Smart Energy Consumption Management System for UTP Academic Buildings

By

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Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Technology (Hons)
(Information & Communication Technology)

MAY 2012

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CERTIFICATION OF APPROVAL

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Approved by,

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(Prof. Dr. Alan Oxley)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
May 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the reference and acknowledgements, and that the original work contained herein has not been undertaken or done by unspecified sources or persons.

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(TERRYSON EDDIE TIDU)

ABSTRACT

Over the years, Universiti Teknologi PETRONAS (UTP) has reported a high reading for its Building Energy Index (BEI). Clearly, this indicates that there are excessive amount of electricity consumption within the campus. The highest BEI comes from the academic buildings. A study conducted to identify the root cause of this issue has shown that there is no systematic system or procedure used to monitor and manage the electricity usage in the campus. Hence, this project aims to develop a system that will help to monitor the energy consumption in UTP academic buildings. The main purpose of this system is to calculate the total amount of electricity consumption, and thus computing the amount of Carbon Dioxide (CO_2) omission based on the amount of consumed electricity by a particular building. Apart from that, the system will also compute the amount of ideal and excess electricity usage for that building. This is calculated by roughly sum up the power consumption by all the available electrical devices includes air conditioned, computers, light bulbs, server (if any), CCTVs, electronic door lock and others that operate on the building. Power consumption for each electronic device can be estimate through its production label and estimated operating hours per day. The summary report for all these data will be generated on monthly and yearly basis. With all these info being produced by this system, UTP management will be aware if there are over omitted CO_2 gas resulting from the electricity usage and also the excessively used electricity and thus take an appropriate action towards a proper way of managing its energy consumption rate to promote a Green IT concept within the campus. This system does not solve the over consumed energy and over omitted CO_2 but only provides all the necessary records and data based on the energy consumed.

ACKNOWLEDGEMENT

First and foremost, the writer would like to take this opportunity to express his greatest gratitude and appreciation to project supervisor, Prof. Dr. Alan Oxley, who had continuously monitored his progress throughout the duration of the project. His constructive comments, advices, and suggestions have guided the project towards its successful final outcome.

This gratitude also dedicated towards Universiti Teknologi PETRONAS (UTP) especially the committee of Final Year Project of Computer Information Sciences (CIS) department for excellent organization and management of this course.

Last but not least; the writer would also like to express his acknowledgement to the participant of interview, especially the management of UTP for their feedback and kind cooperation which have helped a lot in developing, improving and implementation of the system prototype.

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ABBREVIATIONS AND NOMENCLATURES

IEEE	Institute of Electrical and Electronic Engineers
BEI	Building Energy Index
GDC	Gas District Cooling
AHU	Air Handling Unit
MV	Moving Ventilation
EI	Energy Intensity
GHG	Greenhouse Gas
GDP	Gross Domestic Product
SEC	Specific Energy Consumption

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Demand for energy supply in Malaysia, especially electricity has risen rapidly within the last few years. Not only Malaysia, but the statistics produced by the Institute of Electrical and Electronic Engineers (IEEE) has shown the same pattern in energy consumption throughout the world. According to the studies, as per year 2011, Malaysian electricity consumption is 93.8 billion kWh compare to 5 years ago, which the studies recorded that the electricity consumption is 72.71 billion kWh [1]. The reason for this increase is due to the importance of energy in the nation development and growth, in all sectors, mainly the economic sector. Office and organization buildings have been identified to be among the main high energy usage. **Figure 1.1** below shows the statics of energy consumption for Malaysia from 2000 to 2011.

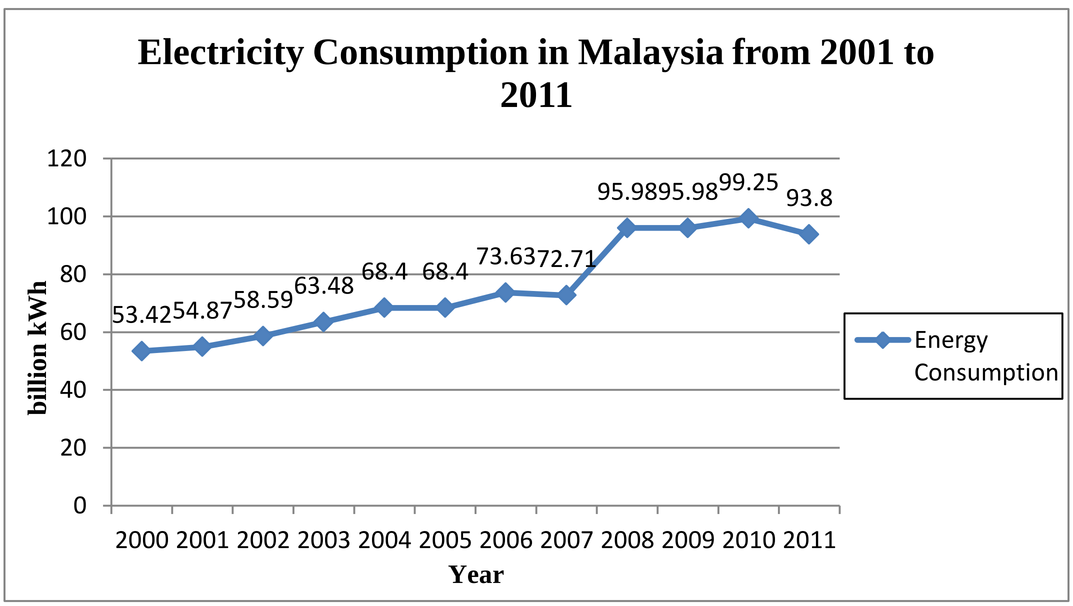

Figure 1.1: Electricity Consumption in Malaysia from 2000 to 2011 (*Source: indexmundi, 2012*)

