9 percent of the total consumption in 2011 (Energy Commission of Malaysia, 2012). Figure 2.2 shows the overall power demand in Malaysia which clearly show an increase of about 3 times from 1990 to 2009.

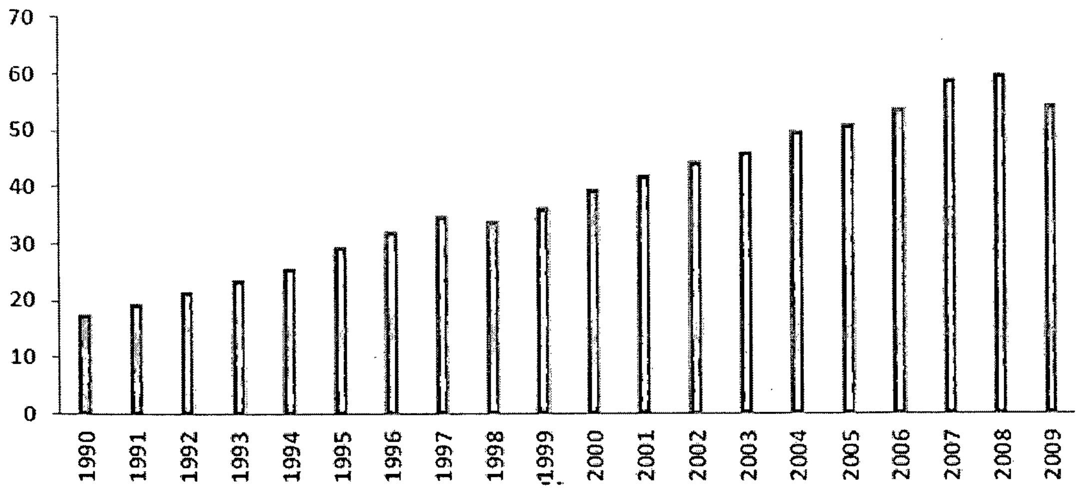

Figure 2.2: Overall power demand in Malaysia (GigaWatt)

(Source: Malaysia Energy Commission)

2.2.1 Sustainable Energy Management in Malaysia

Sustainable energy management refers to the process of managing energy consumption to ensure that energy has been efficiently consumed. Thus, sustainable energy management means steps and processes to achieve it, not just merely product installation (Bower et al., 2012; Shafie, Mahlia, Masjuki, & Andriyana, 2011).

By definition, sustainable energy management refers to the process of managing the energy consumption in the organization to assure that the energy has been efficiently used (Greentech Malaysia, 2012). This process of sustainable energy management will covers all aspect of technical and non-technical energy consumption within the organization. In order to successfully achieve sustainable energy management process, a numbers of guideline principles have been outlined such as involving all staff in the organization, developing the knowledge, creating the continuous improvement process and also to integrate it with the standard working procedure.

2.2.2 Energy Efficiency Framework in Malaysia

A comprehensive framework on energy management in Malaysia starts in 1979 when the National Energy Policy is tabulated. The National Energy Policy was formulated to ensure adequacy, security and cost-effectiveness of energy supply, as well as to promote the efficient utilization of energy. This was further emphasized in the Ninth Malaysia Plan where efforts in the utilization of renewable energy resources and efficient use of energy were further promoted. To enhance further, the government of Malaysia upgrade the function of Ministry of Energy, Green Technology and Water in order to reflects Malaysia's seriousness in driving the a comprehensive and sustainable energy management solution (Ministry of Energy Green Technology and Water, 2009).

There are many initiatives in Malaysia to inculcate the culture of energy efficiency and also to plan towards a more energy efficient country. For example, in Ninth Malaysia Plan, it is stated that the energy sector will further enhance its role as an enabler towards strengthening economic growth. In this regard, the sources of fuel will be diversified through greater utilization of renewable energy. A market-based approach will be promoted to ensure efficient allocation of resources. Emphasis will be given to further reduce the dependency on petroleum products by increasing the use of alternative fuels. (Prime Minister Department, 2009)

The Government of Malaysia also offers attractive incentives to encourage the generation of Renewable Energy (RE) and the adoption of Energy Efficiency (EE) initiatives as well as for improvement of Power Quality (PQ) amongst energy producers and users in Malaysia and to ensure sustained national economic development for the future. (Greentech Malaysia, 2010; Ministry of Energy Green Technology and Water, 2009)The Ministry of Energy, Green Technology and Water is responsible for the implementation of national policies relating to the renewable energy and energy efficiency with the desires to accelerate the adoption of both area in the country and the provision of high quality power where required.

Current situation of the increasing in worldwide energy prices makes it critical for local industries and service providers to adopt these initiatives in order to maintain their business competitiveness. The incentives granted include the Pioneer Status (PS), Investment Tax Allowance (ITA), and exemption from payment of import duty and sales tax on machinery, equipment, materials, spare parts and consumables. (Kementerian Tenaga Teknologi Hijau dan Air, 2009; Noor, 2011)

Besides that, the Government of Malaysia also introduced a National Energy Policy in guiding the future energy sector development. There are three main objectives which cover the areas as follows:

i.The Supply

Aim to ensure the provision of adequate, secure and cost effective energy supply.

ii.The Utilization

Promoting the efficient utilization of energy and discourage wasteful and non-productive pattern of energy consumption.

iii. The Environment

Minimize the negative impact of energy production, transportation, conversion, utilization and consumption on the environment.

2.2.3 National Green Technology Policy

The National Green Technology Policy was launched on 24th of July 2009 by YAB Dato' Sri Mohd Najib bin Tun Abdul Razak, the Prime Minister of Malaysia with the aim to accelerate the national economy and promote sustainable development (Greentech Malaysia, 2013). Green Technology is the development and application of products, equipment and system which used to conserve the natural environment and resources and to minimize the negative impact

National Green Technology Policy also outlines several criteria in order a products, equipment and systems to be referred as green technology. Those criteria are minimizing the degradation of the environment, have a zero or low greenhouse gas (GHG) emission, safe for use and promotes healthy and improved environment and lastly conserves the use of energy and natural resources and it promotes the use of renewable resources.

The Malaysian Green Technology Policy is being carried out in three term planning, namely short-term (2011 – 2015), mid-term (2016 – 2020) and long term (2021 and beyond) goals. Short-term goals refer to the process of increasing public awareness and commitment for the adaption and application of Green Technology through the advocacy programs. It will also aim to widespread the availability and recognition of Green Technology in terms of products, appliances, equipment and systems in the local market standards, rating and labelling programs. Besides that, this short-term goals aims to increased foreign and domestic direct investment and also to expand local research institutions and institution of higher learning to expend research and development activities on Green Technology.

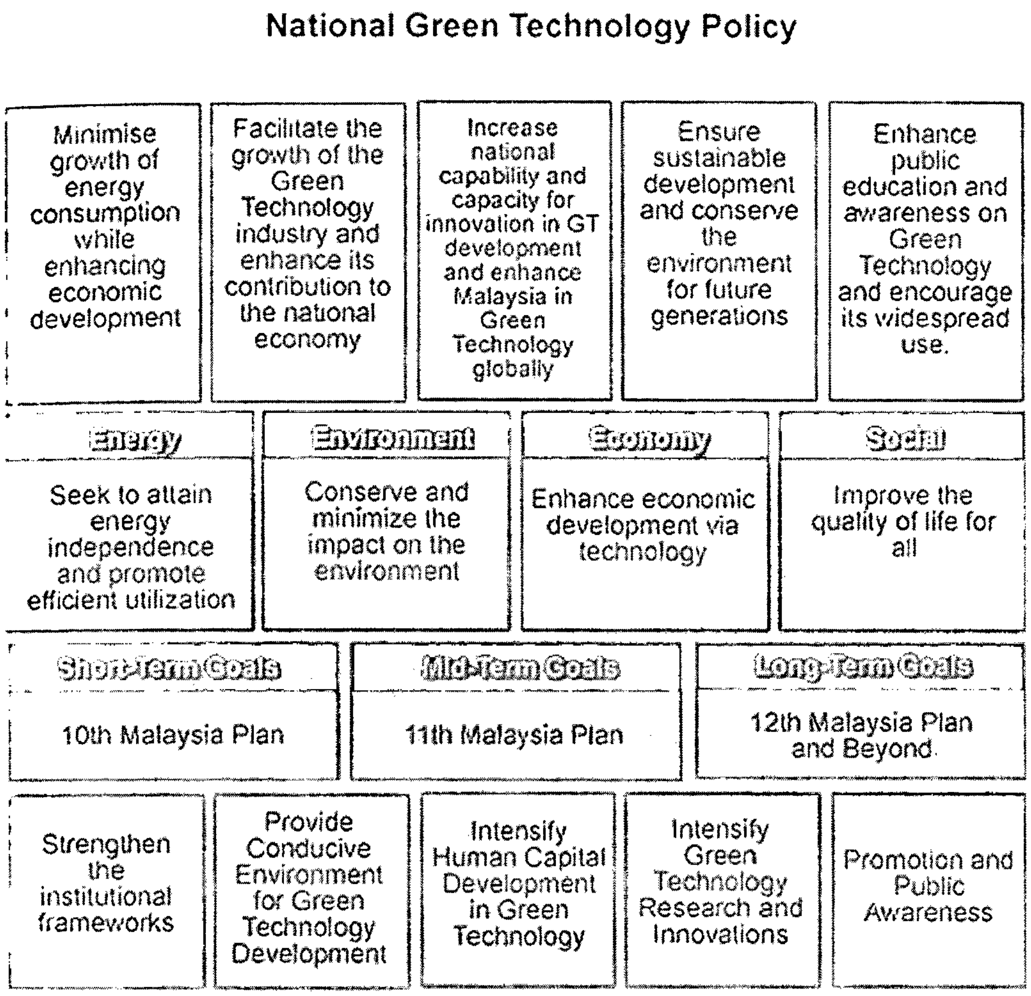

Figure 2.3: National Green Technology Policy

(Source: Ministry of Energy, Green Technology and Water)

The mid-term goal of the Nation Green Technology Policy aims to make green technology to become a preferred choice in procurement of products and services and creating a larger market share against other technology. It will also aim to increase local production of Green Technology products and also to increase the commercialization of research and development activities by local universities with the local industry and multinational companies. Lastly, it will aim to expand local SMEs and SMIs on green technology into the global market and then expand it to the most economics sectors.

The long-term goals, which target the year 2021 and beyond, aims to inculcate the green technology in Malaysian culture and to widespread its adoption in order to reduce overall resource consumption while sustaining national economic growth. It will also target to improve Malaysia ranking in environmental ratings by showing significant reduction in national energy resources. Lastly, the aim is to become a major producer of green technology product in the global market.

2.2.4 Malaysian Standard For Energy Efficiency And Management

Since the rise of concern and interest by the Government of Malaysia in wide spreading the use of energy management and efficiency, a lot of effort is being given in developing the guidelines and standards of energy management and efficiency in Malaysia. These efforts are being spearheaded by the Ministry of Energy, Green Technology and Water, Greentech Malaysia (formerly known as Pusat Tenaga Malaysia) and also the Department of Standard Malaysia. As a framework, Ministry of Energy, Green Technology and Water produced a detail description about National Green Technology Policy formulated by the Government of Malaysia.

Besides formulating the National Green Technology Policy as the main frame in developing the area of energy management and efficiency, Greentech Malaysia also produced a few publications as the guideline to the energy management practitioner and industry to implement the process by their own. Examples of the publication and guidelines produced by Greentech Malaysia are Energy Efficiency and Conservation Guidelines for Malaysian Industry and also Malaysian Industrial Energy Audit Guidelines.

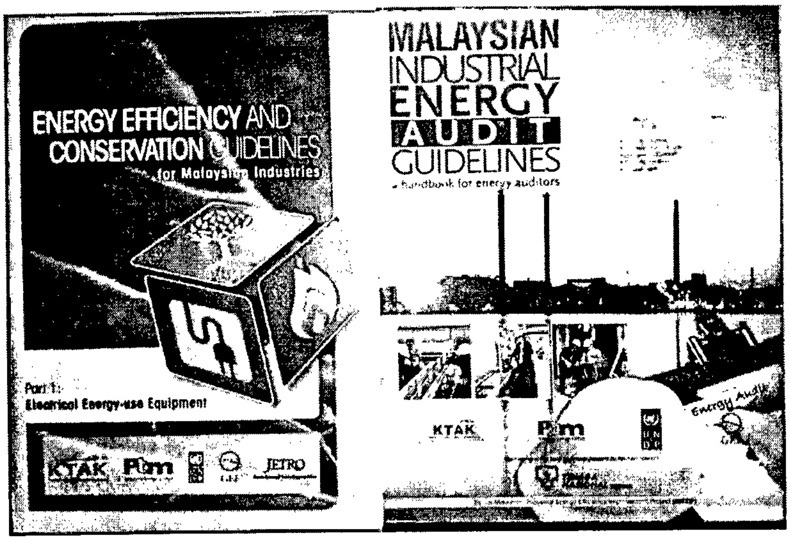

Figure 2.4: Publications by Greentech Malaysia

On the other hand, Department of Standards Malaysia also produced two main documents as reference and guidelines to the energy management practitioners. The first standard document produced by the year 2007 is the Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Building with the code of MS ISO 1525:2007. This standard document is developed with the aim to encourage the design, construction, operation and maintenance of the new and existing building that reduces the use of energy without constraining creativity in design, building function and also the comfort or productivity of the occupants. It is also providing the minimum standards and criteria for energy efficiency and also, as guidance to demonstrate good professional judgment of the practitioner.

The Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Building cover the topics about the architectural aspect of the building, passive design strategy, building envelope, lightings, electrical power and also air conditioning and ventilation. Besides that, this standard document also gives brief guidelines about the energy management control system and building energy simulation method.

Table 2.1

Recommended average luminance levels

Task	Illuminance (Lux)	Example of Applications
Lighting for infrequently used area	20	Minimum service illuminance
	100	Interior walkway and car-park
	100	Hotel bedroom
	100	Lift interior
	100	Corridor, passageways, stairs
	150	Escalator, travellator
	100	Entrance and exit
	100	Staff changing room, locker and cleaner room, cloak room, lavatories, stores.
	100	Entrance hall, lobbies, waiting room
	300	Inquiry desk
	200	Gate house
Lighting for working interiors	200	Infrequent reading and writing
	300 – 400	General offices, shops and stores, reading and writing
	300 - 400	Drawing office
	150	Restroom
	200	Restaurant, Canteen, Cafeteria
	150 – 300	Kitchen
	150	Lounge
	150	Bathroom
	100	Toilet
	100	Bedroom
	300 – 500	Class room, Library
	200 – 750	Shop / Supermarket/Department store
	300	Museum and gallery
Localised lighting for exacting task	500	Proof reading
	1000	Exacting drawing
	2000	Detailed and precise work

(Source : Department of Standards Malaysia)

The second standard document developed by Department of Standards Malaysia in the year of 2011 is Energy Management System – Requirements with Guidance for Use with the code of MS ISO 50001:2011. This standard is developed with the purpose to enable organizations to improve necessary processes for energy performance, efficiency, use and consumption. It is hope that by implementing this standard, it is able to reduce the greenhouse gas emission and other environmental impact by using systematic management of energy. This standard document proposes a Plan-Do-Check-Act approach which requires the organization to conduct the energy review and then establish the organization energy baseline and energy performance indicator. This document also advices organizations to continually take action in order to improve energy performance and energy management system.

2.3 Energy Management System

Energy management systems have been in existence in the energy sector for several decades. The key functions of such systems are to monitor, control, and optimize the flow and use of energy. In general, energy management systems have formidable applications in the generation, transmission and distribution systems of the electrical network. The implementation of energy management system starts with as low as the use of single energy efficient devices up to the use of significant equipments such as the applications of Supervisory Control and Data Acquisition (SCADA) with the combination of energy management and efficiency functionalities. (Kling & Ribeiro, 1970)

2.3.1 Energy Management Based on Level

Building energy management can be divided into the macro level management and micro level management. In the macro level, it mainly refers to the formulation of policies and regulations, the implement energy efficiency standards in architectural design and construction of energy- saving projects for review, evaluation, supervision and acceptance (Rensburg et al., n.d.; Torre & Caparica, 2012; Xiao & Zhang, 2010). In the micro level, it mainly through the day-to-day operation and maintenance of buildings and users of energy-consuming behavior to get the implementation of effective management, as well as through energy efficiency improvement and energy saving transform to achieve energy saving. This level of building energy management is more realistic and more energy saving potential.

2.3.2 Energy Management Based on Building Form and Envelop

The energy use of residential and commercial buildings depends to a significant extent on how the various energy using devices such as fans, lightings, chillers, pumps and heaters are put together as systems, rather than depending on the efficiencies of the individual devices. The idea to construct an energy efficient building requires since the very beginning a design process, in which the building performance and components of its engineering systems has to be selected through an iterative process involving all members of the design team (Hartley, 2013; Jiang & Rahimi-Eichi, 2009; Pengpeng, 2012; Yu, Shi, Gao, & Ou, 2010).

Basic decisions and solutions with great impact for the energy efficiency of a commercial or residential building during the design process are building orientation and forms, thermal performance of building envelop and solution for passive heating, cooling, ventilation, and day lighting (Cheng, Cheng, & Lin, 2010; Dilouie, 2009; Lemos, Coelho, & Valdez, 2010). Besides that other factors such as selection of individual energy-using devices based on their energy efficiency and integration of all engineering systems in an energy management system with defined scenarios for energy efficiency should also be carefully considered.

In general, by selecting an appropriate building form and a high-performance envelope, heating, and cooling loads are minimized, day lighting opportunities are maximized and at the same time the usage of other electrical and mechanical systems can be greatly downsized. This generates cost savings that can offset the additional cost of a high-performance envelope and the additional cost of installing high efficiency equipment throughout the building. (Zavalani, 2011)

2.3.3 Scientific Energy Management Practices

During the early years of energy management and efficiency implementation, energy management practices consisted primarily of replacing inefficient equipment and then using various methods to estimate the savings gained (Torre & Caparica, 2012; Wu, 2009). As the technology evolved and field of energy management matures, the practices within the energy management area become better and the processes within an organization become more efficient. The implementation of energy management and savings can also be dramatically increased and maintained over time by adopting and implementing consistent energy management practices and recognized measurement and verification procedures. Although there are many technologies of building energy efficiency, scientific management is the first step to improve energy efficiency in buildings (Wu, 2009).

One of the success factor contribute to the smoothness of demand side energy management is the active participation of energy consumers in controlling their loads in response to changes in energy prices. For the building sector, this requires a high level of automation of load control in which human interactions are restricted to choosing comfort and efficiency levels from an intuitive graphical user interface (Kyusakov et al., 2012)

In addition to this, several criteria can be outline as to propose a strategic energy management process (Gorp, 2000, 2004; Rensburg et al., n.d.; Wu, 2009). These criteria are the as follows:

i. Organization Commitment

   Effective strategic management plan requires a solid involvement and commitment throughout the organization in order to get continuous improvement.

ii. Baseline Performance Evaluation

   A process of identifying the current energy performance, listing the inventory and energy audit, and then create a profile and energy use at all key points.

iii. Action Plan and Performance Goal

An appropriate action plan drives and guides all energy user in the organization to focus and prioritize their energy management and efficiency efforts. The process of setting the energy performance goals is also very fundamental in order to provide direction for decision making and will be needed during tracking and measuring process.

iv. Educate and Motivates Participants

The ultimate success of a plan will depend on the motivation and capability of the managers and employees implementing its components

v. Evaluate Ongoing Performance

Sustaining improvements in energy performance and guaranteeing long-term success of a plan requires a strong commitment to continually evaluate performance.

vi. Communication and Recognition Strategies

The process of identifying and communicating the contributions of all participants provides a solid foundation throughout an organization. It is important to build successful energy management strategies and also by providing the framework for promoting energy management efforts.

The process of determining energy or demand savings by comparing measured energy use or demand before and after implementation of an energy conservation measure is commonly known as measurement and verification. As to conclude, the process in implementing scientific energy management and efficiency project can be described as in the Figure 2.5 below:

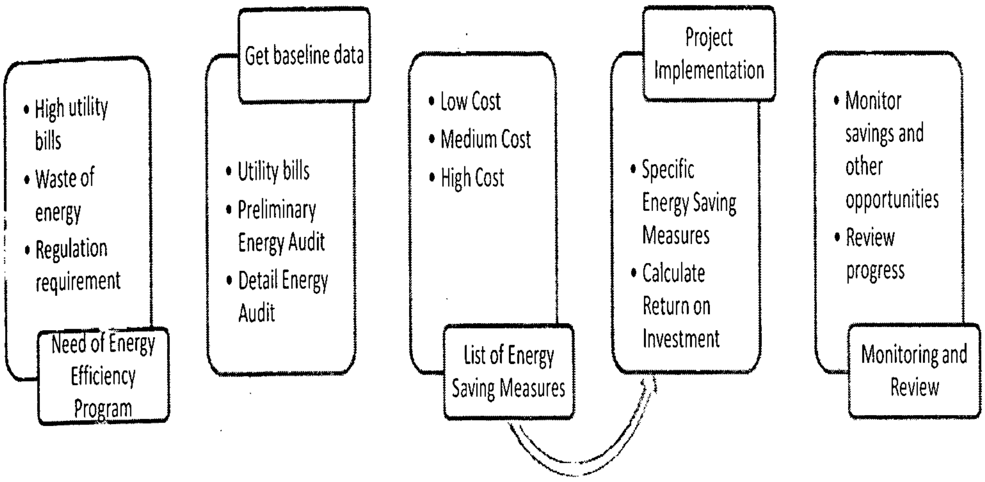

Figure 2.5: General Process of Energy Management Implementation

2.4 Energy Audit

Energy audit is a scientific method to manage and control the energy. It refers to the processes of inspecting, examining and analyzing on the physical and the financial activities processes of enterprises and other high energy-using units according to relevant state regulations and standards of energy-saving.

2.4.1 Energy Audit Definition

An energy audit can be defined as a systematic process to evaluate where a building uses energy and identify the energy saving measures to reduce energy consumption (A. Thumann and W. J. Younger, 2008; Wong & Lee, n.d.) . Energy audit is an essential energy management service which applies energy analysis methods to evaluate the profile of energy utilization to develop energy efficiency measures in buildings. An energy audit will show all incoming energy streams and accounts for how that energy is consumed (Allan, 1995). The incoming energy is determined by analyzing the utility bills such as electricity and water. Once the incoming energy streams are determined, data is then taken from the specific areas to determine how much energy each machine consumes.

By implementing energy audit processes, evaluation of the usage of energy being used within a building or area and could correctly identify the opportunities to reduce consumption could be acquired. Energy audits apply energy analysis methods to evaluate patterns and trends of energy consumption and efficiency opportunities (Gomes, Coelho, & Valdez, 2010) .Energy audits are the first step to improve the energy efficiency of buildings and industrial facilities.

Energy audit cannot be successfully carried out without the commitment from the top management. (Wong & Lee, n.d.) Management must be firstly convinced of the necessity of implementing energy management and hence energy audit. The basic reasons are the potential money return, increasing cost of energy and also the probable destruction to environment burning of fossil fuel in power generation results in increase of carbon monoxide which contributes to global warming.

2.4.2 Typical Type of Energy Audit

Generally, there are four types of energy audits can be briefly being describe further (Krarti 2000). Firstly is a walk-through audit consists typically of a short on-site visit of the facility to identify areas where simple and inexpensive actions. By using this type of energy audit, it will provide immediate energy-use and operating cost savings. Secondly is the utility cost analysis includes a careful evaluation of metered energy-uses and operating costs of the facility (Allan, 1995; Aspalli, Shetagar, & Kodad, 2008; Reed, Ridge, Broadwater, Chandrasekaran, & Oka, 1990). Typically, the utility data over several years are evaluated to identify the patterns of energy use, peak demand, weather effects, and potential for energy savings.

The third typical process of energy audit is using the standard energy audit consists of a comprehensive energy analysis for the energy systems within the building and area. In particular, the standard energy audit includes the development of a baseline for all the energy being used within the area. This will provide the evaluation of the energy savings, and the cost-effectiveness of appropriately selected energy conservation measures (Maricar & Othman, 2013; Ross, 1996; X. Wang & Huang, 2009).

The fourth type of energy audit is by implementing a detail audit, which is most comprehensive but also time-consuming energy audit type. Specifically, the detailed energy audit includes the use of instruments to measure energy-use for the whole building and for some energy systems within the building such as lighting systems, office equipment, fans, and chiller. In addition, sophisticated computer simulation programs are typically considered for detailed energy audits to evaluate and recommend energy retrofits for the facility (Hao et al., 2012; Omar, Mariun, & Radzi, 2003; Pang et al., 2011; Prudenzi et al., 2008).

In service buildings, the implementation of energy efficient measures can significantly reduce energy consumption, greenhouse gas emissions and the energy bill, without compromising comfort, health and security levels. The identification of energy efficient measures that can be implemented in a particular building requires the analysis of the energy flow in the building. (Gomes et al., 2010)

2.4.3 Detailed Energy Audit

Energy audit is conducted by energy utilization units or its competent authorities or entrusted specialist agencies and the main content is objectively inspecting on the energy efficiency, energy consumption level and the economic benefit of the energy unit and proposing the energy saving measures by means of statistical analysis, inspection testing, and diagnostic evaluation (Guan, Xu, & Jia, 2010; Prudenzi et al., 2008; Zhang, Zhang, Chen, & Gong, 2011).

The targets of energy audit are investigating problem and weaknesses in using energy, tapping the energy-saving potential, giving rectification measures, formulating energy saving goals and plan through the evaluation of the enterprise energy management level, energy consumption situation, energy consumption index, financial process, comprehensive utilization of energy. The ultimate aim of energy audit is to encourage enterprises to save energy, reduce production costs and increase economic benefit (Y. Li, Wang, Jiang, & Zhang, 2009).

To perform an energy audit, several tasks are typically carried out depending on the type of the audit and the size and function of the audited building. Some of the tasks may have to be repeated, reduced in scope, or even eliminated based on the findings of other tasks. Therefore, the execution of an energy audit is often not a linear process and is rather iterative (A. Thumann and W. J. Younger, 2008). However, a general procedure can be outlined for most facilities.

i. Facility and Utility Data Analysis.

   The main purpose of this step is to evaluate the characteristics of the energy systems and the patterns of energy-use for the building or the facility. By collecting a few years of utility data, the building facility characteristics can be obtained from technical drawings and from discussions with building operators. The energy-use patterns can be obtained from a compilation of utility bills over several years. Analysis of the historical variation of the utility bills allows the energy auditor to determine if there are any seasonal and weather effects on the building energy-use.

ii. Walk-Through Survey.

   By implementing a walk through survey throughout the targeted building, potential energy savings measures should be identified. The results of this step are important because they determine if the building warrants any further energy auditing work. Some of the tasks involved are identifying the customer concerns and needs, checking the current procedures of operation and maintenance, determining the existing operating conditions of major energy-use equipment such as lighting and air condition and the process of estimating the occupancy, equipment, and lighting hours of operation.

iii. Baseline for Building Energy-Use.

   Baseline for building energy-use model will become the reference to estimate the energy savings incurred from appropriately selected energy conservation measures. The main purpose of this step is to develop a base-case model that represents the existing energy-use and operating conditions for the building. Some of the major tasks to be performed during this step are obtaining and reviewing the mechanical, electrical, and control drawings and evaluating the building equipment for efficiency, performance, and reliability. The process will also cover the task of obtaining occupancy and operating schedules for equipment such as lightings and air conditioning system and then to develop a baseline model for building energy-use. The final step is then to calibrate the baseline model using the utility data obtained during walk through and baseline survey process.

2.4.4 Energy Audit Analysis

For a typical office building lighting represents on average 40% of the total electrical energy-use (Khalid, Gu, Aman, & Hashmi, 2012). There are a variety of simple and inexpensive measures to improve the efficiency of lighting systems. These measures include the use of energy-efficient lighting lamps and ballasts, the addition of reflective devices, delamping and the use of daylighting controls (Cheng et al., 2010; Rocky Mountain Institute, 2004; Safran, 2009). Most lighting measures are especially cost-effective for office buildings for which payback periods are less than one year. The first step in reviewing lighting electricity use is to perform a lighting survey. An inexpensive handheld light meter can be used as a first approximation; however, distinction must be made between raw intensities (lux or foot-candles) and illumination quality recorded in this way.

Several studies also indicated that natural lighting or daylighting can offer a cost-effective alternative to electrical lighting for commercial and institutional buildings. Through sensors and controllers, daylighting can reduce and even eliminate the use of electrical lighting required to provide sufficient illuminance levels inside office spaces. Daylighting was an important element of building design for centuries before the discovery of electricity (Kariyeva, 2006; Lemos et al., 2010; Safran, 2009). In certain types of buildings and operations today, daylighting can be utilized to at least reduce electric lighting.

The energy cost to operate electric motors can be a significant part of the operating budget of any commercial and industrial building. Measures to reduce the energy cost of using motors include reducing operating time by turning off unnecessary equipment, optimizing motor systems, using controls to match motor output with demand, using variable speed drives for air and water distribution, and installing energy-efficient motors (Aspalli et al., 2008; Danish Energy Management, 2006).

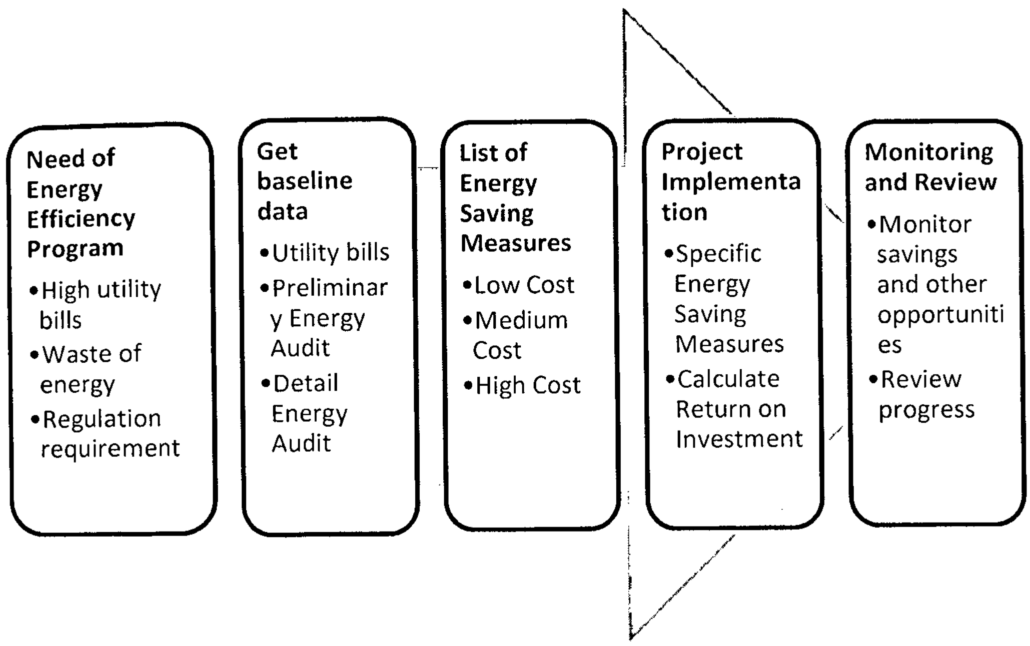

Figure 2.6: Details of energy management and efficiency programs

2.5 Smart Campus Energy Management System

Smart Campus Energy Management System refers to a comprehensive energy management system which can be implemented in any area of university building. The aim is to implement the best energy management practices that been suggested during the third level of Sustainable Energy Management in Campus Model, which is Energy Saving Measures. Discussion for Smart Campus Energy Management System will be covered into four subcategories, which are system architecture, system components, data organization and system operation.

2.5.1 System Architecture

System architecture represents the set of relationship of all elements in Smart Campus Energy Management System. Presented in a pyramid model as in Figure 2.7, the lowest level refers to the data input processes. Mainly, there are three data inputs that will feed into this system, which are the data from sensors, data from logger and also managerial data. The second component in this system architecture is about the communication channel. Two option of communication channel proposed; a typical serial communication and a wireless communication.

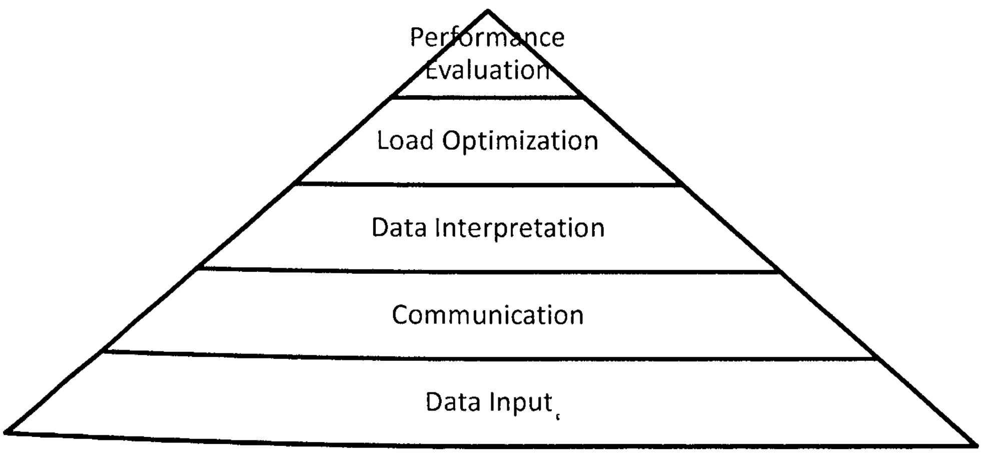

Figure 2.7: System Architecture of Smart Campus Energy Management System

Third component of this system architecture is about data interpretation. Data inputs received through the communication channel will the being interpreted. Data interpretation will give an overview of the existing building condition and allow the system manager to do the system optimization. Optimization options will then allow the system manager to proceed to the next level of system architecture process which is the load optimization.

Load optimization is the process to choose the best option of energy saving measure to be implemented by using this Smart Campus Energy Management System. The success of all energy saving measures implementation will then being evaluated in performance review components which also act as system feedback and continuous improvement.

2.5.2 System Components

System components refer to the related hardware that may involve in the system. There are 5 system components that need to be connected together to form Smart Campus Energy Management System as shown in Figure 2.8. The components are Sensors, Loggers, Metering, Communication Device and System Graphic User Interface.

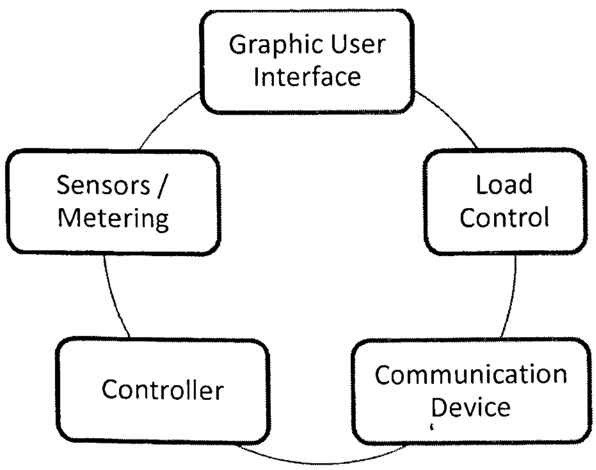

Figure 2.8: System Components for Smart Campus Energy Management System

Sensors could be from the passive infrared or occupancy sensor or may also the temperature and humidity sensor. A current sensor is also being attached to the system in order to get the current usage in terms of voltage, amps and also the kilowatt hour.

2.5.3 System Data Organization

Mainly there are three type of data handled within Smart Campus Energy Management System. Energy Modules data refers to the data collected from the metering equipment such as electrical and water. Managerial data are information collected from other sources such as the building layouts, electrical single line diagrams, building occupancies, working hours, class schedules and maintenance record. The system may also need to have environment data such as temperature and climate data. Overall modelling of system data organization is shown as in

Figure 2.9 below:

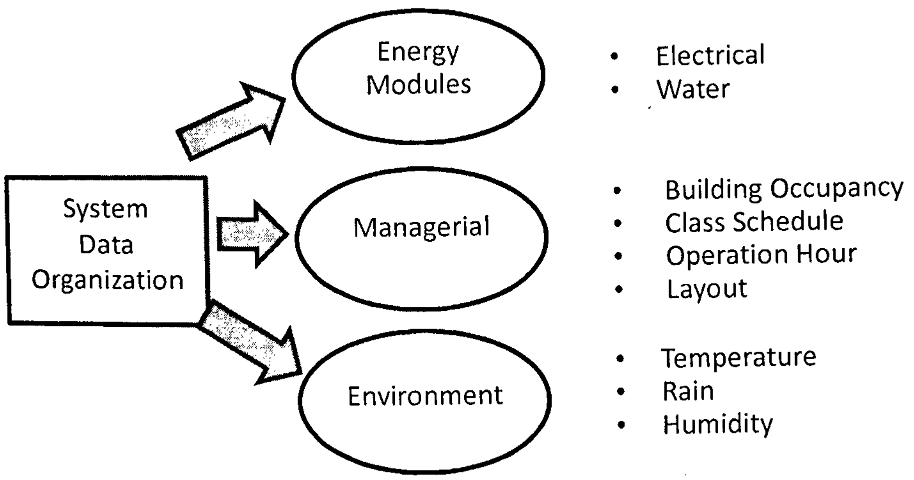

Figure 2.9: System Data Organization for Smart Campus Energy Management System

2.5.4 System Operation

System operation refers to the steps and stages within the Smart Campus Energy Management System. Data retrieve from the managerial, environment and energy module will be gathered in the system and then being analyzed to produce the best energy saving measures.

2.6 Energy Saving Methodology in University Air-Conditioning System

The increased demand for artificial cooling through the use of air conditioning systems in order to provide comfortable learning environments in universities would also mean the increased of energy usage and higher electrical cost to the management of the university (Hussin, Ismail, & Ahmad, 2014). This scenario however may also lead to unnecessary ventilation and wasting large amount of energy if the system is not well-managed (Vakiloroaya, Samali, Fakhar, & Pishghadam, 2014). Up-to-date, there are several methods and areas being explored by researchers as to make sure the comfort provided by the air conditioning system stays at the highest level of efficiency and any unnecessary wastage during the use of the system can be eliminated.

Any strategy to reduce the energy waste should be focused on factors which have significant influence on the total energy consumption. Within a building, there are three areas should be focused, which are the building envelope, internal conditions and building services system (Daghigh, 2015). Strategy that focused on the building envelop should be done from the design stages and would be hard to be implemented on existing building for some extend especially when major changes are required. Adjusting internal conditions such as indoor temperature and can be the easiest way to get energy saving with nearly zero investment. However, the degree of adjustment is limited to the building service system flexibility. Another method is to apply adaptive comfort approach for widening the acceptable indoor temperature without scarifying people's comfort which is also known as adaptive comfort temperature (Gilani, Aris, & Bhaskoro, 2014).

There is also research carried on regarding the thermal comfort of the air conditioning system (Puangmalee et al. 2015). The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) define thermal comfort as the condition of the mind in which satisfaction is expressed with the thermal environment. As such, it will be influenced by personal differences in mood, culture and other individual, organizational and social factors. Based on the above definitions, comfort is not a state condition, but rather a state of mind. Indoor thermal environments can significantly influence human health and comfort. In addition, thermal comfort is very important for architects and engineers to ensure comfort and health of occupant in the building. For university buildings, indoor thermal environments influence on learning of students. In addition, comfortable of student will be able to increase learning.

Another point of view in energy management and efficiency implementation is to design and develop a monitoring and control infrastructure in order to manage appliances so as to effortlessly optimize energy efficiency usage by manipulating the advancement in Information, Communication and Technology (IT) area (Aghemo et al., 2013). With current ICT infrastructure and appliances, dedicated tools to plan and manage energy saving strategies through the enhancement of Building Management System (BMS) are no more a difficult and impossible task. A system to monitor and control buildings services and appliances can be designed and implemented with the aim of optimizing energy usage without compromising occupants comfort and offering decision makers the strategies and tools needed to plan energy saving measures. The process of monitoring environmental and energy data in real time and by controlling the operation of active systems like lighting and HVAC services can also being design and developed to ensure the best possible comfort conditions with the most efficient use of energy.

2.7 Summary

There various type of energy management procedures to be chosen before being implemented in specific places. Energy managers or the person who manage the energy management and efficiency process should carefully choose and select best procedures for their places and organization. There is no such thing as one size does fit all in energy management process. This chapter also discusses different methodology used in implementing energy saving measures in university environment. In the next chapter, a proposed method to be implemented in a campus building will be proposed.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter will discussed about the proposed method based on the study on the literature review. It covers two main parts which is the process of implementing building energy audit and the process of setting up the experiments in order to obtain real results. The implementation of specific building energy audit will cover about the building layout, electrical single line diagram, data logging and also hardware and software setup.

3.2 Research Design

The research starts with implementing building energy audit. The energy audit is carried within the area of Faculty of Electrical & Electronics. The main objective is to get the real situation and understanding of the research area. The focus is to obtain the layout data of the building, function for each area and also the level of occupancy. Besides that, data logging process is also being carried out to obtain electrical energy usage for each specific area in order to compare it with the data taken from electricity bills form Tenaga Nasional Berhad.

As been discussed in Chapter 2, the process of implementing new energy management model will start with a simple project in order to gain confidence from the management. This experimental setup will cover three main areas which are the baseline data preparation, hardware setup and the software development.

Baseline data need to be prepared before implementing any energy management related project. This is to ensure the effectiveness of the energy saving measures and to confirm that the project being done is the most reliable and will give maximum return on investment. In this project, there are four baseline data being prepared, which are the floor plan, general electricity billing, single line diagram for targeted area and lastly data logging for the related area.