A study has been conducted to access the future trend of residential energy consumption and CO_2 emissions in Malaysia and it is estimated that the CO_2 emission is 2,347,538 tonne on 2008, and predicted to increase up to 11,689,308 tonne by 2020 [2]. This large increase is due to a constant increase in electricity consumption, where the power source is mainly generated by Liquid Petroleum Gas (LPG) and other natural resource such as kerosene, coal and natural gas. Meanwhile, there is more growing concern towards the energy consumption in recent years mainly the energy used in commercial buildings. Commercial and residential building only have contributed to about half of total energy consuming in Malaysia [3]. It is estimated that about 70-300kWh/m^2 energy is used per-annum in commercial building [4]. Rapid growth of Malaysian economic has led towards a drastic rise in energy consumption due to the fact that everyone aims and wanted to improve their standard of living. As a results, there is a rapid increase in energy demand, and as a results, increase in the rate of CO_2 emissions.

In Universiti Teknologi PETRONAS (UTP), an energy audit assessment done by Honeywell Pte Ltd in which cooling load was monitored between 25th October 2008 – 3rd November 2008 shows that total estimated existing energy consumption of Air Handling Units (AHU) and Mechanical Ventilations (MV) fans per year in UTP is 5,576,090 kWh/Year which is equivalent to RM 1,672,827/Year at charge rate of RM0.30/kWh [5]. According to Shaarani (2009), the BEI for the year 2007 is 287 kWh/m^2 and this indicates that UTP has consumed too much energy and far from practicing a good energy management [6]. This leads to a high cost need to be pay by the management due to the high amount of energy consumption.

Looking at the data and facts above, it has raised the concern over the importance of having a proper management of electricity usage. Without a good management, apart from running out of the resources, the effect toward environment will become more costly than other effect. Many campaign such as “Energy Awareness” and “Usage of Reusable Energy” has actively conducted to increase the public awareness on the importance of conserving the energy usage to reduce emission rate. Many electronic and technology manufacturer has also taking a major step in supporting the campaign by inventing more energy saving and eco-friendly products. Intel, for example has come out with a brilliant and innovation when they introduced new eco-friendly Intel® Xeon® Server Processors which still maintains the performance of that processor [7].

However, such awareness is not responsibility only to an industrial sectors or any big organization, but should start with a lover level of society. An organization which is closely related to society plays, if not, the most important roles in raised up the awareness regarding this issues, and important to reduce and overcome it. The nearest example is a learning institution, where apart from educating the society, they should show a good example in conserving and managing the energy consumption. Most learning institution especially the higher learning institution are having a lot of big machines, thousands of computers, light bulbs, lifts, air conditioning and lot others within its building [8]. A smart energy consumption management system within the building would play an important role in reducing the energy usage and thus reducing the rate of CO_2 emission.

Having a good policy in energy usage within an organization will leads to an overall reduced in over-use of energy, which is the best step can be taken in ensuring the longer energy sustainability while lowering the rate of its negative effect towards environment.

1.2 PROBLEM STATEMENT

High cost need to be pay for an excessive and uncontrolled amount of energy usage by Universiti Teknologi PETRONAS (UTP). This is truly an unfavorable condition and hence, a good solution is needed to overcome this problem. High cooling demand due to insufficient devices and fixtures used are suspected to be the main cause. Besides that, human behaviors towards energy consumption too were suspected to contribute toward an inefficient amount of energy usage. Even though UTP have its own Gas District Cooling (GDC) plant to supply electricity to all its buildings, excessive usage of electricity will still results in high energy consumption which will give bad impact towards environment. It results in high emission of CO_2 gases and caused a greenhouse effect. Narrowing the root cause, the excessive usage of electricity is mainly due to human behavior itself. The usage of electrical equipment is without proper control and monitor. Air conditioned, light bulb and computer are all identified to be as main equipment that has been over-used.

UTP management has seen this as a serious issue and proper action need to be taken. In compliance with international and government policy which encourage an efficient energy consumption to support Green IT campaign, UTP requires a smart system which helps to monitor the energy usage within the campus.

Managing energy consumption reflecting how UTP can continuously monitoring its electricity usage, most importantly within its own academic buildings where it is identified as main building which consume the biggest amount of electricity. This is due to several high-tech devices being used including devices running for 24 hours a day, mainly for research and learning purpose that is not being turned off even if it is not in use. UTP management team may have not alerted that all of these practices are actually contributing towards a massive electricity usage and thus results in a big amount of CO_2 omission into environment. Without a proper system to manage the energy consumption, years from now, UTP might emerged as one of the biggest contributor towards the greenhouse effect results from an uncontrolled and excessive amount of energy usage.

1.3 OBJECTIVES

The objectives of this project are as outlined below.

1. To record the electricity usage in academic buildings.
2. To compute the amount of CO_2 omission for that particular building based on the amount of electricity usage.

3. To generate complete report for electricity usage, CO_2 omission, ideal electricity usage, excess electricity usage, ideal CO_2 omission rate, and excess CO_2 omission rate on monthly and yearly basis.
4. To record and store all electronic devices being used in the academic buildings.
5. To ensure the reports generated will give clear analysis of electricity consumption in academic building for UTP management to decide on proper action to be taken.