Based on the literature and support from building energy audit result, a test rig is designed in order to represent the real model for energy saving simulation method. A test rig representing a classroom loads such as the aircond and lightings is being set up. A microcontroller is then combined together with this test rig and then 3 sets of programs representing 3 types of conditions

As to get a result comparison, a test rig needed to be setup as a model for room energy saving controller. This test rig is very important to be constructed since the real air conditioning system cannot be disturbed since it is still in warranty and defect period by the developer. Furthermore, testing and configuration in the real air conditioning system may disturb the process of teaching and learning in Faculty Kejuruteraan Electric and Electronics, Universiti Malaysia Pahang

3.3 Energy Management Methodology

Based on the literature review, it is concluded that there are three types of energy management and efficiency program being implemented in current days. Those are:

i. Simple and focused to specific equipment, area or processes.
ii. Basic energy audit included in the process, and then implements energy saving measures based on level of energy saving cost.

iii. Implementing sustainable energy management process which covers not only the technical parts but also covers all aspect of management and embedded in the organization hierarchy.

Table 3.1

Three Types of Energy Management System

Level	Type	Criteria
High Level	Sustainable Energy Management System	Covers not only the technical parts but also covers all aspect of management and embedded in the organization hierarchy.
Medium Level	Complete Energy Audit Process	Basic energy audit included in the process, and then implements energy saving measures based on level of energy saving cost.
Low Level	Specific target	Simple and focused to specific equipment, area or processes.

3.3.1 Simple and focused to specific equipment, area or processes

This is the most simple process and method in implementing energy management project, and thus preferred by many researchers. Without any management constrain, the project can easily being implemented and immediate result can be obtain without due hassle. Researcher that used this method may also use state-of-the art technology and ICT infrastructure in order to enhance their energy efficiency program.

However, this type of energy management project will not cover all system and area in the building and may be stopped when the researcher is not around due to certain reason. This type of energy management project is more on individual basis and hardly being accepted as an organization effort.

Furthermore, the project implemented may not be the most crucial, suitable and appropriate saving measures because there is no specific study on the environment and much more related to the researcher's expertise.

3.3.2 Basic energy audit included in the project

This type of project should be as similar as the first one, but will be in more comprehensive method. By using this method, a simple energy audit is being done in order to understand more about the building area ant to get the baseline data. Based on the energy audit, a proper report that consists of list of measures will be produced.

Normally, the proposed method will be divided into three groups as follows:

i. No cost measures – Simple energy saving measures that can be implemented immediately and require not much cost.

ii. Low cost measures – Normally require several installation or replacement but should be fast return on investment. Small amount of money needed to be invested to gain significant saving of energy.

iii. High cost measure – This type of implementation referred to high risk high return process. The return on investment will be longer but the energy saving will be benefited for a long period.

3.3.3 Sustainable energy management process

This type of energy management project will cover not only the technical parts but also covers all aspect of management and embedded in the organization hierarchy. Due to the management awareness and commitment on energy saving, it will be a top down project and may involve all personnel in the organization.

The organization may start with the development of policy and procedures then will form a committee to look in details of every aspect of energy management process. Each and every aspect of energy management will be covered using this method and really need a strong commitment and effort in order to make it success.

This type of energy management method will last long and will give the most benefit to all parties but will require a significant amount of effort and commitments. Figure 2.6 shows the process overview about the energy management and efficiency programs within a targeted building.

3.4 Proposed Energy Management Model For Campus Building

Based on the discussion in previous chapter, a new method of energy management for campus building is proposed. This method will take into consideration several obstacles commonly faced by researcher during the implementation of energy management projects such as management bureaucracy and budget constrain.

The proposed energy management model for campus building will cover three main components, which are sustainable process flow, target energy saving measures and Smart Campus Energy Management System. Figure 3.1 below show the details of proposed energy management implementation model for university building, namely Sustainable Campus Energy Management Model.

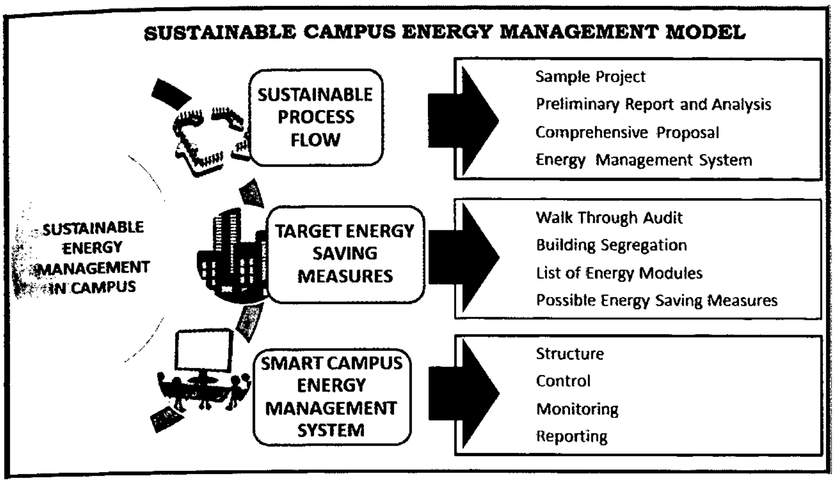

Figure 3.1: Sustainable Campus Energy Management Model

Sustainable process flow refers to the recommended procedures need to be followed during implementing a complete energy management system in campus or university building. The process flow is meant for a long term process and not just for a short period or for specific task or project. This will cover a complete work flow starting from initiating the process until the exit meeting and report to the management. Sustainable process flow for energy management system in university will start with a small sample project in order to gain experience and as a kick-start to a larger project. This lean start will also give confidence to the team to handle a bigger and more complex energy saving measures.

The second process in Sustainable Campus Energy Management model is target energy saving measures. Researchers and staff in university are not being full time hired to do the energy management processes. Thus, it is a better option to target a few specific energy saving measures that will give significant effect to university. The processes will cover a walk through energy audit, defining the building segmentation, listing all energy modules available within the university compound, and then to come out with the list of possible energy saving measures implementation.

Third component of this model will propose a combination of hardware and software which is called as Smart Campus Energy Management System. The hardware used as the main controller which will have sensors and relays as the application level of energy management process. A user friendly Graphic User Interface (GUI) will also being develop as a control and monitoring tool to the hardware.

3.4.1 Sustainable process flow

It is very important to develop a work flow process in managing energy management project as it will become the framework of the process. Without proper framework, a project may fail during the implementation of a lot of problem will occur during the implementation process.

This sustainable process flow is proposed by taking into consideration all constrain that may occur within a university campus and management. For example, a university will have a limited budget, specific semester schedule, different level of occupancy in buildings and also the management bureaucracy. Energy management projects implemented in the university will need to consider these constraint in order to make sure the process will be smooth without due hassle. Form 1 list down the details on the process of listing all constrains during the implementation of energy management project in university.

In this sustainable process flow, there are four main activities which are implementing sample project, preparing the preliminary report and analysis from the data obtain from the sample project, preparing the comprehensive proposal for the management and the to have a complete energy management system.

Sample project refers to the process of finding a small project to be implemented which will only use small budgeting in order to give confidence to the management of the university. As a start, the energy management team will need to do a simple walk through within the university compound in order to have a complete view about the university environment. Contrary to typical energy management process in commercial building or industry, this model proposes to start the project by implementing walk through audit within the building. The main objective is to discover a few possible small projects that may give good finding and result.

Project selection in this process is very important since it will determine the continuity of the next energy management level. Basically, the project selected in this level should be a simple but high return basis. It should not involve a difficult approval process or requires a large amount of budgetary.

Findings and saving measures during the implementation of this initial project should then been properly reported to the management. All cost, possible returns, processes involve and also return on investment timeframe should also be included inside the report. Besides that, a proposal on nest possible medium size project should also being included during the presentation so that a larger scale of project could directly being implemented as soon as the presentation finishes.

Upon approval on the larger scale project to be implemented, a comprehensive proposal should be prepared. It will consist of overall view on sustainable energy management process within the university building complete with stages of implementation, budgeting, personnel resources, equipment and area involved. An energy audit need to be implemented in order to get the baseline data of the building. This is very important as it will become the main data to be compared after the implementation of specific energy saving measures.

After compiling all the needed baseline data and implementing an energy audit, an official energy management system must be established in order to have a sustainable process. This will involve the process of forming the team and the officially put it inside the organization structure. The team then needs to start with an awareness program to all staff since sustainable energy management process will involve all personnel in the organization. A blueprint of Smart Energy Management System also need to be laid out and being presented to all related staff.

Figure 3.2 shows the detail workflow process of energy management implementation in university.

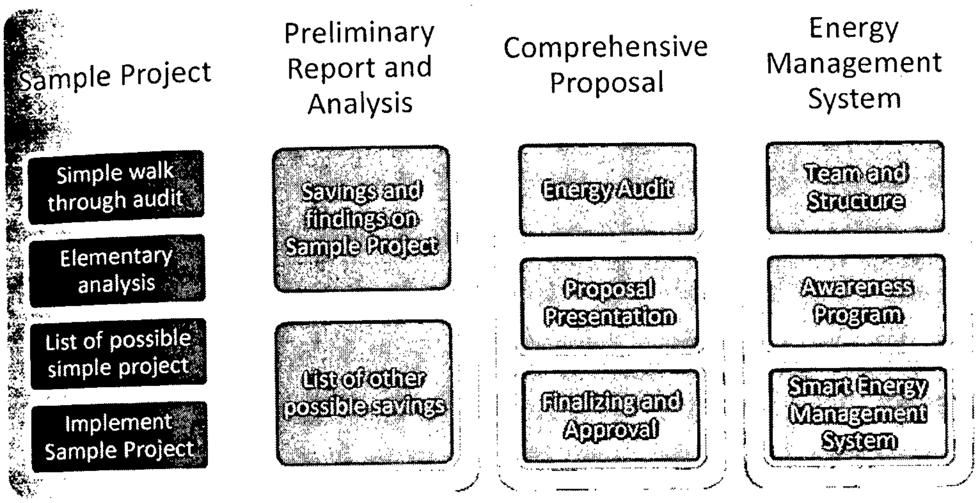

Figure 3.2: Detail job list for Work Flow Process

3.4.2 Target Energy Saving Measures

The second process in Sustainable Campus Energy Management model is target energy saving measures which will a walk through energy audit, defining the building segmentation, listing all energy modules available within the university compound, and then to come out with the list of possible energy saving measures implementation.

Walk through audit enables the energy management team to identify potential areas and system that may be included or targeted as high return energy saving measures. Each and every area within the university need to be checked and covered as to get the maximum potential energy saving measures.

Building segmentation method will cover the process of gathering information on the campus building and then to segregate it into appropriates group of energy saving area. Based on the literature study, buildings in a university campus have different type of target groups and different operating hours. Thus, each group will require different type of energy management approach.

To successfully implement sustainable energy management system, the whole areas need to be segregated correctly. Correct building segregation will maximize the output of the energy saving process and at the same time will optimize the whole work process. In managing building segregation, an energy manager or the person in charge in energy management project should consider at least four factors before finalizing the segregation process. The factors are the working function, operation hours, areas and occupancy level.

Normally in factory, energy management processes are divided by working function. As the case in university, building segregation by work function factor may divide the buildings by function as classrooms, office management, security, hostels, library and recreational building. By segregating the building by the working function, each personnel in the dedicated area can focus and easily understand the of energy management requirements.

There is also possibility to segregate the building by the operation hour. For example, in a university, there are buildings that will operate 8 hours a day like the management or maintenance office. There are also buildings that may operate almost all time such as hostels and security office. Hence, there is also high possibility to segregate the buildings according to its operating hours.

In large area where the distance is quite far from each other, building segregation can be categorized based on the area the building situated. Segregate the building by area category may cause a multifunctional process within the dedicated area but it may save time and other resources since all personnel and project being done within the communication range. There is no need of personnel from a far distance from the area to come and implement the energy management process.

The last factor that may need to be considered during the process of building segregation is the occupancy level in each building. In university campus for example, different lab may have different occupancy level. A Printed Circuit Board laboratory may have a lower occupancy level compared to a computer lab or workshop. Therefore, it is also possible to segregate the building based on the occupancy level so that the areas can be equally group and the will be easier to manage.

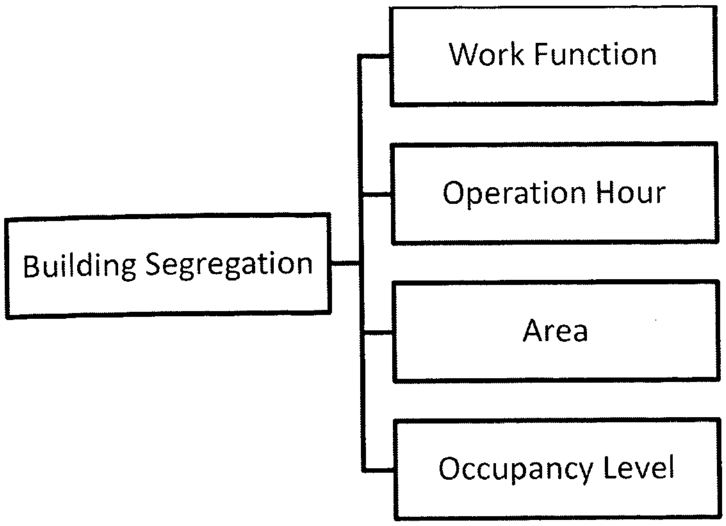

Figure 3.3: Building Segregation Elements

3.5 Test Rig Design and Configuration

The test rig hardware can be divided into two main part, which are the control segment and the loads segment. The control segment consist of the microcontroller, relays and the magnetic contactor. The loads segment consist of compact flourescent lamps and an AC motor. Figure 3.4 shows the block diagram of the test rig.

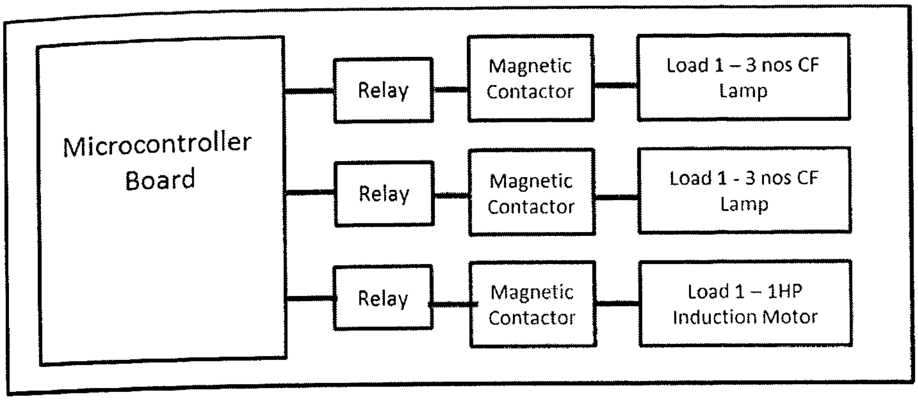

Figure 3.4: Block diagram for test rig

The control segment will present the real control instruments which all the setting and program configuration will be loaded into it as to gain the experimental result. The microcontoller used in this test rig in PIC 18F4550. This segment also consist of relays and magnetic contactors which are used as switching devices to the load segments. The microcontroller will give signal and control the switching of 12V relay coil based on the program configuration. The relays will then directly connected to 240V AC coil of magnetic contactor, while the contacts are connected to the loads segements. This configuration is being set up as to isolate the heavy load segments that may cause problems to the brain of the control segments, which is the microcontroller.

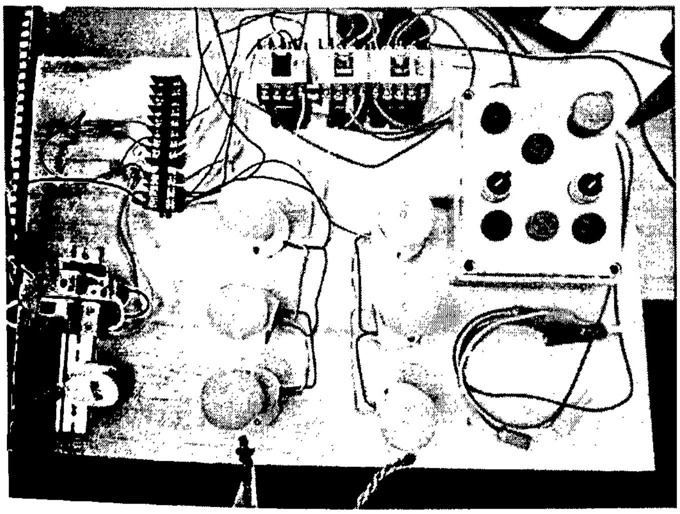

Figure 3.5: Picture of the test rig

The loads segment is used as a model for real loads. As the study focus for enhancement of energy saving measures for classromm, the real load identified are the lightings, air conditions,computer and also the LCD screen projector. As to model it using a test rig, three subsegment of loads are being prepared. The first two are the lighting modelling by using two set of compact flourescent lamps and the third one is a 1hp induction motor. The compact flourescent lamp, which consist of three lamp per set is used to represent the lightings inside the classroom, while the induction motor represent the air conditioning system.

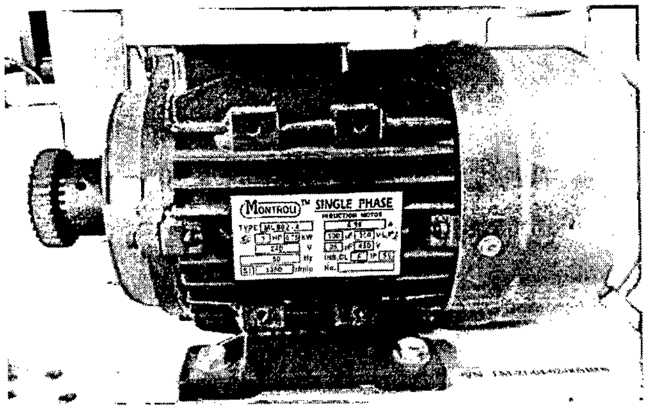

Figure 3.6: AC induction motor used for load testing

3.5.1 Test Rig Control Configuration

Control configuration refers to the programming setting and requirement which is being set up inside the microcontroller in order to represent the data collection condition. Based on the result obtained from the literature and energy audit implementation, three data collection condition need to be configured.

The first condition is the normal setting of classroom utilization, which is the usage from 8.00 am until 6.00 pm for teaching and learning purposes. In this first configuration, all loads are switched on at 8.00 am and will only be switched off at 6.00

pm. This will represent the system as when using a normal timer to control the classroom.

The second condition is to represent the normal uncontrolled condition. This configuration is to represent the condition where no electronics and intelligent control is applied at all for the classroom utilization. The control is totally depended on the user's awareness. Therefor, the control condition for the microcontroller is configured differently compared to the first configuration.

The third condition is the main purpose of the research, which is schedule-based classroom control. As the previous study in energy audit implemented, schedule-based control could contribute up to thirty percent energy savings based on the current timetable condition. Thus, the third configuration refers to the dedicated timetable for the target classroom.

3.5.2 Controller Board Setup

As to operate the test rig, a controller board is being developed as the operation control for the whole experiment. The aim is to construct a device that can control the electrical energy supplied to the classroom by tapping the device to the main supply of the room. A GUI is also developed to make sure that user can easily monitor and control the devise. As to reduce the control and switching problem, the on-off process will be based on the timetable for the semester. Therefore, the issue of inrush current and wear-and-tear problem could be reduced.

A simple block diagram of main board system was shown in Figure 3.7. All loads are connected to relays which been controlled by the microcontroller. Besides that, current information data from the center is display on PC by using graphical user image. All information of the schedule is saved in database before the system run and controls the main board.

As to enhance the system, wireless transceivers used in order to enhance the communication process. By using wireless communication, hardware and wiring cost can be reduced and at the same time enhance the flexibility of the system. At any time, the system can be moved or transferred to other places if needed without affecting the cost.

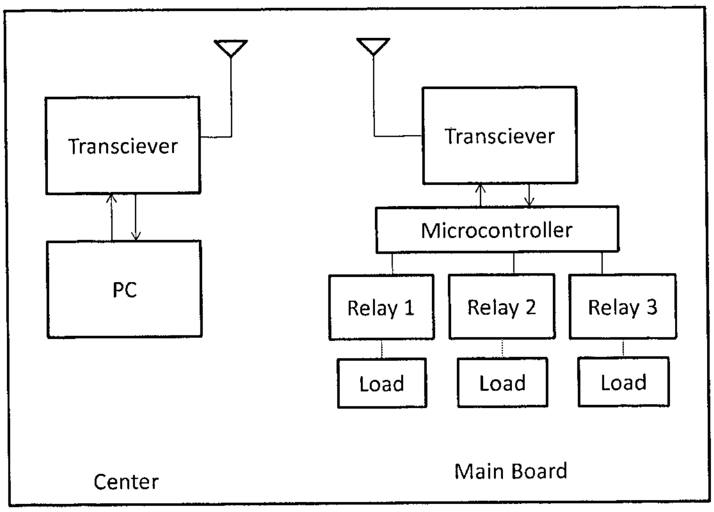

Figure 3.7: Block Diagram of Smart Energy Controller System

The hardware is being design to be as simple as it can to reduce cost and also at the same time reduce the power consumption. The main brain of the system is microcontroller PIC18F4550 has huge program memory size of 32kbytes or 16384 instructions can be programmed and also embedded with 2kbytes of SRAM and 256byte of EEPROM. 24 pins from the total of 28 pins can be used as input or output port. Thus, the features of PIC can fully utilized without adding any external hardware such as RAM and ROM.