1.4 SCOPE OF STUDY

The scope of study of the project is Universiti Teknologi PETRONAS (UTP) academic buildings. Overall, there are 16 academic blocks in UTP and each block is referred to as below:

- Block 1
- Block 2
- Block 3
- Block 4
- Block 5
- Block 13
- Block 14
- Block 15
- Block 16
- Block 17
- Block 18
- Block 19
- Block 20
- Block 21
- Block 22

- Block 23

Each academic block is 4 level building structures, in which the 4th level of each building is specifically allocated for lecturer's office. As for 1st, 2nd and 3rd level, it is used as lecture rooms, computer laboratories, engineering laboratories, meeting rooms and research centers. **Figure 1.2** below shows the full plan of UTP academic building plan.

Figure 1.2: Overall Plan of UTP Academic Buildings

1.5 SIGNIFICANCE OF THE PROJECT

A research conducted regarding the energy consumption in Universiti Teknologi PETRONAS (UTP) indicates that UTP has consume a high amount of electricity, which is way beyond the standard average rate of electricity it should consumed [9]. For this research, the visit has been made in UTP Control Room to monitor the building system performance and the data gathered is used to indicate the building system performance in UTP. The reading is compared to the Green Building Index of Malaysia, referred to as MS 1525:2007 to check for the compliance of the UTP system to the standard [10]. **Table 1.1** shows the Standard Indoor Design Condition for Air-Conditioned Space as set in MS 1525:2007.

Table 1.1: Standard for Indoor Design Condition for Air-Condition Space as set in MS 1525:2007

Condition	Required Design Value
Dry bulb temperature	23ºC - 26ºC
Relative humidity	55% - 70%
Air Movement	0.15 m/s – 0.50 m/s
Maximum Air Measurement	0.7 m/s

This research also gathers the data for amount of electricity consumption for year 2007, 2008 and 2009. **Table 1.2** below shows the summarized Annual Energy Consumption within these three years in UTP.

Table 1.2: Total Energy Consumption by UTP in Year 2007, 2008 and 2009 (January only)

Year	Total Energy Consumption (kWh)
2007	26,629,520
2008	25,982,110
2009 (as in January only)	1,959,281

Hence, it is significance to develop a system that will help to monitor the energy consumption in UTP buildings. The development of Smart Energy Consumption Management System for UTP Academic Building will help to monitor the total amount of electricity usage and amount of CO_2 emission by the buildings.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

Before this project can be started, it is important to understand and analyze the current energy usage trend within the similar scope where this system will be implemented. In Malaysia, the electricity consumption rate between the commercial buildings does not really have an obvious difference. Only for some organization that really practicing the Green IT concept, they have their own alternative and energy consumption plan to control and reduce the amount of energy they consumed [11]. As for Universiti Teknologi PETRONAS (UTP), the energy consumption rate is still high and beyond the ideal usage rate if being compared to the devices being used and the population that live within the area. Hence, this chapter covers the literature review which is the analytical, critical and objective review of written materials. There are three published research articles and journals that are being used as the main references for the literature review of this project. Each is be further describes in part **2.2**, **2.3** and **2.4.**

2.2 ENERGY AND ELECTRICITY CONSUMPTION ANALYSIS OF MALAYSIAN INDUSTRIAL SECTOR

This research paper [12] was written by Masjuki H.H et al., from Department of Mechanical Engineering and Electrical Engineering, University of Malaya, Malaysia is about the analysis of energy and electricity consumption by the industrial sector in Malaysia. This project scope comprises of a total of 64 factories from different part in Malaysia coming from 7 different manufacturing sectors.

The research main parameters are power rating, operation time of energy consuming equipment, source of energy consumption, production figure, peak tariff usage behavior and also power factor [13]. All the data obtained is analyzed to investigate the breakdown of end-use equipment or machinery, peak usage behavior, power factor trend and specific energy and electricity consumption of the factories. The study shows that 64% of electrical energy was consumed in peak hours. This refers to the time period where the manufacturing equipment operates during factory's optimum operation time [14]. Besides that, the study also aims to investigate the effect of energy consumption in industrial sector towards the greenhouse gas emissions (GHG) and how can industrial sector reduce its emissions. Emphasis was given to electrical and fossil fuel energy consumption pattern for end-use machineries or equipment. Other than that, specific energy consumption, peak hour of electricity consumption and power factor at production process are among the data collected.

During the study too, all equipment on production floor are counted and the data for rated power from technical specifications and its daily operating hours is also taken. The most important data collected was the power rating and operating time for each machines and equipment used for productions. With all the data collected, the team have come out with an approaches used to estimate the specific energy consumption (SEC) for each machines and equipment. The SEC of each sector is represented by SEC from the audited industries of the particular sector. Such methodology and estimation of energy consumption will be very useful for other research or study which related to the energy consumption management and the invention of devices which used to calculate the energy usage.

This study has concluded that majority of factories are still operating by using the old equipment which are not efficient and consume large amount of energy.

2.3 ENERGY CONSUMPTION, ENERGY SAVINGS, AND EMISSION ANALYSIS IN MALAYSIA

This journal was written by R. Saidur from the Department of Mechanical Engineering, University of Malaya. The objective of this journal is to study the estimated amount of energy being consumed in office and commercial buildings in Malaysia. The main parameter being used is the energy use, which also act as the equipment tools throughout the research. The unit used for measuring the energy performance in buildings is the Energy Intensity (EI).