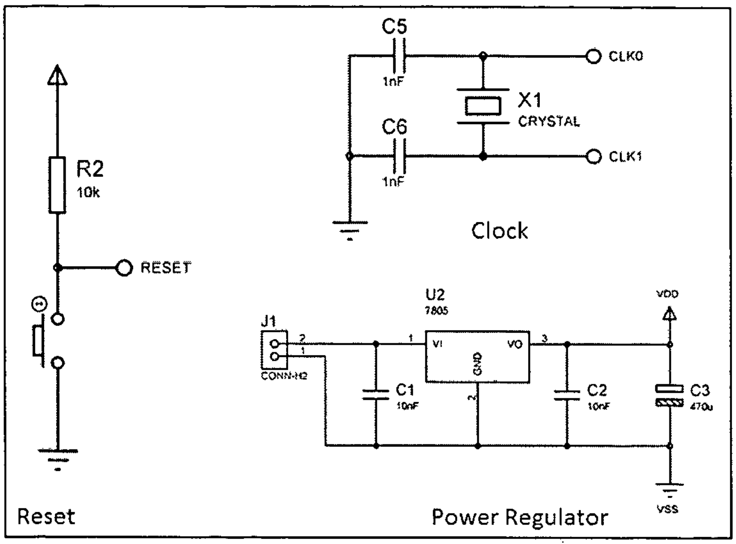

Figure 3.8 Reset, Clock and Power Regulator Circuit

The microcontroller PIC18F4550 is operating in normal mode. Hence, both OSC1 and OSC2 pins are connected to external clock circuit. By using the feature of PIC18F4550, it consists of internal crystals that can support microcontroller therefore pin OSC1 and OSC2 are not connected. Microcontroller board module consists of power circuit, reset circuit, and clock circuit module. They are very important to support the basic operation of microcontroller.

In order to power up the whole circuit, an AC to DC power adapter is being used as power supply. Two different DC power supply is needed to power up this project which are 3 Volts and 12 Volts. The 3 Volts supply is design to support the wireless transceiver XBEE and also the PIC18F4550, while 12V is design to support the entire relay which is being connected to the load as a control. The capacitor are used filter some of the fluctuations in the power supply voltage. A single pole single throw switch is added as an on/off switch as well as reset button.

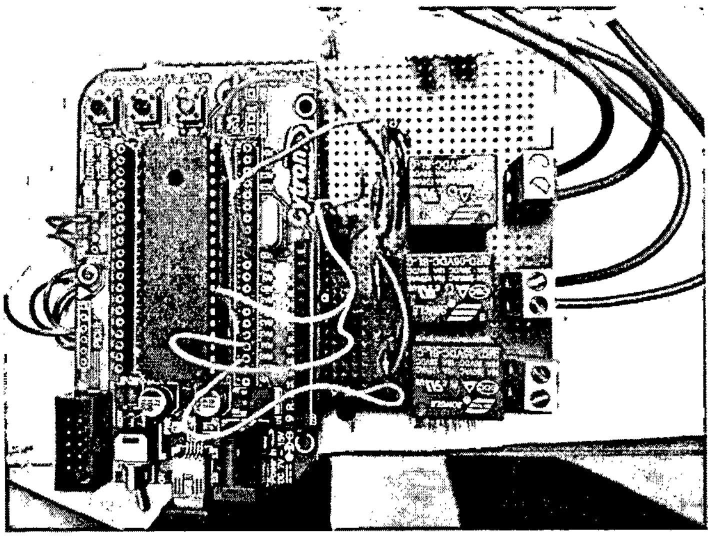

Figure 3.9: Initial hardware setup

3.5.3 Software

In order to have a user-controlled energy management system, a Graphic User Interface is developed. Microsoft Visual Basic 2008 is used as the base of this Graphic User Interface due to its flexibility and user-friendly features. The aim is to develop a GUI that will enable user to do the configuration and control of the entire load connected to the board. Some of the features that could be embedded within the GUI are the scheduling options, timers, daily and weekly set or completely on or off as shown in Figure 3.10.

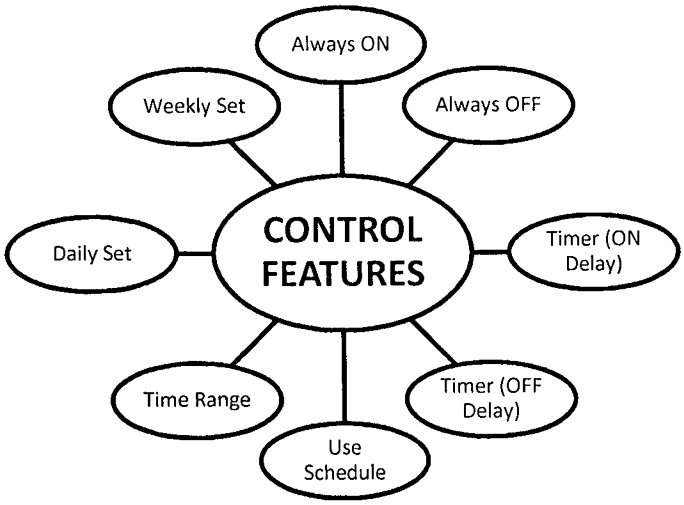

Figure 3.10: Control features inside the software

The main function of the Graphic User Interface is to prepare the connection and then can control the entire load connected to the Mainboard. The basic control process is to switch it on and off. The more advanced control option is to enable the hardware to control the load by using timer or scheduling function.

Additional function of this Graphic User Interface is to do a monitoring process. In other word, any user can check through this Graphic User Interface the status of each load connected to the Mainboard, whether it is being used or not. Another advance function is to collect the electrical usage data and represent it in the Graphic User Interface in the form of graphs or tables. A comprehensive system modelling which comprises of the graphic user interface, communication module and also the controller is shown in Figure 3.11.

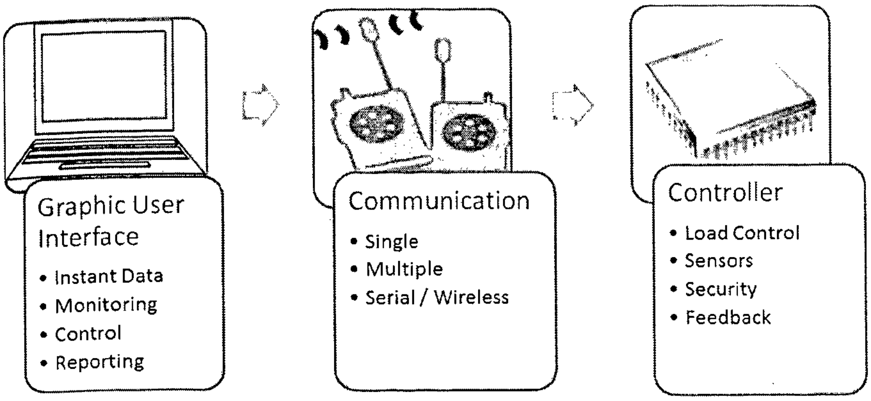

Figure 3.11: System modelling for the hardware and software

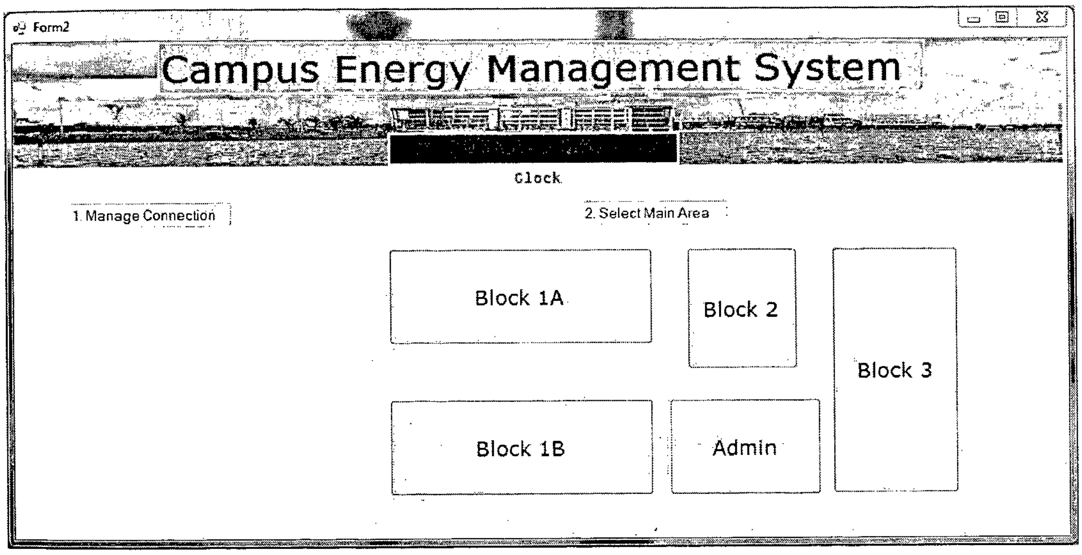

Figure 3.12: Main page of Campus Energy Management System

A Graphic User Interface is being developed as to control the hardware by using Microsoft Visual Basic as shown in Figure 3.12. The software contains four main items which are the main page, port selection and communication testing page and the room control page. The main page will have the option to the other two pages and also have the current time as the reference. All area within the FKEE building is being laid out in this page, namely Block 1A, Block 1B, Block 2, Admin and lastly Block 3.

The second page is about the port selection. This page is important since the port may change when using other PC or wireless devices. This page will also have the connection testing option. This option will able the user to test the connection after the port setting by sending the signal from the Graphic User Interface to the mainboard through the wireless signal in order to make the LED blink. The main purpose of this page is test the communication channel weather by using usual serial Universal Asynchronous Receiver/Transmitter controller or by using the wireless option with XBEE transmitter.

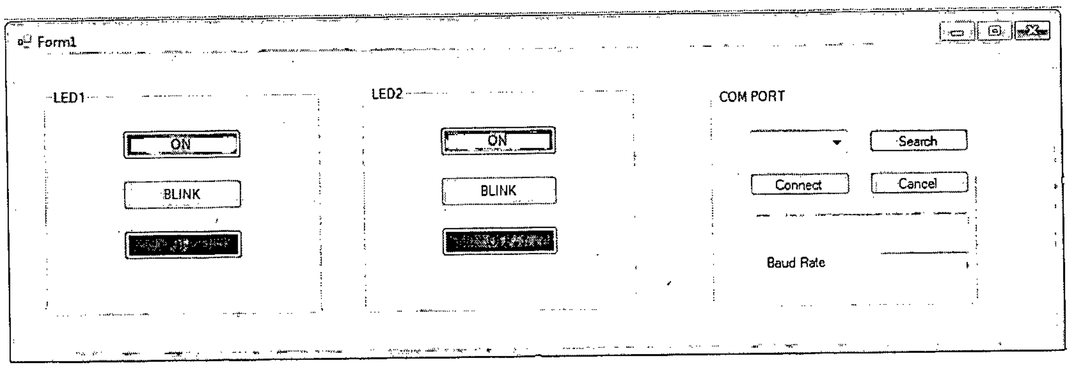

Figure 3.13: Port and communication testing page

The third page, which is the most important part of the system, is where the user may enter the input based on the timetable. By referring to the timetable, the user will select which time the Lecture Hall is occupied throughout the weekdays. This configuration is needed by the mainboard in order to control the air condition system and lightings within the dedicated Lecture Room. After finish entering all required configuration, the setting will then uploaded to the board through the wireless communication system.

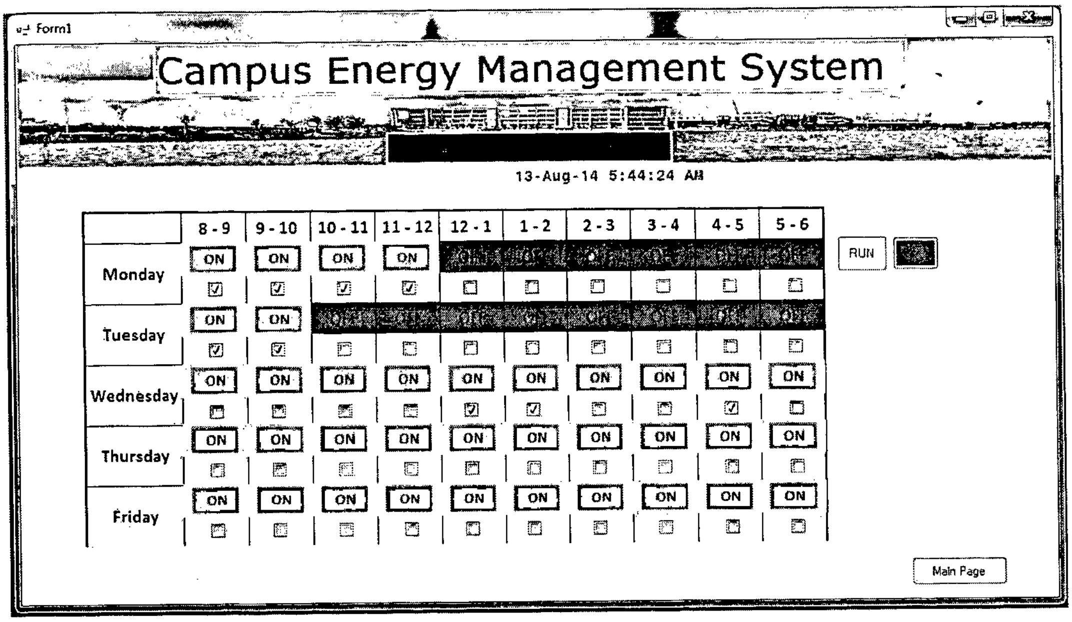

Figure 3.14: Time selection for the timetable based control

3.6 Summary

Based on different models of energy management and efficiency implementation discussed, a model of implementing in in university campus building is proposed. The new model for university campus building is proposed due to the different building function, occupancy levels and also due to different task being carried out within the same campus area. This model also take into account the limited financial budgets being allocated for energy management and efficiency programs inside university and also the time constraint to the staff to really put full commitment to this energy efficiency programs.

CHAPTER 4

RESULT ANALYSIS AND DISCUSSION

4.1 Introduction

This chapter will consist of two subsections of results, which are the energy audit results and also the energy management test rig model results. The energy audit results will show the lists of proposed energy saving measures for each target areas and also the calculations of implementing simple energy audit measures. The second subsection will show the result for the test rig model developed as to represent the real and detail energy audit implementation.

4.2 Energy Audit Results

Based on all data from floor plan, electricity billing, electrical single line diagram and also the data logging result, a specific energy management target area is being decided. By having specific target area, a proper energy management project can be carried out and will produce a more accurate and good result.

4.2.1 Target Area Layout Plan

The main target area in this research is the building of Faculty of Electrical and Electronics, University Malaysia Pahang. In general, FKEE building consists of five main blocks, namely Block 1, Block 2, Block 3, Admin Block and Classroom Block. Detailed descriptions are as in Table 4.1 below:

Table 4.1

FKEE Building Profile

No	Block	Description
1	Admin	Consist of administration office, cafeteria and ICT office and three Lecture Hall
2	Classroom	Consist of 6 Lecture Room, 8 Project Briefing Room and 8 Discussion Room
3	Block 1	Consist of staff room and laboratories
4	Block 2	Consist of staff room and laboratories
5	Block 3	Consist of staff room and laboratories

The administration area normally operates on 8.00 am to 5.00 pm working hours where the main activities are the faculty management purposes and student related administration. Normally the number of occupancy in this building is around 15 to 30 person in normal working condition throughout the year.

The classroom area which operates mainly for discussion and lecturing among the students and lecturers operates during the semester only. Normally, this area is not being occupied during the semester breaks and will be no occupancy at all. During normal semester season, this area will be used within 8.00 am to 6.00 pm with a very high occupancy level which may up to 200 people at a time. Sometimes there are also room in this area being used after 6.00 pm up to 11.00 pm as for discussion and lecturing.

The other three blocks in FKEE being used mainly as laboratories and staff rooms. The main operation hours is also between 8.00 am to 6.00 pm and operates mostly during semester season only. However, a higher use of electricity can be expected as the area are the biggest and equipped with laboratories apparatus, research and lab equipment and also computers.

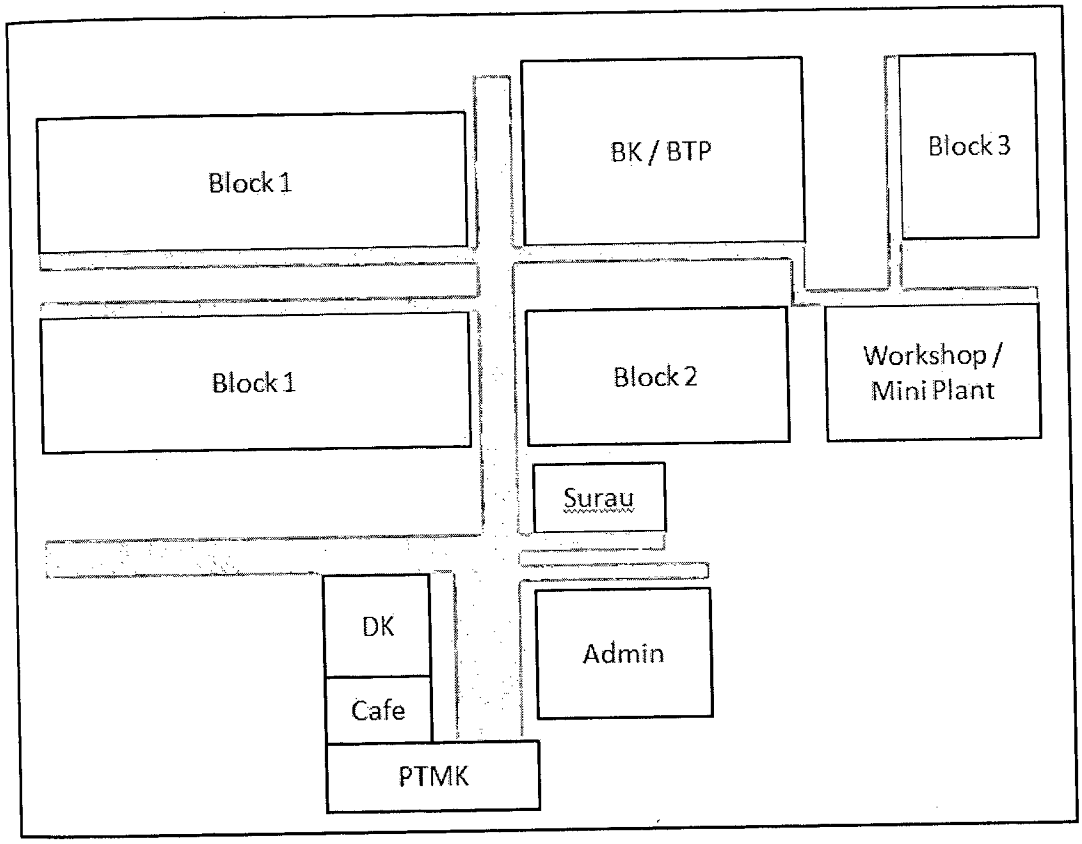

Figure 4.1: FKEE Building Layout

4.2.2 Electricity Billing

Electricity billing is one of the crucial information needed to be obtained before making any decision on energy saving measures since it will give an overview of the electrical usage within the area. Electricity billing profile will also become a baseline record as to compare with after completing any energy saving measures. It is also needed in order to understand where and when the energy being consumed within the targeted area.

In Pekan Campus of University Malaysia Pahang, Tenaga Nasional Berhad will only check the main kWh meter at substation for billing process. It means that only one bill will be prodiced for the whole campus of UMP Pekan. In order to get the accurate consumption data, Jabatan Pengurusan Harta UMP has installed own separate meter in several location. Hence, the data for different area and buildings can be obtained.

University Malaysia Pahang is using Tariff B, which is for Low Voltage Commercial Tariff. The charge does not have peak-off peak rate and also with no maximum demand charges. The charge is flat rate 43 cent per kilowatt hour for the usage of more than 200 kWh per month. The minimum charge of this tariff is RM7.20.

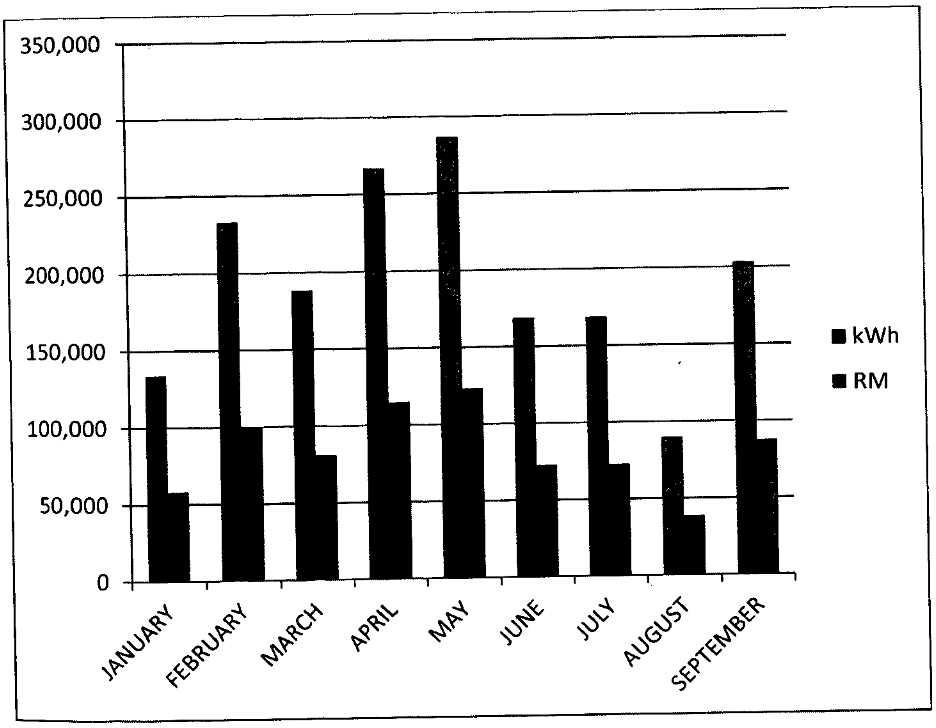

Figure 4.2: Electrical Energy Consumption within FKEE Building

Table 4.2 below shows the overall energy usage in term of kilowatt-hour and in Ringgit Malaysia for Faculty of Electrical & Electronics in the year 2013. The highest reading recorded in 2013 is in May with 286,678 kWh usages. The lowest usage is during August, which is 89,687 kWh. The main contribution throughout the year is during the semester and become almost half usage during semester break. For example, in 2013, during the semester, which is from February to May, the average consumption is 243,675 kWh or about RM104,780. The maximum usage during the semester is in May with 286,678 kWh usages and the lowest is 188,240 kWh, which is in March.

Table 4.2

Average Consumption during Semester

Month	**KWh**	**RM**
FEBRUARY	232,869	100,134
MARCH	188,240	80,943
APRIL	266,914	114,773
MAY	286,678	123,272
Total	974,701	419,121
AVERAGE	243,675	104,780

During semester break, the average consumption is 142,232 kWh or about RM61,160. The maximum usage during the semester break is in June with 168,604 kWh usage and the lowest is 89,687 kWh, which is in August.

Table 4.3

Average consumption during semester break

JUNE	168,604	72,500
JULY	168,405	72,414
AUGUST	89,687	38,565
	426,696	183,479
AVERAGE	142,232	61,160

4.2.3 Single Line Diagram

After having the layout plan of the building and the electricity bill, the next step is to have the single line diagram. The electrical single line diagram will be used as the reference in processing the building segmentation. By studying the electrical single line diagram, a proper plan and process could be developed before implementing any energy management project. Examples of full electrical single line diagram are attached in Appendix A1.

As shown in Figure 4.3, there are three Main Switchboards within FKEE building which are located in Block 1, Block 3 and Admin Block. By using these three Main Switchboard, data logger clamps were tapped in order to get the baseline electrical data. Main Switchboard at Block 1 has three Sub Switchboard which is Sub Switchboard for Block 1 right wing, Sub Switchboard for Block 1 left wing, and Sub Switchboard for Block 2 and Lecture Building.

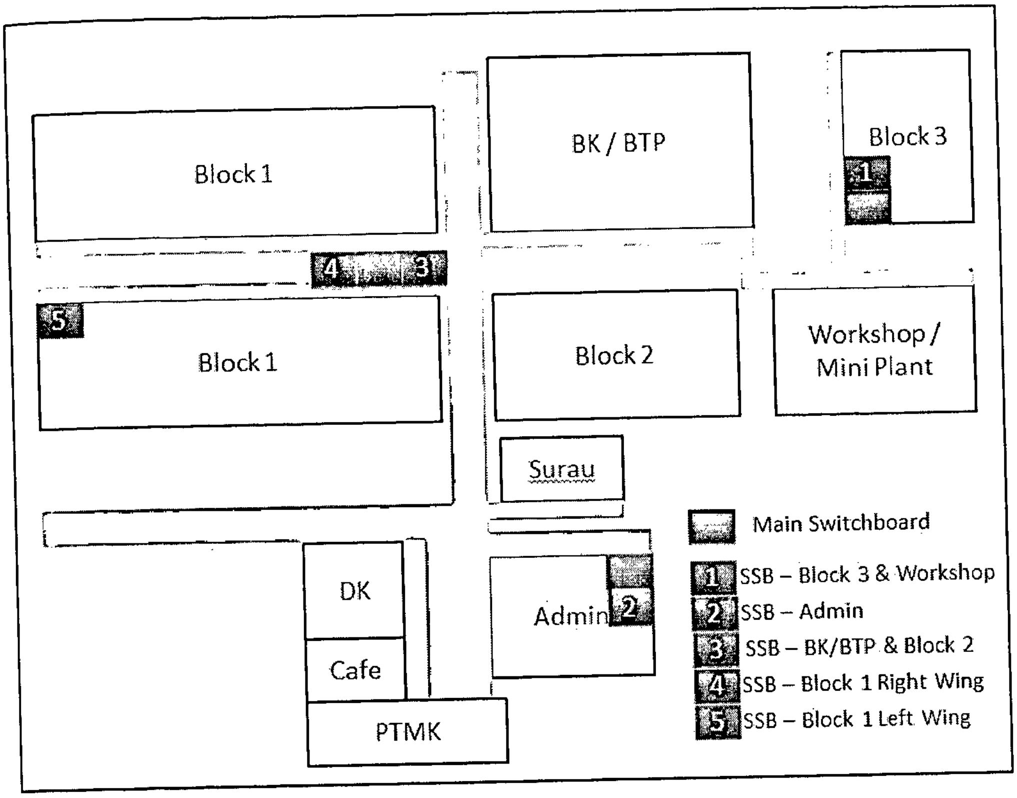

Figure 4.3: Layout of Electrical Sub Switch Board in FKEE

By using this configuration, a separate data of each building can be obtained and can get a proper segmentation of electrical energy used within the area. By having each separate electrical energy baseline data, a proper and more accurate result of return on investment could be obtained after the implementation of energy management project.

The second Main Switchboard will cover Admin Block, Cafeteria, Lecture Hall and also the ICT Office. The third Main Switchboard will cover Block 3 area and also the Workshop / Mini Plant building.

4.2.4 Building Segmentation and Targeted Area

The main factor of the segmentation is based on the function of each target area. Figure X shows the result of building segmentation after all data of layout plan and electrical single line diagram being analyzed. Basically buildings in Faculty of Electrical and Electronics Engineering can be segmented into four main areas. The details are as in Table 4.4 below:

Table 4.4

List of Target Area

No	Segment	Area Covered
1	Target Area 1	Block 1
2	Target Area 2	Lecture Rooms Block
3	Target Area 3	Administration Block
4	Target Area 4	Block 2, Block 3 and Workshop

The first target area, which is the Block A, is mainly for staff rooms and laboratories. The second target area is the lecture room block. This block contains 5 Lecture Room with the capacity of 30 people, 5 Project briefing rooms and also 6 Discussion Room. This building is the main focus area and has the highest occupancy during the semester. Target Area 3 and Target Area 4 will be less priority in this case study since the level of occupancy is relatively low compared to the other two target area. Figure 4.4 shows the layout plan for all the target area for energy saving measures and proposal.

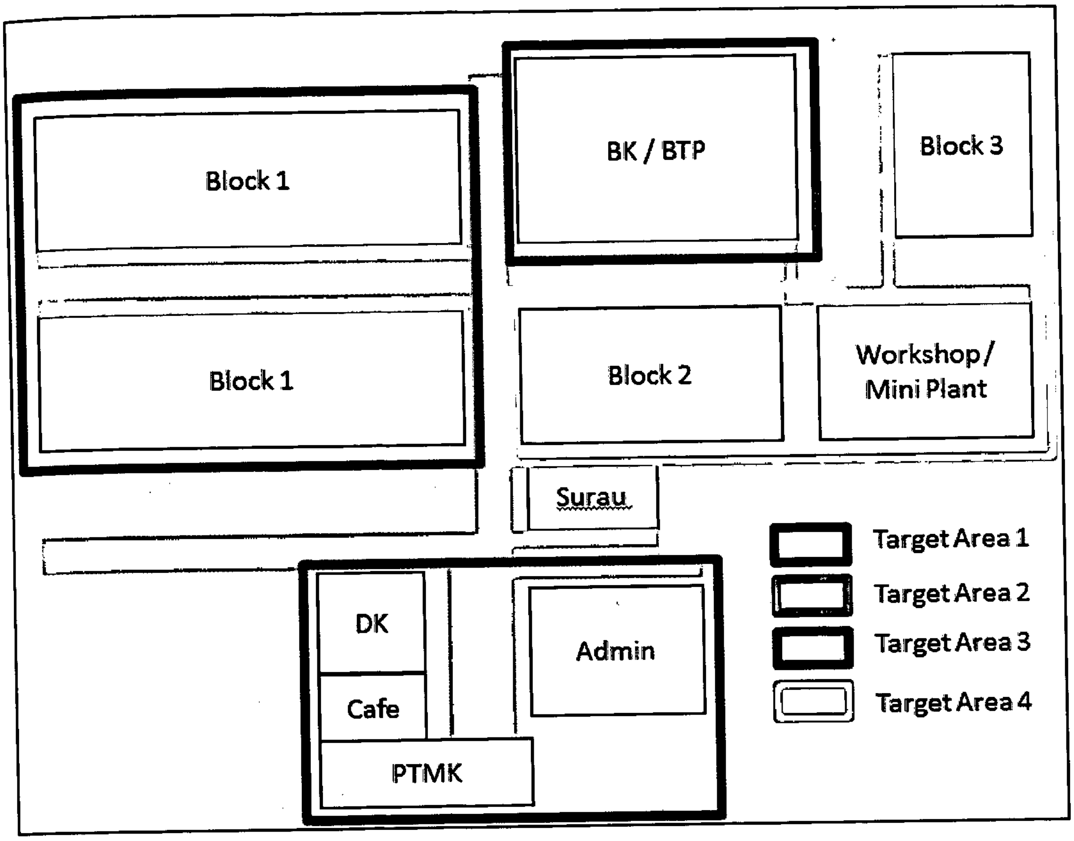

Figure 4.4: Layout of Target Area

4.2.5 Energy Saving Measures

After fulfilling all the requirement and setup the building segmentation and energy saving target area, the process continued with identifying possible energy saving measures for each area. This is being done through a detailed walk through audit.

As for Target Area 1, which covers all compound of Block 1, the area is mostly for staff rooms and laboratories. There are about 30 staff rooms for a level and consists of 18 large laboratories. All staff room is using centralized air condition and 95 percent of the laboratories use the same system. There are a small number of laboratories that used split air condition system, for example the Postgraduate Laboratories and Research Laboratories. Laboratories in this area are mainly for basics and computer laboratories.

There is no heavy machine that use large amount of electrical energy except for the compressors used in Programmable Logic Controller and Pneumatic Laboratories.

Based on the walk-through audit and detail observation for Target Area 1, energy saving issues and saving measures are being concluded as in Table 4.5 below

Table 4.5

Energy Saving Solution for Target Area 1

No	Issues	Energy Saving Solution
1	Staff door rooms and window keep open during office hour and thus increase the usage of energy in air conditioning system	Awareness program and reminder to close the door.
2	Aircond and lightings sometimes not switched off after office hour	Create sticker on awareness and energy saving.
3	6 x 32W fluorescent lamp in staff room, thus producing extra lighting	Rearrange the position and reduce number to 4 x 32W fluorescent lamp
4	Laboratory door rooms and window keep open during office hour and thus increase the usage of energy in air conditioning system	Awareness program and reminder to close the door.
5	Heating due to sunrise and afternoon inside the laboratory	Install window tinted
6	Lamps at corridor are too close to each other and thus waste energy.	Disconnect and reduce number on lamps at the corridor.

Target Area 2 is mainly for teaching and learning purposes. There are lecture rooms, discussion rooms and also project briefing rooms. Students are allowed to use these rooms during weekdays. The rooms in this area are locked during weekends. Lecture rooms are mainly used based on the timetables generated by the academic administration office. During the free time, there are also student uses these rooms to do discussions and homework. All the air conditioning system in these rooms are connected to the centralized system and will be automatically switched on at 8.00 in the morning and switched off at 6.00 pm.

Based on the walk-through audit and detail observation for Target Area 2, energy saving issues and saving measures are being concluded as in Table 4.6 below:

Table 4.6

Energy Saving Solution for Target Area 2

No	Issues	Energy Saving Solution
1	Air Condition and lightings are not switched off after classes at lecture room.	Install device or system to enable automatic on off.
2	Some of door closer are broken, thus the cool air keep flow out.	Replace new door closer, regular maintenance.
3	Lamps at corridor are too closed to each other and thus waste energy.	Disconnect and reduce number on lamps at the corridor.
4	Frequent use of Discussion Room and Lecture Room after office hour and weekend for student activity, air condition need to be switched on for the whole building.	Change the air condition type from centralized to split system to cater after office hour usage.

Target Area 3 consist of laboratories with advanced system such as the Control & Instrumentation Mini Plant, robot arms, printed circuit board machines and high voltage power system equipment. There is also a General Workshop that has equipment like welding machines, milling machines, drilling machine, compressors and steel sheet cutter. Most of the areas within this Target Area 3 have no air conditioning system and just used fan and roof ventilator for cooling purposes. The main building in this target area is a double-volume type building and thus it uses a relatively higher number of high rise lamp system compared to normal building.

Based on the walk-through audit and detail observation for Target Area 3, energy saving issues and saving measures are being concluded as in Table 4.7 below:

Table 4.7

Energy Saving Solution for Target Area 3

No	Issues	Energy Saving Solution
1	Staff door rooms and window keep open during office hour and thus increase the usage of energy in air conditioning system	Awareness program and reminder to close the door.
2	Leak in compressed air system	Repair the leak.
3	Air condition and lightings are not switched off at Discussion Room.	Put awareness signage. Maintain log book.
4	Lamps at corridor are too closed to each other and thus waste energy.	Disconnect and reduce number on lamps at the corridor.

Target Area 4 is mainly the Administration Office, Cafeteria and three lecture hall that can occupy 100 people at a time. Based on the observation, the setting of the air condition within this building might have some problems since the temperature is quite low. In order to temporarily overcome the coldness, the main door of administration office is being kept open and thus clearly wastes of energy occur within this area.

Based on the walk-through audit and detail observation for Target Area 4, energy saving issues and saving measures are being concluded as in Table 4.8 below:

Table 4.8

Energy Saving Solution for Target Area 4

No	Issues	Energy Saving Solution
1	Main door always open due to coldness.	Repair air conditioning system
2	Frequent of door open during office hour, causing the cold air flow out to surrounding.	Change door to rotating type to preserve cool environment.
3	Lighting and air conditioning not switched off after classes	Put awareness signage. Develop smart control system.
4	Frequent changing of corridor lamp	Change to high quality energy saving lamp.
5	Doors at Lecture Hall not closed properly.	Repair the door and do regular maintenance.
6	Frequent use of Lecture Hall after office hour and weekend for student activity, air condition need to be switched on for the whole building.	Change the air condition type from centralized to split system to cater after office hour usage.

4.2.6 Energy Saving Measures by Priorities

After listing all possible energy saving measures within the four target area, the next step is to list it all together and do further analysis.

Table 4.9

Combine list of low cost Energy Saving Solution

No	Issues	Solution	Target Area
1	Staff door rooms and window keep open during office hour and thus increase the usage of energy in air conditioning system	Awareness program and reminder to close the door.	1, 2
2	Air condition and lightings sometimes not switched off after office hour	Create signage on awareness and energy saving.	1, 3
3	Laboratory door rooms and window keep open during office hour and thus increase the usage of energy in air conditioning system	Awareness program and reminder to close the door.	1
4	Staff door rooms and window keep open during office hour and thus increase the usage of energy in air conditioning system	Awareness program and reminder to close the door.	3
5	Air condition and lightings are not switched off at Discussion Room.	Put awareness signage.	3
6	Some of door closer are broken, thus the cool air keep flow out.	Replace new door closer, regular maintenance.	2
7	Doors at Lecture Hall not closed properly.	Repair the door and do regular maintenance.	4
8	Leak in compressed air system	Repair the leak.	3

All listed energy saving measures needed to be divided to three typical type of energy saving measures, which are the low cost measures, medium cost measures and high cost measures. By dividing it based on these cluster, a proper plan to execute the project could be set up and then enhanced it with the return on investment aspect. The detail lists of low cost measures are listed as in Table 4.9.

The low cost energy saving measures refers to the immediate action can be taken and needed only small amount of cost. Based on the observation and analysis form previous step, the saving measures that can immediately implement with low cost are awareness program and energy saving signage.

Table 4.10

Combine list of medium cost Energy Saving Solution

No	Issues	Solution	Target Area
1	Lamps at corridor are too close to each other and thus waste energy.	Disconnect and reduce number on lamps at the corridor.	1, 2, 3
2	Air Condition and lightings are not switched off after classes at lecture room.	Install device or system to enable automatic on off.	2
3	6 x 32W fluorescent lamp in staff room, thus producing extra lighting	Rearrange the position and reduce number to 4 x 32W fluorescent lamp	1
4	Frequent of door open during office hour, causing the cold air flow out to surrounding.	Change door to rotating type to preserve cool environment.	4
5	Heating due to sunrise and afternoon inside the laboratory	Install window tinted	1
6	Lighting and air conditioning not switched off after classes	Develop smart control system.	4

These signage will remind the users to always aware about the energy usage and try to not to waste it. Besides that, it is appropriate to maintain and repair the entire door closer for laboratories, lecture room, lecture hall and discussion rooms. This action can prevent unnecessary energy wastage from air conditioning system. Details on the medium cost energy saving measures are listed in Table 4.10.

Medium cost energy saving measures refers to detail preparation and need some amount of money to implement it. A detail look into the system is needed and some engineering work needs to be carried out to finish it.

For example, the proses of disconnecting existing corridor lamp will need a detail calculation on the load and electrical system. Besides that, developing a smart controller in order to control the air condition system and lighting in classes also need a proper plan and design. A few testing also needed to be implemented in order to get the most efficient system configuration.

High cost energy saving measures refers to a more complex solution which requires a detail engineering designs and calculation. For example, in order to overcome the high energy usage during weekends of after office hours at classrooms or halls, a smaller energy efficient centralize cooling tower system may be needed to replace current conventional centralize air conditioning system. Besides that, a high quality energy saving lamp is proposed in order to replace the old compact lamp which requires frequent change due to damage.

Based on the lists of all energy saving measures listed above, two project will be discussed further, which are the repositioning of lamps in staff rooms and smart controller to control air conditioning and lighting system. These two project will be discussed further as the example of detailed implementation of energy saving measure based on the new energy management model proposed.

Table 4.11

Combine list of high cost Energy Saving Solution

No	Issues	Solution	Target Area
1	Frequent changing of corridor lamp	Change to high quality energy saving lamp.	4
2	Frequent use of Lecture Hall after office hour and weekend for student activity, air condition need to be switched on for the whole building.	Change the air condition type from centralized to split system to cater after office hour usage.	4
3	Frequent use of Discussion Room and Lecture Room after office hour and weekend for student activity, air condition need to be switched on for the whole building.	Change the air condition type from centralized to split system to cater after office hour usage.	2

4.3 Lightings in Staff's Room

One of the energy saving measures proposed in medium cost cluster is about repositioning of lightings in staff's room. Current installation in staff rooms is 6 units of 32 Watt fluorescent lamp. These 6 units of lamps produce about 526 lux of and it is more than enough for lighting in a room. As for record, Department of Standards Malaysia suggest the lighting for general offices is 300 – 400 lux (Department of Standard Malaysia, 2007).