This study is focusing only on the office and commercial buildings within Malaysia in comparisons of the residential buildings. The study has shown that energy being used in office buildings is about 70-300kWh/m² per annum. A rapid growth of energy usage within the office and commercial buildings is due to the rapid growth in population and increase in standard of living of the citizen of Malaysia. This has contributed towards a serious global effect that is the CO_2 emissions. Improvement in standard of living has caused more and more equipment such as air conditioned, lifts, fridge and many more which consume large amount of energy being used and therefor resulting in more energy being used.

This research has also figured out that the pattern of energy usage in Malaysia is largely affected by changes in economic trend of Malaysia itself. High economic growth in Malaysia has led to a dramatic increase in energy consumption in recent years, particularly in the commercial buildings. Rising Gross Domestic Product (GDP) will increase the demand for electricity but in different proportion. Malaysian electricity per GDP is around 1.5 which means that for every 1% rise in GDP, electricity consumption will increased by 1.5%. This research has also come out with a statistics of energy uses in Malaysia, where the highest percentage is the industrial sector with 48%, followed by commercial sector with 32%, then residential with 19% while others with 1%. Besides that, this research has also stressed out the importance of managing and reducing the energy usage as it contributed towards a huge amount of CO_2 emissions, which can only be reduced by reducing the energy usage. R. Saidur also suggest that the most cost-effective ways towards achieving this is by having a smart way of managing the electricity usage within the commercial and office buildings.

The study has come out with smart ways in estimating the EI, where the data collection procedures are based on criteria such as age of building, type of building, weekly usage hours, gross floor area, occupancy numbers, air-conditioned area and equipment or appliances specification and capacity (kW).

2.4 UNIVERSITI TEKNOLOGI PETRONAS ENERGY RETROFITTING: TURNING CHALLENGES INTO OPPORTUNITIES

This research paper was written by M.F Khamidi, A.S Khalid, R Rahadjati, and A Idrus from the Department of Civil Engineering, Universiti Teknologi PETRONAS. The objective of this research is to plan a project which helps to reduce UTP cooling load and energy consumption, thus being in line with Government calls for energy efficiency. The scope of study for the research is the electricity consumption within the UTP campus, mainly in academic buildings; Block 13, 14 and Pocket C.

Methodology used to gather data for this research are including UTP electricity bills, academic building plan, number of staffs and students and list of machineries used in that particular buildings. These are all the identified factors that affect the amount of energy consumption. The study done estimated that UTP is consuming too large amount of energy which has contributed towards a worrying negative effect on environment. High electricity usage requires a huge amount of energy to generate the electricity in which this results in high emission rate of CO_2 gas [16].

Other implication is huge cost need to be pay by UTP management due to high electricity usage. Energy audit assessment report done between 25th October 2008 – 3rd November 2008 by Honeywell Pte Ltd estimated that energy consumption for all Air

Handling Units (AHU) and Mechanical Ventilation (MV) that serve the academic buildings is 5,576,090 kWh/Year. This equals to RM1,672,827/Year at RM0.30/kWh.

The Building Energy Index (BEI) for respective building where the study is conducted is summarized in **Table 2.1** below.

Table 2.1: Summary of BEI Calculation as per Building

Building 13	Building 14	Pocket C
$BEI_{13} = \frac{376{,}072\ kWh}{3\ 067.859 m^2}$ $= \mathbf{122.5\ kWh/m^2}$	$BEI_{14} = \frac{376{,}672\ kWh}{3\ 569.396 m^2}$ $= \mathbf{105.36\ kWh/m^2}$	$BEI_{C} = \frac{301{,}352\ kWh}{990.450 m^2}$ $= \mathbf{304.26\ kWh/m^2}$

By referring to the above table, it shows that Building 13 and Building 14 respectively have an ideal energy consumption rate where both having BEI lower than 136 kWh/m^2; which reflected the level energy efficiency expected to be achieved. Pocket C meanwhile having BEI of 304.26 kWh/m^2a value which has exceed the worst case range of 200-300 kWh/m^2as stated in MS 1525:2007.

This research also identified what is the main challenge faced when it comes to energy saving. The main challenge is human attitudes where the low level of awareness among the students and staffs of UTP leads towards inefficient usage of electricity.

Khamidi et al. concluded that UTP electricity usage is so high that action needs to be taken in order to reduce the amount of energy consumption.

CHAPTER 3
METHODOLOGY

3.1 SOFTWARE PROCESS MODEL

In this project, the software process model that being used is Rapid Application Development (RAD) method [17]. This methodology is chosen due to the time constrain of this project which in total is 9 months. This methodology is also chosen due to the possibility of there might be functionality and performance compromising in order to allows a faster development process. The benefits of using this methodology is it allows any changes to be made during the development phase if there is needs to review and recheck at any other phase of project development. This is important as it provides flexibility throughout completing the project such as debugging process. As illustrated in **Figure 3.1**, the software process model has 4 main phases:

1. Analysis and quick design
2. Prototyping cycles
3. Testing
4. Implementation

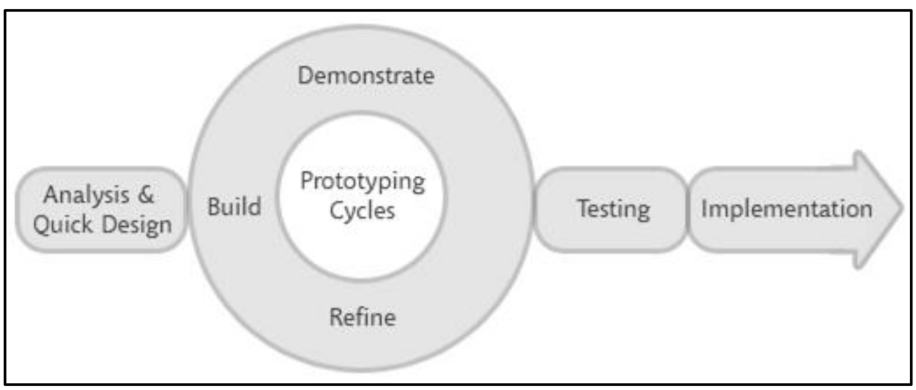

Figure 3.1: Rapid Application Development (RAD) Model

3.1.1 Analysis and Quick Design

This stage is mostly being done and completed during the 1st phase of this project, which is referred to as FYP1. In this stage, the problem statement has been analyzed to have a better understanding of the problem encountered. Apart from that, the requirements for the Smart Energy Consumption Management System for UTP Academic Buildings are gathered in order to understand the basic functions and performance and system prototype that will be built in this project. The system's requirements and objectives are established by gathering information with system users.

Once all the necessary data and information being gathered, the basic design architecture of the system is develop. The system architecture will need to be established to identify and describe the fundamental software system abstractions and their functionality. This system is intended to compute the total amount of energy consumed by the UTP academic buildings based on the meter reading input by user. This system does not integrated with any auto-reading hardware, hence it requires user to manually input the meter reading as its main input. Apart from that, this system will also require user to manually input the device information that is being used in the building. All the data is needed by the system to compute the actual amount of energy consumed by all the devices and hence computing the ideal amount energy usage and excess energy usage in the building. With this energy consumption values, the system will hence able to compute the rate of CO_2 emission.

Figure 3.2 shows the system architecture which includes the element of user's input, database relationship details and the output to be display to user. An in depth review has been conducted on the tools that are available in order to select the most appropriate tools for the development of the Smart Energy Consumption Management System for UTP Academic Buildings. As a result, Microsoft Visual Studio 2010 has been chosen for the development of the system and Microsoft Access 2010 as the system database.