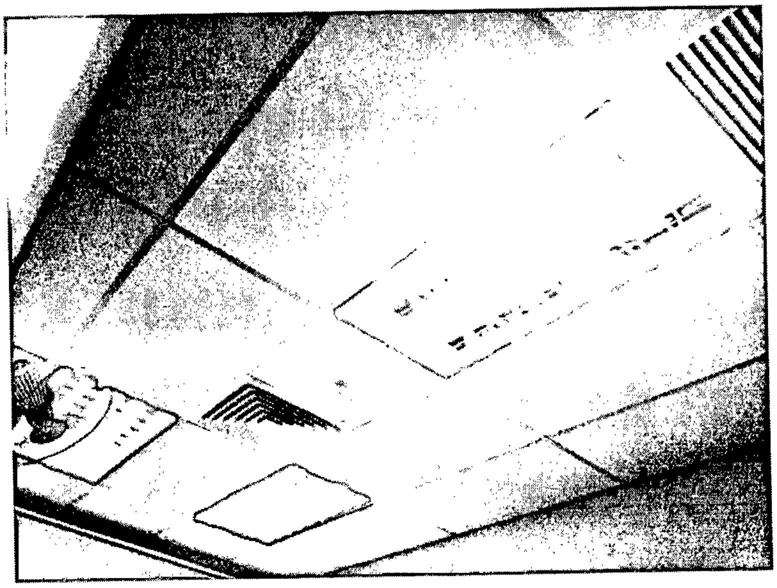

Figure 4.5: Staff room lighting

The more important issue is about the arrangement of lighting inside the staff rooms. The current arrangement requires more lamps than needed and the effect of lighting is not thorough to all side of the room. Current arrangement of lightings in staff rooms is shown in Figure 4.6 below:

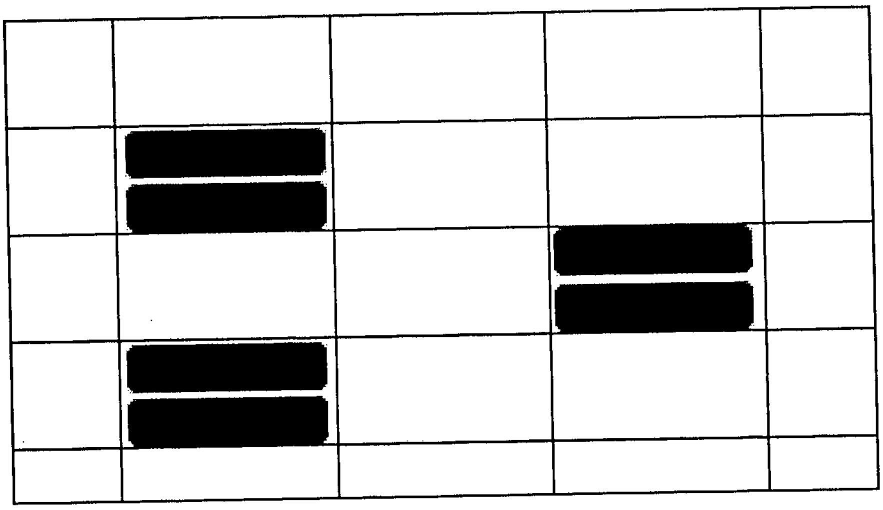

Figure 4.6: Current arrangement of lamps

In order to use the energy efficiently, it is proposed that the arrangement of lamps inside the staff room is reduce and rearrange it in order to get the maximum and uniform lighting inside the room. The new lamp arrangement propose of using three or four lamps configuration. Those comparison is shown Figure 4.7 below:

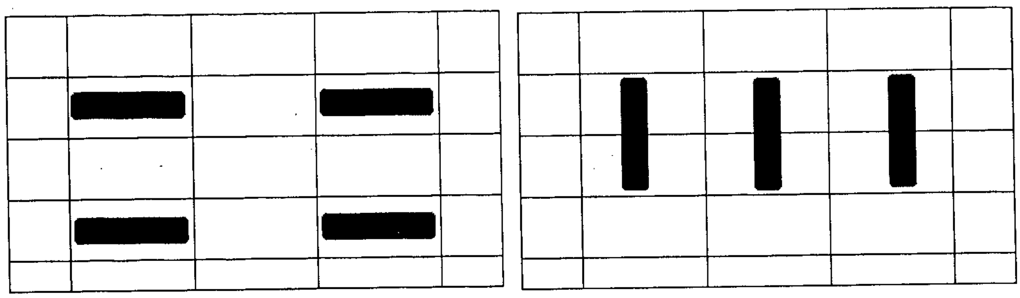

Figure 4.7: Proposed arrangement of lamps

Based on the new lamps arrangement, a detail calculation on energy and cost saving by using this new configuration is carried out. The data is about the numbers of rooms, calculation of total number of lamps, electrical tariff and also the operation hours. There are 102 staff rooms in FKEE building and 80 rooms are currently occupied. All the detail on the raw data is been compiled as in Table 4.12.

Then, by creating a template in Microsoft Excel software, calculation can be done easily in order to get the current cost estimation for staff room lightings. Based on the calculation, the cost involving all staff room as the lamp is being used throughout of eight hours of working hours is RM 1462 per month, taking into consideration only 22 working days only, as in Table 4.13.

Table 4.12

Comprehensive data for staff's room lighting energy saving solution

ROOM		
Number of room in Block 1 (C Type)	80	room
Number of room in Block 2 (C Type)	12	room
Number of room in Block 3 (C Type)	10	room
Total Number of Room	102	room
Current Room Occupied	80	room
LAMP		
Number of lamp in a room	6	unit
Total Number of lamp (Occupied Room)	480	unit
Total Number of lamp (All Room)	612	unit
Power of a lamp	32	watt
ELECTRICAL TARIFF		
Electrical Tariff	B	
Price / kWh	0.43	RM
HOUR DURATION		
Normal Working Hour	8	hour
Night Hour Duration	16	hours
Weekend Hour Duration	64	hours

Table 4.13

Lighting cost calculation

CURRENT ALL ROOM WITH NORMAL WORKING HOUR		
kWh of each lamp	0.26	kWh
Total kWh of lamp / day	156.67	kWH
Total Cost /day	67	RM
Total Cost / month (22 days)	1482	RM

With the arrangement of four lamps configuration, the total cost will decrease to RM 988, with the savings of RM 494 per month. By using three lamps configuration, total cost per month will decrease to RM 741 and the saving is also RM 741, which is half compared to current configuration. To have a good lighting inside the staff room, it is recommended to use the four lamps configuration. However, 3 lamps configuration could also installed and have a good light amount by also integrating the daylight factor in this arrangement. The detailed calculation is shown in Table 4.14.

Table 4.14

Lamps configuration solution

4 Lamp Configuration		
Number of lamp in a room	4	unit
Total Number of lamp (All Room)	408	unit
kWh of each lamp	0.26	kWh
Total kWh of lamp / day	104.45	kWH
Total Cost /day	45	RM
Total Cost / month (22 days)	988	RM
Saving / Month	494	RM
3 Lamp Configuration		
Number of lamp in a room	3	unit
Total Number of lamp (All Room)	306	unit
kWh of each lamp	0.26	kWh
Total kWh of lamp / day	78.34	kWH
Total Cost /day	34	RM
Total Cost / month (22 days)	741	RM
Saving / Month	741	RM

4.3.1 Smart Energy Management System in Lecture Room

Smart Energy Management System is one of the detailed projects proposed after the process of detail walk-through audit. This energy saving measures is proposed to control the energy usage within Block 2 since it is the most occupied area during the semester and the main focus of the teaching and learning happens there. As been discussed previously, Block 2 consists of 6 Lecture Room, 8 Project Briefing Room and 8 Discussion Room.

The most common energy saving problem identified within this area is the air condition system and lightings are still working even after classes or office hours. The air condition system and lightings may only been shut of when the security personnel check the area during the night. There are also cases that the air conditioning system and lightings are not shut off over the weekends. Thus, it is a very crucial thing to take action on this issue in order to minimize energy wastage and have a good return of energy saving.

After doing some analysis on this energy issues, a new and smart energy control strategy is being proposed, which is developing a smart controller that can control the load within the lecture room. This smart energy management system will be synchronized with the lecture room's timetable and control the air conditioning system and based on the allocated time within the timetable. This method is proven to be the most efficient control strategy for this energy issue.

Based on the timetables obtain from the Academic Management Office, a detail analysis is being done to three Lecture Room. The timetables obtained if for the Semester II of the year 2012/2013 Session and also for the Semester I of 2013/2014 sessions. It is set that the overall usage of the Lecture Room is 10 hours per day, which is from 8.00 am till 6.00 pm during the weekdays. Replacement class and other activity during weekends are not being counted in this analysis. As been shown in Table 4.15 and Table 4.16, a comparison of the time the classroom being occupied for teaching and learning with the free time is being detailed out.

Table 4.15

Occupancy data for Sem II 2012/12

DK1			**DK2**			**DK3**		
	Class	Free		Class	Free		Class	Free
Monday	6	4	Monday	8	2	Monday	6	4
Tuesday	6	4	Tuesday	9	1	Tuesday	7	3
Wednesday	6	4	Wednesday	4	6	Wednesday	2	8
Thursday	8	2	Thursday	9	1	Thursday	4	6
Friday	5	5	Friday	6	4	Friday	6	4
Total Hours	**31**	**19**	**Total Hours**	**36**	**14**	**Total Hours**	**25**	**25**

Table 4.16

Occupancy data for Sem II 2012/12

DK1			**DK2**			**DK3**		
	Class	Free		Class	Free		Class	Free
Monday	9	1	Monday	8	2	Monday	8	2
Tuesday	9	1	Tuesday	8	2	Tuesday	10	0
Wednesday	5	5	Wednesday	8	2	Wednesday	6	4
Thursday	7	3	Thursday	6	4	Thursday	4	6
Friday	6	4	Friday	6	4	Friday	2	8
Total Hours	**36**	**14**	**Total Hours**	**36**	**14**	**Total Hours**	**30**	**20**

From the data above, it can be concludes that the overall occupied times for Semester II of the year 2012/2013 Session is 92 hours per week and the free time is 58 hours per week. As for Semester I of the year 2013/2014 Session, the occupied times is 102 hours per week and the free time is 48 hours per week. It is about 39 percent free time during Semester II of the year 2012/2013 Session and about 32 percent free time during Semester I of the year 2013/2014 Session as shown in Figure 4.8 and Figure 4.9 below.

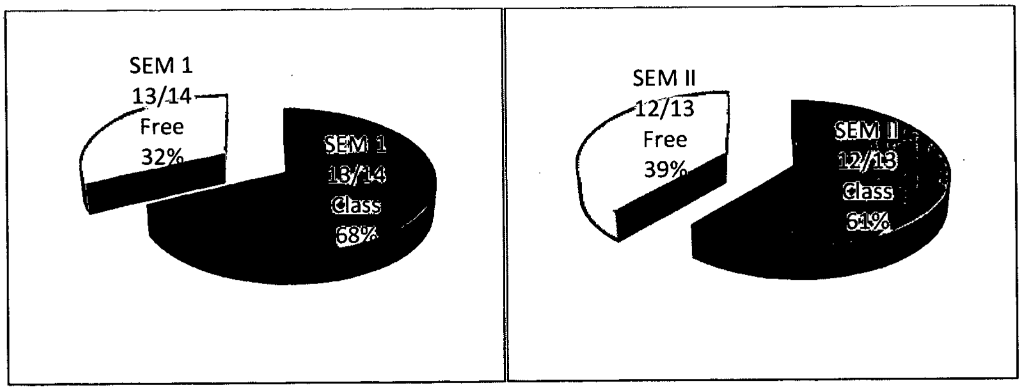

Figure 4.8: Analysis of occupancy percentage

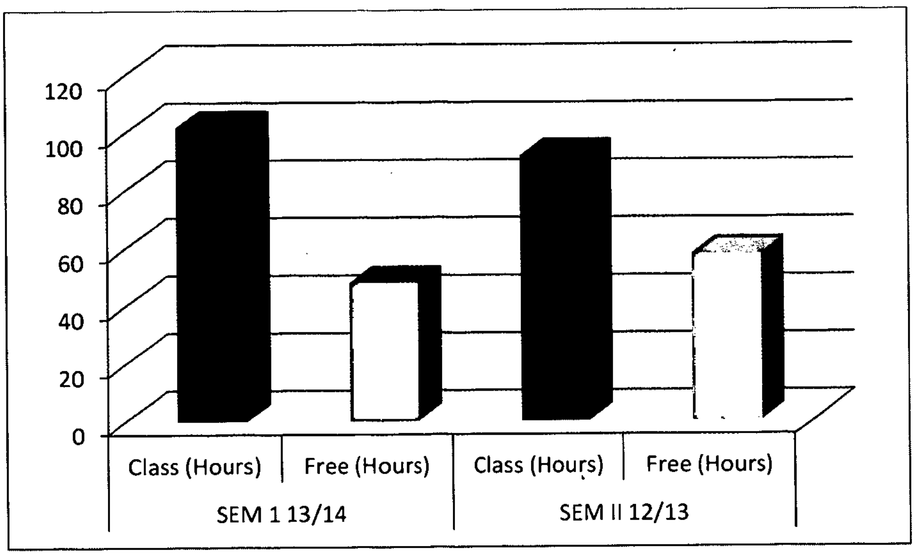

Figure 4.9: Comparison of occupied and free hours

As the conclusion, the control strategy by installing a smart energy management system with timetable based synchronized will be to 30 percent energy and cost saving within this Target Area 2. It is a much better result compared to just putting a simple timer which will control only a one time switch on at 8.00 am and one time switch off at 6.00 pm.

4.4 Test Rig Results

Based on the earlier arrangements, the test rig undergoes three types of experiments, which are the normal office hour operation, sensor-based operation and smart operation by scheduling method. Figure 4.12 shows the daily load based on current trend and also the total energy consumption by using the normal office hour operation configuration. The usage of the room is configures as full load from 8.00am up to 6.00pm with a normal 1.00pm to 2.00pm class break. The maximum total energy recorded is 143Wh.

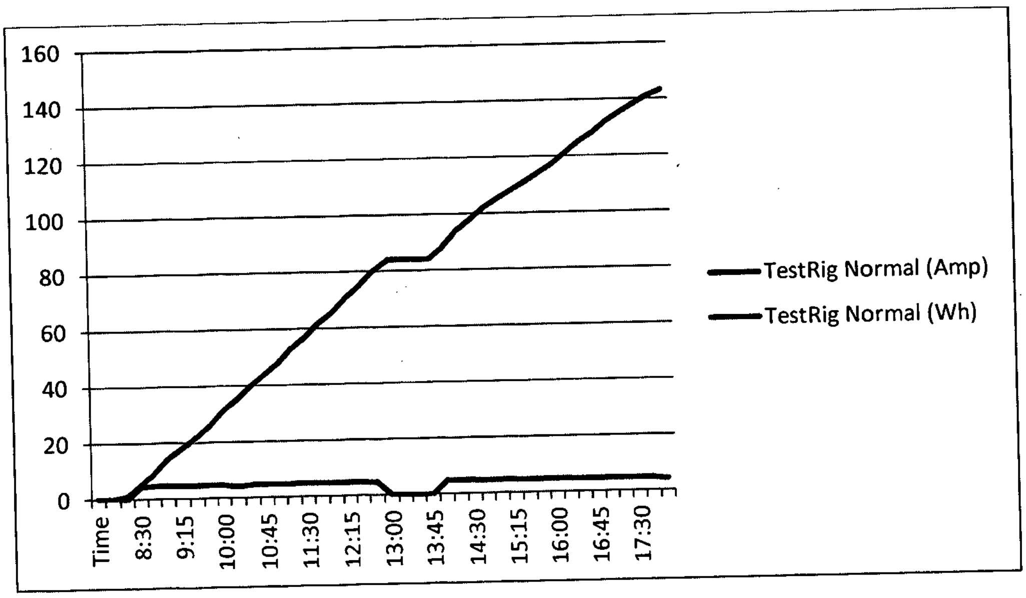

Figure 4.10: Voltage and current of the test rig normal configuration

Figure 4.13 show the daily load based on current trend and also the total energy consumption by using the sensor-based control configuration. During the day, the room is controlled by the motion sensor which will turn on all loads when movement is detected and will switch all loads when no movements detected. The maximum total energy recorded is 139 Wh.

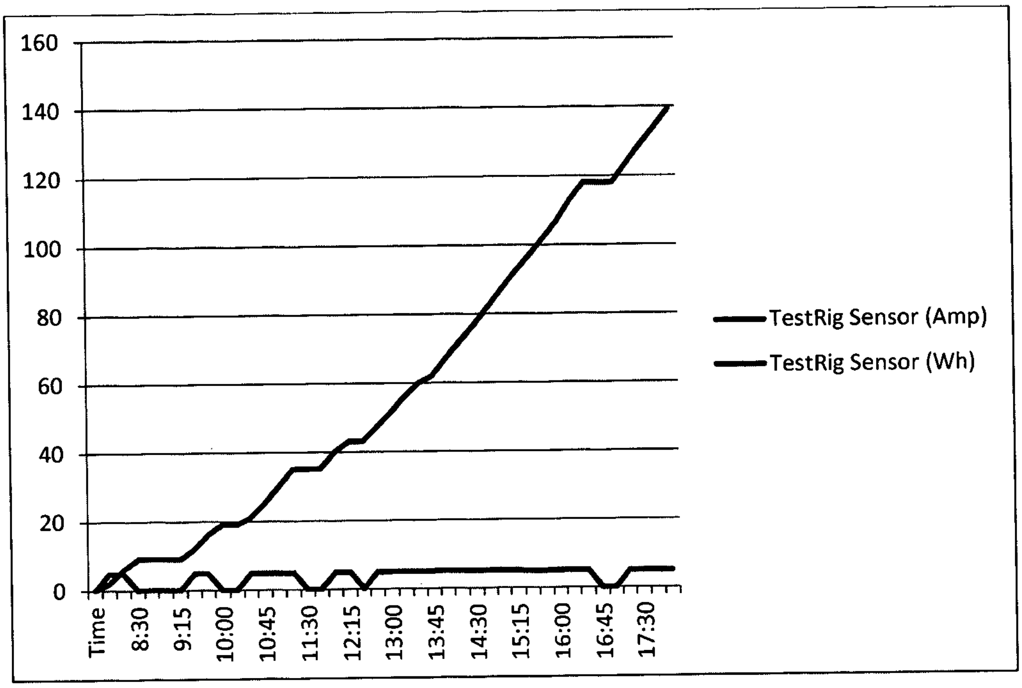

Figure 4.11: Voltage and current of the test rig for sensor configuration

Figure 4.14 show the daily load based on current trend and also the total energy consumption by using the scheduled-based smart operation configuration. The loads inside the room will be switched on and off based on the pre-configuration done by the administrator based on the real class schedule. The maximum total energy recorded is 85 Wh.

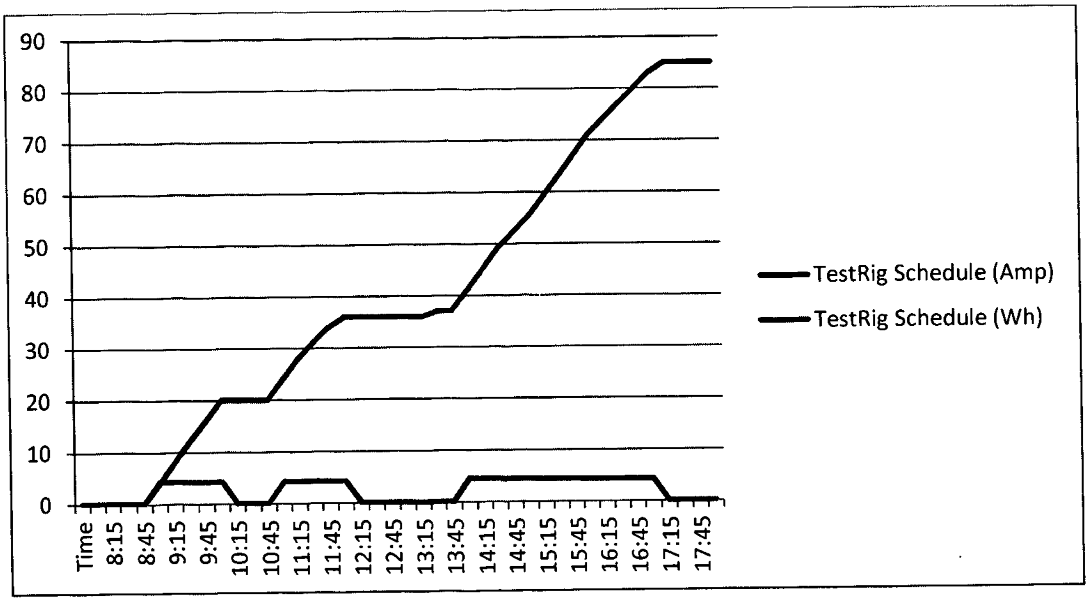

Figure 4.12: Voltage and current of the test rig for smart operation configuration

Table 4.17 summarizes the overall results of energy consumption for all three test rig configurations and also the maximum, minimum and average value of the results.

Table 4.17

Summary of energy consumption for three testing configuration

No	**Item / Configuration**	**Total Energy (Wh)**
1	Normal	143
2	Sensor	139
3	Schedule	85
4	Maximum Energy Used	143
5	Minimum Energy Used	85
6	Average Energy Used	122

4.5 Result Discussion

Figure 4.15 shows the comparison of daily load current trend for all 3 test rig configurations, which are the normal office hour operation, sensor-based operation and smart operation by scheduling method. The figure shows the load on and off trends for the whole day operations.

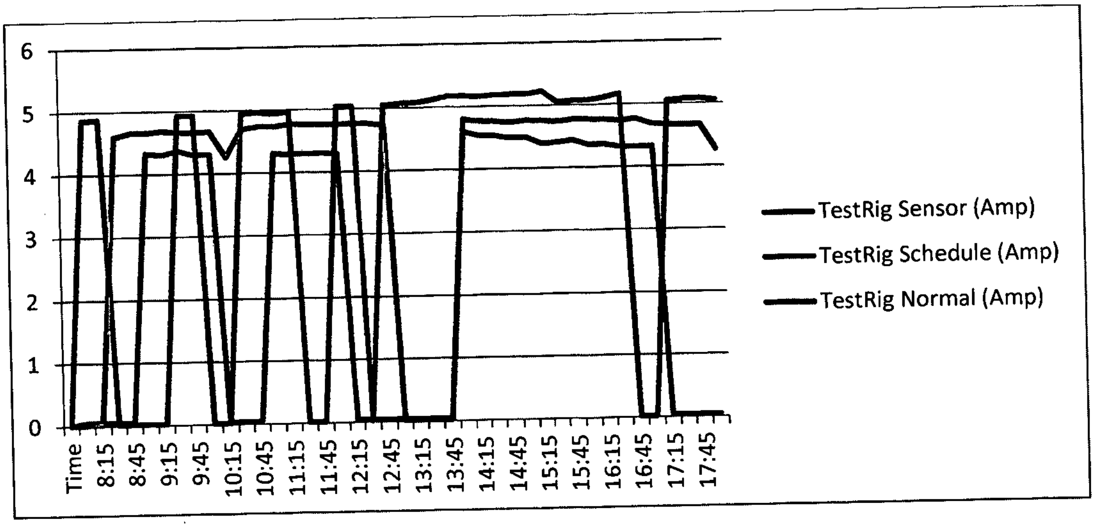

Figure 4.13: Total current comparison of 3 testing configuration

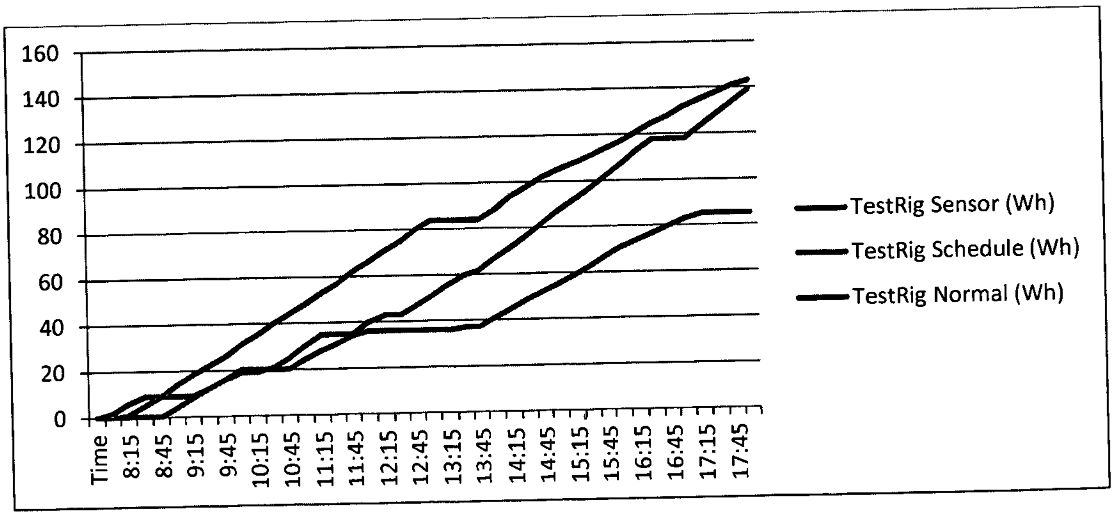

Figure 4.14 : Watt-hour comparison of 3 testing configuration

Figure 4.16 shows the energy consumption trending for all 3 test rig configurations. The energy consumption for normal office hour configuration is on the top of the graph while the scheduled-based smart operation recorded the lowest energy consumption.

Table 4.18 shows the related data of total energy consumed based on all three tested configuration. Maximum energy used is when using the normal office hour configuration with 143Wh while the schedule-based smart operation configuration recorded lowest with 85 Wh. Compared to the maximum usage of 143Wh, the scheduled-based smart operation uses less 40 percent of energy consumption, which is very much lower to the normal office hour operation.

Table 4.18

Total Energy Consumed

No	**Item / Configuration**	**Total Energy (Wh)**
1	Normal	143
2	Sensor	139
3	Schedule	85
4	Difference	58

Therefore, it is concluded that the best configuration which will give the best energy consumption level is by using the scheduled-based smart system compared to the normal office hour operation or the motion sensor room control operation.

4.6 Summary

In this chapter, all data collected is being compiled in order to get the overal idea in implementing energy management and efficiency programs within the university campus building. All calculation regarding the cost and the savings are also being put together as a result of detailed analysis. Lastly, a proposed hardware and software to be used together within the campus energy efficiency and management system is being brifly discussed. This hardware will become part of the comprehensive energy management system to be used within university campus building, namely the Smart Campus Energy Management System (SCEMS).

CHAPTER 5

CONCLUSION

5.1 Introduction

There is a crucial need in formulating a completely focused and special energy management and efficiency system for university campus. This is due to the uniqueness within the university campus such as the various type of laboratories, different functions of buildings such as libraries, hostels, classrooms and also administration building. There are also factors such as the bureaucracy and red tapes problems, different managerial structure and also the limitation within the financial budget. Therefore, the process of formulating an appropriate and precise energy management and efficiency system is very critical and important in order to get the best system to be implemented.

5.2 Different Method in Energy Management System

As been discussed earlier in Chapter 2, different areas and building will see the different practice and implementation of energy management and efficiency system. This covers from the simplest form of energy management processes such as installing control devices up to the use of state-of-the art technology within the building in order to get the best result of energy saving solutions. There are also simple steps taken by implementing walk through energy audit and also the much more comprehensive implementation of sustainable energy management system. Thus the process of selecting appropriate devices and system is a must when trying to develop a comprehensive energy management model for university campus building.

5.3 Literature to Research Design

In literature study, some cases of energy management implementation has been briefly discussed. These projects consist of simple energy management measures like finding for the thermal comfort of users up to the modification inside the HVAC system inside the university building. As to add-in to these implementation, this research propose to implement a step-by –step energy audit process for the university campus building in order to find lists of energy saving measures.

Baseline data such as the layout, electrical single line diagrams and energy usage for the Faculty of Electrical and Electronics Engineering is also being obtained as to create the basis of analysis. Proposals of energy saving measure for different energy target area are also being comprehensively analyzed and recommended for further implementation. Details of calculation are also being put together in order to show examples of energy saving solution that could be implemented.

Based on the findings, an area is being selected with the aim to reduce at least 20% of the current energy usage. A test rig is then being developed as a resaearch model and at the same time to not to interfere to the existing system. Intefering the real loads and bilding with preliminary study of the controller may effect the process of teaching and learning in the faculty.

The controller in then bieng developed and then combined with the test rig. Pre-outlined testing configuration in then loaded into the controler and each data for collected. All the data is then analyed and it is proved that the newly proposed control strategy based on classroom scheduled prodeced the highest energy saving percentage adn preceed the inital target, which is 20% energy saving.

5.4 Recommendations and further works

As to enhance this project, a wider project scope may be included such as to get all the energy usage details for all sections within the campus building of University Malaysia Pahang. By implementing this sort of wider project scope, a more detail, complete and accurate building baseline data could be obtain and hence will produce a more reliable energy efficiency solutions. In terms of hardware and software, improvements can be made by integrating a more user friendly wireless module in order to enhance the communication process and also to improve the overall system performance. A more detailed energy audit process within the university campus could also be investigated as the further work of this research.

5.5 Conclusion

As a conclusion, this project proposes a new model for energy management and efficiency system to be implemented within the university campus building especial in University Malaysia Pahang. Implementation of any energy saving project inside a university should be handled through a systematic and comprehensive implementation procedure in order to get the best result. Proposed energy saving configuration based on the classroom schedule may also become another point of view for other research to look in as it proves to give higher energy saving percentage compared to other conventional method.

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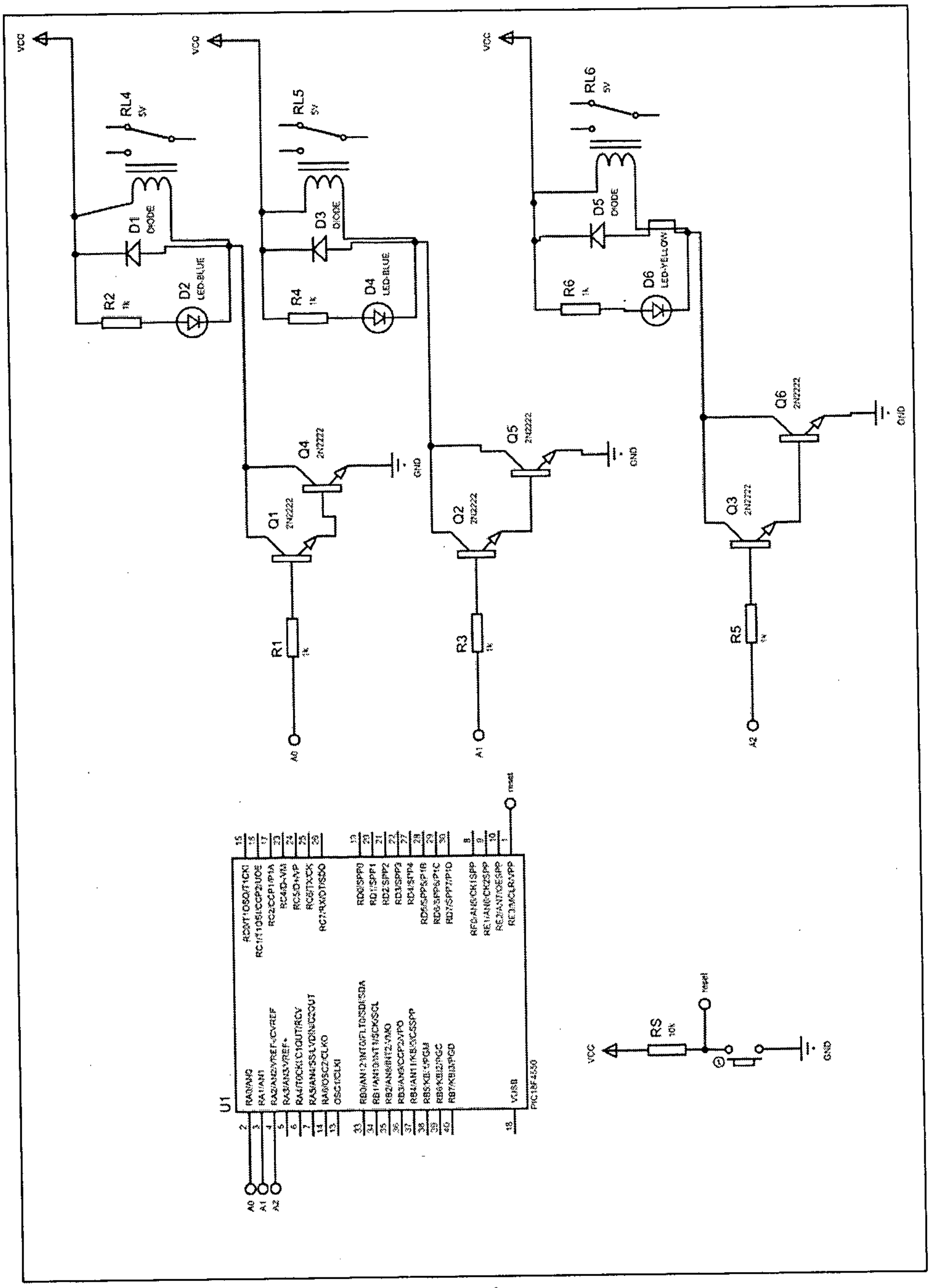
APPENDIX A1

CONTROLLER BOARD CIRCUIT



APPENDIX A2

CLASSROOM TIMETBALES - FIRST SAMPLE

Room Code E00DK1 DEWAN KULIAH 1 FKEE 100										
	08:00 - 08:50	09:00 - 09:50	10:00 - 10:50	11:00 - 11:50	12:00 - 12:50	13:00 - 13:50	14:00 - 14:50	15:00 - 15:50	16:00 - 16:50	17:00 - 17:50
MON	BEE3323 Grp: 01 L Cap: 60 0125 - HBA	BEE3323 Grp: 01 L Cap: 60 0125 - HBA	DUM1113 Grp: L ED11LD Cap: 30 1782 - NWSD	DUM1113 Grp: L ED11LD Cap: 30 1782 - NWED		BUF1113 Grp: 02P L Cap: 100 01412 - SABH	BEE4413 Grp: 02 L Cap: 50 0345 - NBS	BEE4413 Grp: 02 L Cap: 50 0345 - NBS	UHR1012 Grp: 13P L Cap: 30 0894 - AKBJ	UHR1012 Grp: 13P L Cap: 30 0894 - AKBJ
			DUM1113 Grp: L ED12LD Cap: 30 1782 - NWSD	DUM1113 Grp: L ED12LD Cap: 30 1782 - NWED						
TUE	UHR1012 Grp: 14P L Cap: 30 0266 - ZBMD	UHR1012 Grp: 14P L Cap: 30 0266 - ZBMD	DUM1113 Grp: L ED11LD Cap: 30 1782 - NWSD	DUM1113 Grp: T ED11TD Cap: 30 1782 - NWED		BUF1113 Grp: 02P L Cap: 100 01412 - SABH	UHR1012 Grp: 15P L Cap: 30 0266 - ZBMD	UHR1012 Grp: 15P L Cap: 30 0266 - ZBMD	DUF1113 Grp: L ED11LD Cap: 30 01412 - SABH	DUF1113 Grp: L ED11LD Cap: 30 01412 - SABH
			DUM1113 Grp: L ED12LD Cap: 30 1782 - NWSD	DUM1113 Grp: T ED12TD Cap: 30 1782 - NWED					DUF1113 Grp: L ED12LD Cap: 30 01412 - SABH	DUF1113 Grp: L ED12LD Cap: 30 01412 - SABH
WED			UHR1012 Grp: 15P L Cap: 30 0894 - AKBJ	UHR1012 Grp: 16P L Cap: 30 0894 - AKBJ	DEE1123 Grp: L E11LD Cap: 30		DEE3233 Grp: L E21LD Cap: 37	DEE3233 Grp: L E21LD Cap: 37		
					DEE1123 Grp: L E12LD Cap: 30					
THU	UHR1012 Grp: 17P L Cap: 30 0433 - MHBMS	UHR1012 Grp: 17P L Cap: 30 0433 - MHBMS			DUF1113 Grp: L ED11LD Cap: 30 01412 - SABH	BUF1113 Grp: 02P L Cap: 100 01412 - SABH	UHR1012 Grp: 18P L Cap: 30 0433 - MHBMS	UHR1012 Grp: 16P L Cap: 30 0433 - MHBMS	DEE3213 Grp: L E21LD Cap: 37	
					DUF1113 Grp: L ED12LD Cap: 30 01412 - SABH					
FRI	UHR1012 Grp: 19P L Cap: 30 0266 - ZBMD	UHR1012 Grp: 19P L Cap: 30 0266 - ZBMD	UHR1012 Grp: 20P L Cap: 30 0894 - AKBJ	UHR1012 Grp: 20P L Cap: 30 0894 - AKBJ				UHR1012 Grp: L M01LD Cap: 25 0266 - ZBMD	UHR1012 Grp: L M01LD Cap: 25 0266 - ZBMD	
								UHR1012 Grp: L M02LD Cap: 25 0266 - ZBMD	UHR1012 Grp: L M02LD Cap: 25 0266 - ZBMD	

Room Code E00DK2 DEWAN KULIAH 2 FKEE 100

	08:00 - 08:50	09:00 - 09:50	10:00 - 10:50	11:00 - 11:50	14:00 - 14:50	15:00 - 15:50	16:00 - 16:50	17:00 - 17:50
MON	UGE2002 Grp: 07P L Cap: 100 0517 - IRBT	UGE2002 Grp: 07P L Cap: 100 0517 - IRBT	DEE3313 Grp: L E21LD Cap: 37	DEE3313 Grp: L E21LD Cap: 37	BEE1112 Grp: 01 L Cap: 60 0101 - RBR	BEE1112 Grp: 01 L Cap: 60 0101 - RBR	BEE3133 Grp: 02 L Cap: 60 0134 - NRHBA	BEE3133 Grp: 02 L Cap: 60 0134 - NRHBA
TUE	BEE3133 Grp: 01 L Cap: 60 01366 - NBM	BEE3133 Grp: 01 L Cap: 60 01366 - NBM	BEE3313 Grp: 01 L Cap: 60 01425 - MZBMT	BEE3313 Grp: 01 L Cap: 60 01425 - MZBMT	DEE3213 Grp: L E21LD Cap: 37	DEE3213 Grp: L E21LD Cap: 37	UGE2002 Grp: 09P L Cap: 100 0517 - IRBT	UGE2002 Grp: 09P L Cap: 100 0517 - IRBT
WED	BEE2143 Grp: 01 L Cap: 60 01323 - FBN	BEE2143 Grp: 01 L Cap: 60 01323 - FBN	BEE4323 Grp: 01 L Cap: 60 0068 - MRBO	BEE4323 Grp: 01 L Cap: 60 0068 - MRBO	BEE3233 Grp: 01 L Cap: 60 0351 - FBS	BEE3233 Grp: 01 L Cap: 60 0351 - FBS	BEE3313 Grp: 02 L Cap: 60 01315 - YBAW	BEE3313 Grp: 02 L Cap: 60 01315 - YBAW
THU			BEE3313 Grp: 01 L Cap: 60 01425 - MZBMT	BEE3313 Grp: 01 L Cap: 60 01425 - MZBMT	UGE2002 Grp: 11P L Cap: 78 0843 - ABHA	UGE2002 Grp: 11P L Cap: 78 0843 - ABHA	BEE3233 Grp: 01 L Cap: 60 0351 - FBS	BEE3233 Grp: 01 L Cap: 60 0351 - FBS
					UGE2002 Grp: L F01LB Cap: 22 0843 - ABHA	UGE2002 Grp: L F01LB Cap: 22 0843 - ABHA		
FRI	BEE2143 Grp: 01 L Cap: 60 01323 - FBN	BEE2143 Grp: 01 L Cap: 60 01323 - FBN	BEE1112 Grp: 02 L Cap: 60 0101 - RBR	BEE1112 Grp: 02 L Cap: 60 0101 - RBR		BEE3313 Grp: 02 L Cap: 60 01315 - YBAW	BEE3313 Grp: 02 L Cap: 60 01315 - YBAW	

Room Code E00DK3 DEWAN KULIAH 3 FKEE 100

	08:00 - 08:50	09:00 - 09:50	10:00 - 10:50	11:00 - 11:50	12:00 - 12:50	13:00 - 13:50	14:00 - 14:50	15:00 - 15:50	16:00 - 16:50	17:00 - 17:50
MON	BEE4343 Grp: 01 L Cap: 60 01315 - YBAW	BEE4343 Grp: 01 L Cap: 60 01315 - YBAW	BEE4143 Grp: 01 L Cap: 60 0824 - WIBI	BEE4143 Grp: 01 L Cap: 60 0824 - WIBI			BEE1133 Grp: 04 L Cap: 0	BEE1133 Grp: 04 L Cap: 0	BEE4153 Grp: 01 L Cap: 60 0143 - HBD	BEE4153 Grp: 01 L Cap: 60 0143 - HBD
TUE	BEE4343 Grp: 01 L Cap: 60 01315 - YBAW	BEE4343 Grp: 01 L Cap: 60 01315 - YBAW	DEE3313 Grp: L E21LD Cap: 37	DEE2313 Grp: L E21LD Cap: 37	BEE4323 Grp: 02 L Cap: 50 0068 - MRBO	BEE4323 Grp: 02 L Cap: 50 0068 - MRBO	BEE1133 Grp: 04 L Cap: 0	BEE1133 Grp: 04 L Cap: 0	BEE4153 Grp: 01 L Cap: 60 0143 - HBD	BEE4153 Grp: 01 L Cap: 60 0143 - HBD
WED	BEE4143 Grp: 01 L Cap: 60 0824 - WIBI	BEE4143 Grp: 01 L Cap: 60 0824 - WIBI	UHM2022 Grp: L ED21LD Cap: 30 0415 - IBA	UHM2022 Grp: L ED21LD Cap: 30 0415 - IBA			BEE4223 Grp: 01 L Cap: 60 0339 - AHBMH	BEE4223 Grp: 01 L Cap: 60 0338 - AHBMH		
THU	BEE4323 Grp: 02 L Cap: 50 0068 - MRBO	BEE4323 Grp: 02 L Cap: 50 0068 - MRBO							BEE4223 Grp: 01 L Cap: 60 0338 - AHBMH	BEE4223 Grp: 01 L Cap: 60 0338 - AHBMH
FRI			BEE4632 Grp: 02 L Cap: 60 01425 - MZBMT	BEE4632 Grp: 02 L Cap: 60 01425 - MZBMT						