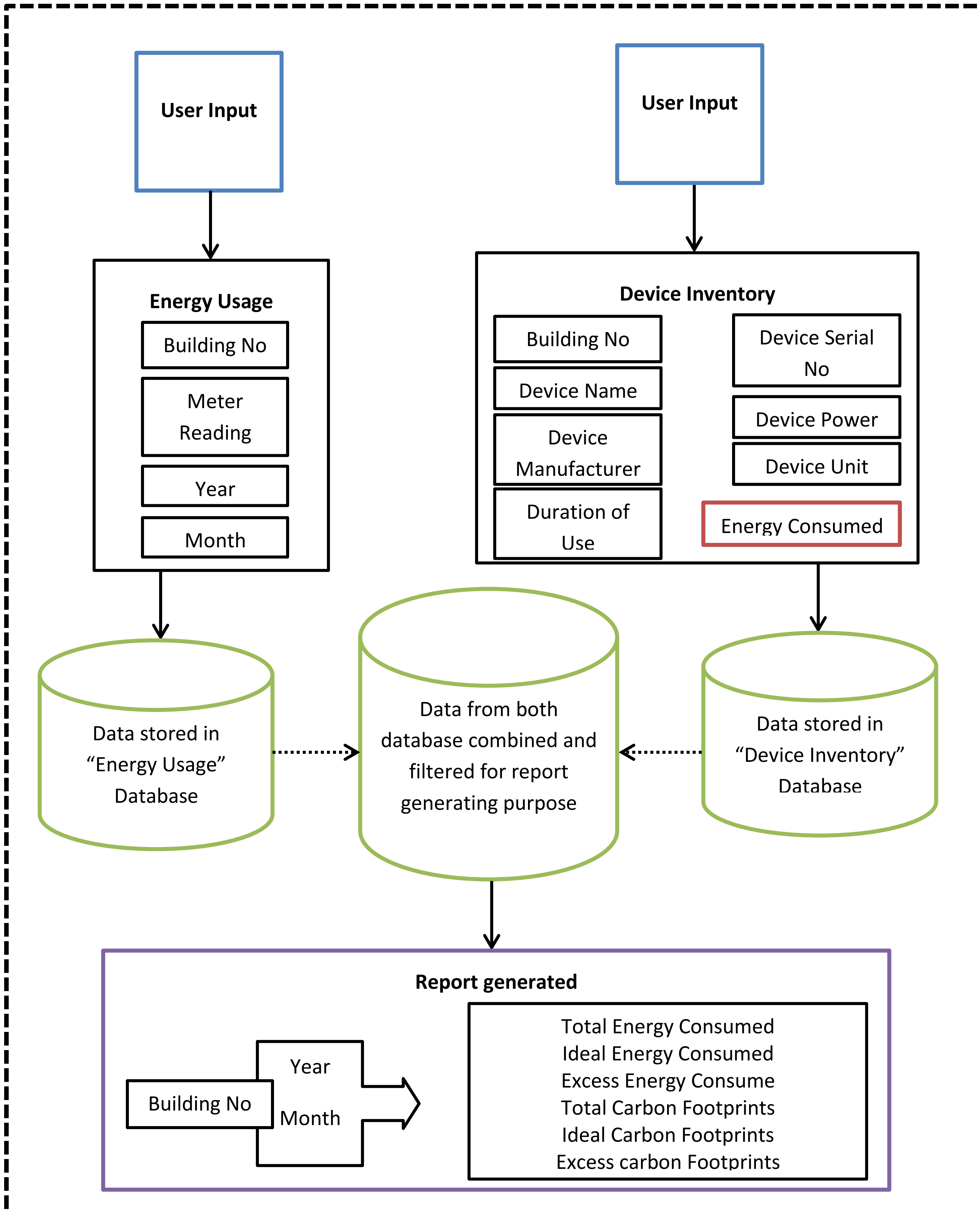

Figure 3.2: System Architecture

After the system architecture is being established and designed, the next step is to develop the system. This phase consists of 3 main categories namely; build, demonstrate and refine. These 3 steps is performed in cycle order, where its starts with building the system. The development of the system began and is performed part by part. Each completed part is then demonstrated to check for its functionality. If there are any requirements or new functionality being identified, the system will be refine, where the building proses will start again from where it has initially completed. These 3 steps cycles after one another until its functionality achieve satisfaction. Further explanation on these 3 parts is described below.

3.1.2 Prototyping Cycle

3.1.2.1 Build

This is the part where the interface of 4 main parts of the system is being developed. These parts are referred to as "Main Page", "Energy Usage", "Device Information Details" and "Statistics of Usage" respectively. The 1st part, the "Main Page" is the page that will allow user to select on any of the 3 pages that they desired. The 2nd page "Energy Usage" and 3rd page "Device Information Details" will represents the page where the input will be entered by user and finally the 4th page "Statistics of Usage" is where the output will be displayed for analysis purpose to user. Once the interface of window for each part completed, the database is then develop. There are 2 databases that will receive the data entered by user, which is the database for "Energy Usage" and "Device Information Details". All the data from these 2 databases will be combined in one database (3rd database) as the selected information will display in output window, which is "Statistics of Usage" for report generating purpose.

Main Page

The main page is the page that will appear when the program is run by the user. In this page, there is no input needed to be entered and no output will be display. The intention of this page is just to introduce and welcome the user when using the system. The main function of this page is to redirect the user to other 3 part of the system on which they intended to perform any transaction. This page contains 3 buttons named with each of the other 3 pages, and link user to the respective page when user clicked on it. As for all the 3 pages, there is "Home" button available on each page to allow user to navigate back to this "Main Page". **Figure 3.3** shows the main component of the "Main Page".

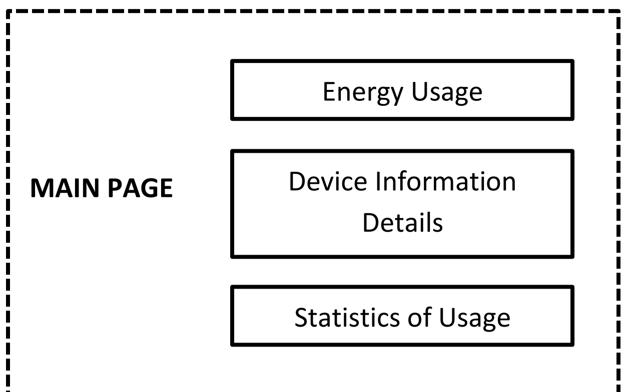

Figure 3.3: Components of "Main Page"

Energy Usage

"Energy Usage" is the first input page in the system which its function is for user to enter the amount of energy consumption as recorded by the electrical meter. In this section too, user will need to specify which building is the energy reading being recorded, the year and also the month of the recorded data to be retrieve is the "Statistics of Usage" section. **Figure 3.4** shows the components of the "Energy Usage" page.

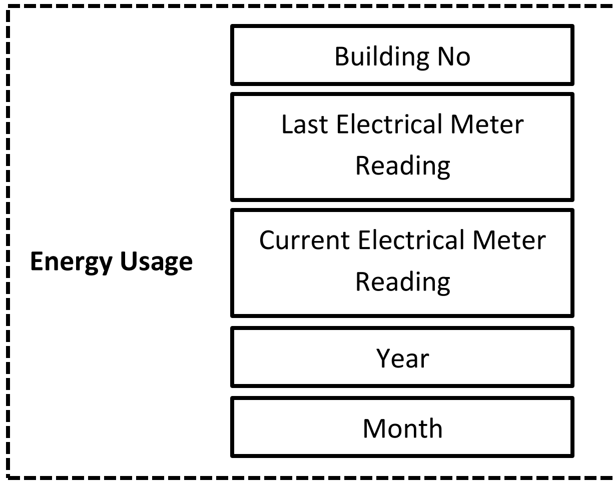

Figure 3.4: Components of "Energy Usage Page"

Device Information Details

“Device Information Details” page is the second input page in the system which its function is for user to enter the information of the devices being used in the building. This page in other words is will function as the electronic device inventory system where all devices entered is stored into system database named as “Device_Inventory”. The information on device being used is important to compute the amount of energy consumed by the devices, and hence the comparisons can be made to check if the amount of energy consumed by the devices is match with the recorded data usage from the electrical meter reading. **Figure 3.5** shows the component of “Device Information Details” page.

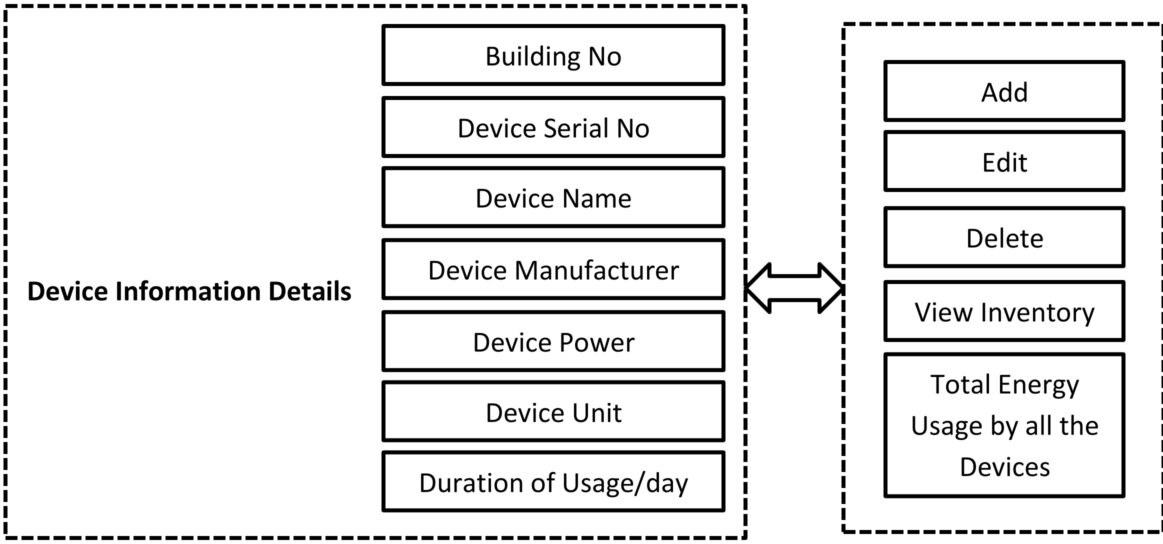

Figure 3.5: Components of "Device Information Details Page"

Statistics of Usage

"Statistics of Usage" page is the page where only the output will be display and no input is needed to be entered, except for the viewing selection process. This page generated the report of energy usage by which user can select to view by building no, year and month. All the data will be retrieved from the system database. **Figure 3.6** shows the components of the "Statistics of Usage" page.

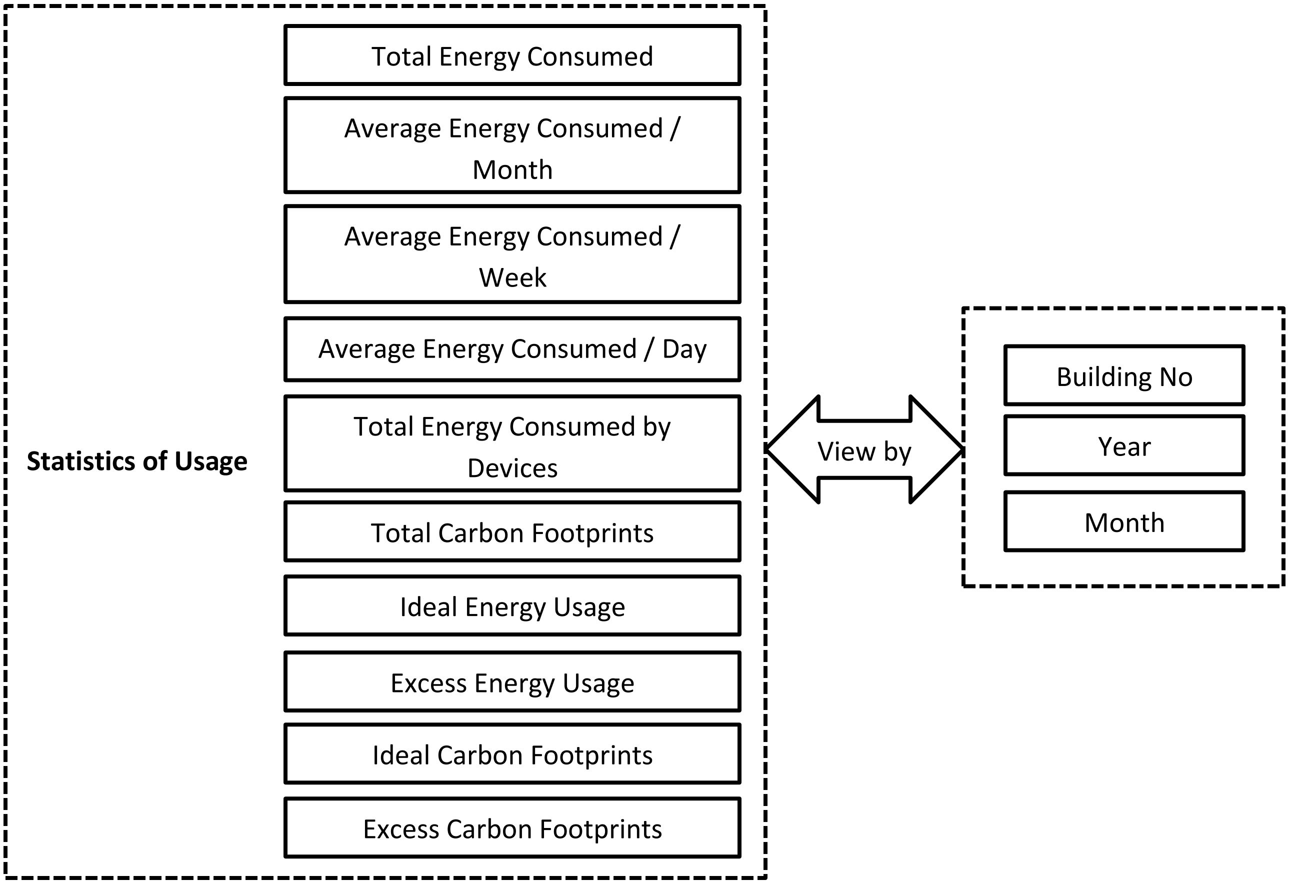

Figure 3.6: Components of "Statistics of Usage Page"