APPENDIX A3

CLASSROOM TIMETBALES - SECOND SAMPLE

Room Code E00DK1 DEWAN KULIAH 1 FKEE 100

	08:00 - 08:50	09:00 - 09.50	10:00 - 10:50	11:00 - 11.50	12.00 - 12:50	13.00 - 13:50	14.00 - 14:50	15:00 - 15:50	16.00 - 16:50	17.00 - 17.50	20:00 - 20:50	21:00 - 21.50
MON	BEE1213 Grp: 01 L Cap: 60 0634 - NWBA	BEE1213 Grp: 01 L Cap: 60 0634 - NWBA			UHE3042 Grp: 02P L Cap: 60 01473 - SFBG	UHE3042 Grp: 02P L Cap: 60 01473 - SFBG	BEE1313 Grp: 02 L Cap: 60 01316 - MSBS	BEE1313 Grp: 02 L Cap: 60 01316 - MSBS				
TUE			UHE3122 Grp: 02P L Cap: 73 0894 - AKBJ	UHE3122 Grp: 02P L Cap: 73 0894 - AKBJ			UHR1012 Grp: 15P L Cap: 50 0266 - ZBMD	UHR1012 Grp: 15P L Cap: 50 0266 - ZBMD	BEE3313 Grp: 02 L Cap: 60 01315 - YBAW	BEE4373 Grp: 02 L Cap: 60 0470 - AIBH		
WED	BEE2233 Grp: 01 L Cap: 60 01348 - IHBM	BEE2233 Grp: 01 L Cap: 60 01348 - IHBM					BEE1112 Grp: 02 L Cap: 60 0101 - RBR	BEE1112 Grp: 02 L Cap. 60 0101 - RBR	BEE2123 Grp: 03 L Cap: 60 0654 - NLBR	BEE2123 Grp: 03 L Cap: 60 0654 - NLBR	UGE2002 Grp: 09P L Cap: 116 0517 - IRBT	UGE2002 Grp: 09P L Cap: 116 0517 - IRBT
							BEE1112 Grp: 03 L Cap: 0 0101 - RBR	BEE1112 Grp: 03 L Cap: 0 0101 - RBR				
THU			DEE2123 Grp: L U21LD Cap: 15 0077 - MBM	DEE3223 Grp: L E21LD Cap: 37 0345 - NBS	UHE3032 Grp: 02P L Cap: 65 01461 - HBH	UHE3032 Grp: 02P L Cap: 65 01461 - HBH	UHR1012 Grp: 18P L Cap: 50 0266 - ZBMD	UHR1012 Grp: 18P L Cap: 50 0266 - ZBMD	BEE1133 Grp: 01 L Cap: 60 0134 - NRHBA	BEE1133 Grp: 01 L Cap. 60 0134 - NRHBA		
FRI			UHR1012 Grp: 20P L Cap: 50 0266 - ZBMD	UHR1012 Grp: 20P L Cap: 50 0266 - ZBMD				BEE2223 Grp: 02 L Cap: 60 0014 - NMKBNY	BEE2223 Grp: 02 L Cap: 60 0014 - NMKBNY	BEE1133 Grp: 01 L Cap: 60 0134 - NRHBA		

Room Code E00DK2 DEWAN KULIAH 2 FKEE 100

	08:00 - 08:50	09:00 - 09:50	10:00 - 10:50	11:00 - 11:50	12:00 - 12:50	13:00 - 13:50	14:00 - 14:50	15:00 - 15:50	16:00 - 16:50	17:00 - 17:50
MON		DUM1123 Grp: L E12LD Cap: 30 1782 - NWBD	BEE1213 Grp: 02 L Cap: 60 01323 - FBN	BEE1213 Grp: 02 L Cap: 60 01323 - FBN		BUF1113 Grp: 03P L Cap: 10 0084 - YBH	UGE2002 Grp: 07P L Cap: 100 0517 - IRBT	UGE2002 Grp: 07P L Cap: 100 0517 - IRBT	BEE1213 Grp: 03 L Cap: 60 0088 - KHBG	BEE1213 Grp: 03 L Cap: 60 0088 - KHBG
			DUM1123 Grp: L E12LD Cap: 30 1782 - NWBD							
TUE	BEE2213 Grp: 01 L Cap: 60 1408 - YR		BEE3313 Grp: 01 L Cap: 60 01425 - MZBMT	BEE2233 Grp: 02 L Cap: 60 1811 - MH	BEE3233 Grp: 01 L Cap: 60 0351 - FBS	BUF1113 Grp: 03P L Cap: 10 0084 - YBH	BEE4641 Grp: 01 L Cap: 60 FP0002 - SRBTM	BEE4641 Grp: 01 L Cap: 60 FP0002 - SRBTM	BEE3413 Grp: 02 L Cap: 60 1748 - S	BEE3143 Grp: 01 L Cap: 60 01493 - MHBS
							BEE4641 Grp: 03 L Cap: 0 FP0002 - SRBTM	BEE4641 Grp: 03 L Cap: 0 FP0002 - SRBTM		
WED							BEE4213 Grp: 02 L Cap: 60 01348 - IHBM	BEE4213 Grp: 02 L Cap. 60 01348 - IHBM	DEE3313 Grp: L U21LD Cap: 20 1987 - DP	DEE3313 Grp: L U21LD Cap: 20 1987 - DP
THU	BEE1123 Grp: 01 L Cap: 1 01356 - RBH	BEE1123 Grp: 01 L Cap: 1 01356 - RBH		DUM1123 Grp: L E11LD Cap: 30 1782 - NWBD	DUM1123 Grp: T E11TD Cap: 30 1782 - NWBD	BUF1113 Grp: 03P L Cap: 10 0084 - YBH	BEE2233 Grp: 03 L Cap: 62 0822 - MRBG	BEE2233 Grp: 03 L Cap: 62 0822 - MRBG	DEE3223 Grp: L E22LD Cap: 36 0055 - MBMN 0237 - MFBA	DEE3313 Grp: L U21LD Cap: 20 1987 - DP
	BEE1143 Grp: 01 L Cap: 60 01356 - RBH	BEE1143 Grp: 01 L Cap: 60 01356 - RBH		DUM1123 Grp: L E12LD Cap: 30 1782 - NWBD	DUM1123 Grp: T E12TD Cap: 30 1782 - NWBD					
FRI	BEE3113 Grp: 01 L Cap: 60 0464 - ARBZ	BEE3113 Grp: 01 L Cap: 60 0464 - ARBZ	BEE1611 Grp: 02 L Cap: 60 FP0002 - SRBTM	BEE1611 Grp: 02 L Cap: 60 FP0002 - SRBTM				DEE3143 Grp: L E22LD Cap: 36 01066 - MBY 01154 - ZBM	DEE3143 Grp: L E22LD Cap: 36 01066 - MBY 01154 - ZBM	

APPENDIX A4

18F2550 DATASHEET

TABLE 1-1: DEVICE FEATURES

Features	PIC18F2455	PIC18F2550	PIC18F4455	PIC18F4550
Operating Frequency	DC – 48 MHz	DC – 48 MHz	DC – 48 MHz	DC – 48 MHz
Program Memory (Bytes)	24576	32768	24576	32768
Program Memory (Instructions)	12288	16384	12288	16384
Data Memory (Bytes)	2048	2048	2048	2048
Data EEPROM Memory (Bytes)	256	256	256	256
Interrupt Sources	19	19	20	20
I/O Ports	Ports A, B, C, (E)	Ports A, B, C, (E)	Ports A, B, C, D, E	Ports A, B, C, D, E
Timers	4	4	4	4
Capture/Compare/PWM Modules	2	2	1	1
Enhanced Capture/ Compare/PWM Modules	0	0	1	1
Serial Communications	MSSP, Enhanced USART	MSSP, Enhanced USART	MSSP, Enhanced USART	MSSP, Enhanced USART
Universal Serial Bus (USB) Module	1	1	1	1
Streaming Parallel Port (SPP)	No	No	Yes	Yes
10-bit Analog-to-Digital Module	10 Input Channels	10 Input Channels	13 Input Channels	13 Input Channels
Comparators	2	2	2	2
Resets (and Delays)	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST), MCLR (optional), WDT	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST), MCLR (optional), WDT	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST), MCLR (optional), WDT	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST), MCLR (optional), WDT
Programmable Low-Voltage Detect	Yes	Yes	Yes	Yes
Programmable Brown-out Reset	Yes	Yes	Yes	Yes
Instruction Set	75 Instructions; 83 with Extended Instruction Set enabled	75 Instructions; 83 with Extended Instruction Set enabled	75 Instructions; 83 with Extended Instruction Set enabled	75 Instructions; 83 with Extended Instruction Set enabled
Packages	28-pin PDIP 28-pin SOIC	28-pin PDIP 28-pin SOIC	40-pin PDIP 44-pin QFN 44-pin TQFP	40-pin PDIP 44-pin QFN 44-pin TQFP

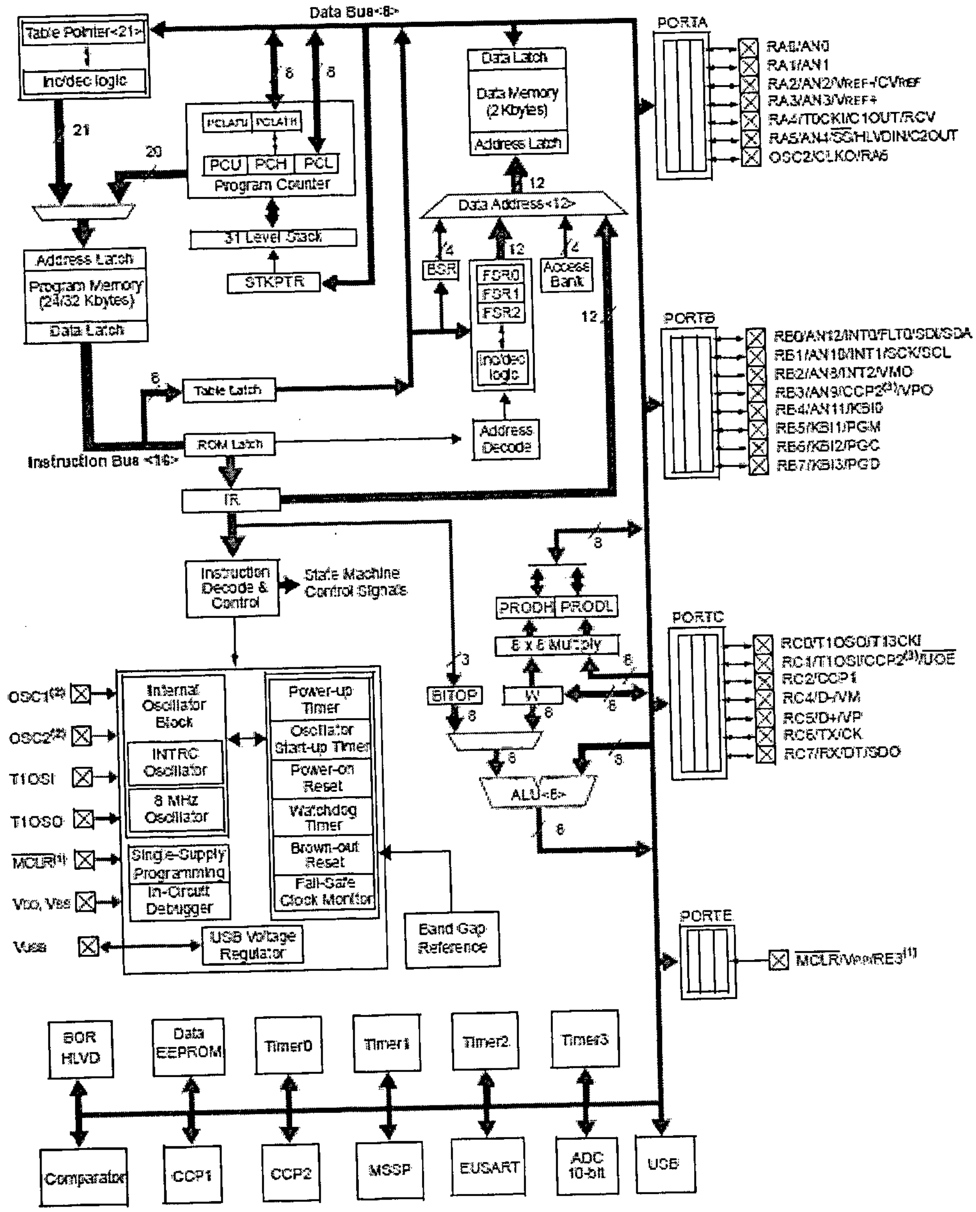

Data Bus<8>
Table Pointer<21>
inc/dec logic
21
20
PCLATU PCLATH
PCU PCH PCL
Program Counter
31 Level Stack
STKPTR
Address Latch
Program Memory (24/32 Kbytes)
Data Latch
Table Latch
ROM Latch
Instruction Bus <16>
IR
Instruction Decode & Control
State Machine Control Signals
Data Latch
Data Memory (2 Kbytes)
Address Latch
Data Address<12>
BSR
FSR0
FSR1
FSR2
inc/dec logic
Access Bank
Address Decode
PRODH PRODL
8 x 8 Multiply
BITOP
W
ALU<8>
PORTA
RA0/AN0
RA1/AN1
RA2/AN2/VREF-/CVREF
RA3/AN3/VREF+
RA4/T0CKI/C1OUT/RCV
RA5/AN4/SS/HLVDIN/C2OUT
OSC2/CLKO/RA6
PORTB
RB0/AN12/INT0/FLT0/SDI/SDA
RB1/AN10/INT1/SCK/SCL
RB2/AN8/INT2/VMO
RB3/AN9/CCP2(3)/VPO
RB4/AN11/KBI0
RB5/KBI1/PGM
RB6/KBI2/PGC
RB7/KBI3/PGD
PORTC
RC0/T1OSO/T13CKI
RC1/T1OSI/CCP2(3)/UOE
RC2/CCP1
RC4/D-/VM
RC5/D+/VP
RC6/TX/CK
RC7/RX/DT/SDO
PORTE
MCLR/VPP/RE3(1)
OSC1(2)
OSC2(2)
T1OSI
T1OSO
MCLR(1)
VDD, VSS
VUSB
Internal Oscillator Block
INTRC Oscillator
8 MHz Oscillator
Single-Supply Programming
In-Circuit Debugger
USB Voltage Regulator
Power-up Timer
Oscillator Start-up Timer
Power-on Reset
Watchdog Timer
Brown-out Reset
Fail-Safe Clock Monitor
Band Gap Reference
BOR HLVD
Data EEPROM
Timer0
Timer1
Timer2
Timer3
Comparator
CCP1
CCP2
MSSP
EUSART
ADC 10-bit
USB

TABLE 1-2: PIC18F2455/2550 PINOUT I/O DESCRIPTIONS

Pin Name	Pin Number PDIP, SOIC	Pin Type	Buffer Type	Description
$\overline{MCLR}$/VPP/RE3	1			Master Clear (input) or programming voltage (input).
$\overline{MCLR}$		I	ST	Master Clear (Reset) input. This pin is an active-low Reset to the device.
VPP		P		Programming voltage input.
RE3		I	ST	Digital input.
OSC1/CLKI	9			Oscillator crystal or external clock input.
OSC1		I	Analog	Oscillator crystal input or external clock source input.
CLKI		I	Analog	External clock source input. Always associated with pin function OSC1. (See OSC2/CLKO pins.)
OSC2/CLKO/RA6	10			Oscillator crystal or clock output.
OSC2		O	—	Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode.
CLKO		O	—	In select modes, OSC2 pin outputs CLKO which has 1/4 the frequency of OSC1 and denotes the instruction cycle rate.
RA6		I/O	TTL	General purpose I/O pin.

TABLE 1-2: PIC18F2455/2550 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number PDIP, SOIC	Pin Type	Buffer Type	Description
				PORTA is a bidirectional I/O port.
RA0/AN0	2			
RA0		I/O	TTL	Digital I/O.
AN0		I	Analog	Analog input 0.
RA1/AN1	3			
RA1		I/O	TTL	Digital I/O.
AN1		I	Analog	Analog input 1.
RA2/AN2/VREF-/CVREF	4			
RA2		I/O	TTL	Digital I/O.
AN2		I	Analog	Analog input 2.
VREF-		I	Analog	A/D reference voltage (low) input.
CVREF		O	Analog	Analog comparator reference output.
RA3/AN3/VREF+	5			
RA3		I/O	TTL	Digital I/O.
AN3		I	Analog	Analog input 3.
VREF+		I	Analog	A/D reference voltage (high) input.
RA4/T0CKI/C1OUT/RCV	6			
RA4		I/O	ST	Digital I/O.
T0CKI		I	ST	Timer0 external clock input.
C1OUT		O	—	Comparator 1 output.
RCV		I	TTL	External USB transceiver RCV input.
RA5/AN4/$\overline{SS}$/HLVDIN/C2OUT	7			
RA5		I/O	TTL	Digital I/O.
AN4		I	Analog	Analog input 4.
$\overline{SS}$		I	TTL	SPI™ slave select input.
HLVDIN		I	Analog	High/Low-Voltage Detect input.
C2OUT		O	—	Comparator 2 output.
RA6	—	—	—	See the OSC2/CLKO/RA6 pin.

TABLE 1-2: PIC18F2455/2550 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number PDIP, SOIC	Pin Type	Buffer Type	Description
				PORTB is a bidirectional I/O port. PORTB can be software programmed for internal weak pull-ups on all inputs.
RB0/AN12/INT0/FLT0/SDI/SDA	21			
RB0		I/O	TTL	Digital I/O.
AN12		I	Analog	Analog input 12.
INT0		I	ST	External interrupt 0.
FLT0		I	ST	PWM Fault input (CCP1 module).
SDI		I	ST	SPI™ data in.
SDA		I/O	ST	I²C™ data I/O.
RB1/AN10/INT1/SCK/SCL	22			
RB1		I/O	TTL	Digital I/O.
AN10		I	Analog	Analog input 10.
INT1		I	ST	External interrupt 1.
SCK		I/O	ST	Synchronous serial clock input/output for SPI mode.
SCL		I/O	ST	Synchronous serial clock input/output for I²C mode.
RB2/AN8/INT2/VMO	23			
RB2		I/O	TTL	Digital I/O.
AN8		I	Analog	Analog input 8.
INT2		I	ST	External interrupt 2.
VMO		O	—	External USB transceiver VMO output.
RB3/AN9/CCP2/VPO	24			
RB3		I/O	TTL	Digital I/O.
AN9		I	Analog	Analog input 9.
CCP2[1]		I/O	ST	Capture 2 input/Compare 2 output/PWM 2 output.
VPO		O	—	External USB transceiver VPO output.
RB4/AN11/KBI0	25			
RB4		I/O	TTL	Digital I/O.
AN11		I	Analog	Analog input 11.
KBI0		I	TTL	Interrupt-on-change pin.
RB5/KBI1/PGM	26			
RB5		I/O	TTL	Digital I/O.
KBI1		I	TTL	Interrupt-on-change pin.
PGM		I/O	ST	Low-Voltage ICSP™ Programming enable pin.
RB6/KBI2/PGC	27			
RB6		I/O	TTL	Digital I/O.
KBI2		I	TTL	Interrupt-on-change pin.
PGC		I/O	ST	In-Circuit Debugger and ICSP programming clock pin.
RB7/KBI3/PGD	28			
RB7		I/O	TTL	Digital I/O.
KBI3		[illegible]	[illegible]	[illegible]
PGD		[illegible]	ST	[illegible] data pin.

TABLE 1-2: PIC18F2455/2550 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number PDIP, SOIC	Pin Type	Buffer Type	Description
				PORTC is a bidirectional I/O port.
RC0/T1OSO/T13CKI	11			
RC0		I/O	ST	Digital I/O.
T1OSO		O	—	Timer1 oscillator output.
T13CKI		I	ST	Timer1/Timer3 external clock input.
RC1/T1OSI/CCP2/$\overline{UOE}$	12			
RC1		I/O	ST	Digital I/O.
T1OSI		I	CMOS	Timer1 oscillator input.
CCP2[2]		I/O	ST	Capture 2 input/Compare 2 output/PWM 2 output.
$\overline{UOE}$		—	—	External USB transceiver $\overline{OE}$ output.
RC2/CCP1	13			
RC2		I/O	ST	Digital I/O.
CCP1		I/O	ST	Capture 1 input/Compare 1 output/PWM 1 output.
RC4/D-/VM	15			
RC4		I	TTL	Digital input.
D-		I/O	—	USB differential minus line (input/output).
VM		I	TTL	External USB transceiver VM input.
RC5/D+/VP	16			
RC5		I	TTL	Digital input.
D+		I/O	—	USB differential plus line (input/output).
VP		O	TTL	External USB transceiver VP input.
RC6/TX/CK	17			
RC6		I/O	ST	Digital I/O.
TX		O	—	EUSART asynchronous transmit.
CK		I/O	ST	EUSART synchronous clock (see RX/DT).
RC7/RX/DT/SDO	18			
RC7		I/O	ST	Digital I/O.
RX		I	ST	EUSART asynchronous receive.
DT		I/O	ST	EUSART synchronous data (see TX/CK).
SDO		O	—	SPI™ data out.
RE3	—	—	—	See $\overline{MCLR}$/VPP/RE3 pin.
VUSB	14	O	—	Internal USB 3.3V voltage regulator.
VSS	8, 19	P	—	Ground reference for logic and I/O pins.
VDD	20	P	—	Positive supply for logic and I/O pins.

REFERENCES

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