3.1.2.2 Demonstrate

This is the stage where all the components of system pages that has been build being demonstrate for its functionality relevancy and satisfaction. There have been several designs being made for each of the system page, and modification is being made to satisfy the user requirements. Initially, the system does not have the main page which it allow user to choose on which transaction page to be viewed. However, the page is then added to improve the navigation and link between different pages in the system to make it easier for user to use. Each page is also being demonstrated for its functionality purposes. There are request from user to add some features into each page to make it more understandable and improve the ease of use of the system. For example, it is more convenience if the user can view, edit, and delete the device information in the “Device

Information Details" page instead of the data being directly being stored into database once the user add its information.

3.1.2.3 Refine

The changes and modification required have made the system to undergo several modification processes. This process is referred to as the refinement process where the system components, interfaces and database are being modified. **Table 3.1** shows the modification that is being made to the system, page by page.

Table 3.1: Modification made on the system

System Page	Modification	Remarks
Main Page	-	Initially the system does not have the main page
Energy Usage	Add the dropdown menu function for user to select on year and month	-
Device Information Details	- Add the Serial No section - Add option for user to update/edit stored data - Add option for user to delete stored data - Add section to allow user to view all the stored data - Add option to allow user to view the device information by filtering the data via building no - Add section to compute and display total energy consumption by all devices being used in the building - Remove section that compute and display the total energy consumption by one type of device	All the changes made must also allow the information stored in the database to be updated and refreshed

Statistics of Usage	- Add option that allow user to filter the statistics of usage via year and month - Separate the section that display the ideal and excess of energy usage and carbon footprint. This section is labeled as "Remarks"	-

3.1.3 Testing

The completed subpages of the system will be tested individually before being integrate to form the complete system. In this stage, all subpages are tested for several kind of error testing as descried in **Table 3.2**. The testing process is also taking place in database if the system to ensure that each page of the system is properly connected to the database. As for "Energy Usage Page" and "Device Information Details Page", all the data input by the user in this page must be able to be stored inside its respective database. Meanwhile, for "Statistics of Usage Page", it should be able to retrieve all the data from its connected database without returning any wrong information or empty data. The testing phase is also important to ensure that the system can successfully retrieve all the data with reference to the building no, year and month of the data. Each page and its respective database must be interrelated with each other and hence, provide the correct energy statistical usage to user. **Table 3.3** meanwhile shows the type of testing being performed to check the system as a whole.

Table 3.2: Error Handling Testing

Test No	Type of Error Handling Test	Purpose	Status
1	Calculation and Computation Error	To make sure that the system can correctly perform all mathematical operations and return the correct values.	Passed

2	Invalid Data Type Error Handling	To make sure that the system do not proceed with execution and notify user when the input data type is wrong. For example, if the supposed data to be entered is numbers, and user entered characters, the system will notify user that the input data is wrong and the operation will break.	Passed
3	Data Storing in the system database	All the data entered by user should be stored in the database and the data shall not miss when the data is checked in the database.	Passed
4	Empty input error handling	The system will not proceed with execution whenever it required the input data, if there is no input being entered.	Passed
5	Error notification message	For all error that occurs, the system should prompted user to notify them.	Passed

Table 3.3: Type of System Testing performed

Test No	**Type of System Testing**	**Purpose**	**Status**
1	Black Box testing	To test for system requirement and functionality without considering the internal architecture of the system.	Passed
2	White Box Testing	To test for internal functionality of the system. This testing included the coding of the system.	Passed
3	Unit Testing	To test for the functionality of each separated system page.	Passed
4	Acceptance Testing	To ensure the system is completed and performed as requested by user.	Passed
5	Functional Testing	To ensure the system able to performed all its intended functionality.	Passed
6	Usability Testing	To ensure the system is understandable and	Passed

		can be easily used by the user	
7	Integration Testing	To verify that all different part of the system pages can integrate with each other and function with no error	Passed

3.1.4 Implementation

After all the testing performed is completed and passed, the system is ready for the implementation. The Smart Energy Consumption Management System for UTP Academic Buildings has received a positive response and will be considered to be use soon. This is the final phase of the system development and hence, the system is expected to be fully functioning as it intended for.

3.3 DEVELOPMENT TOOLS

- Electric Meter Reading
- Microsoft Visual Studio 2010 Ultimate Edition
- Microsoft Access 2010 Professional Plus Edition
- Platform Windows 7 Ultimate 32Bit

3.4 GANTT CHART FOR FYP II – SMART ENERGY CONCUMPTION MANAGEMENT SYSTEM FOR UTP ACADEMIC BUILDINGS

Table 3.4: Gantt Chart FYPII

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Learn on how to use Development Tools														
2	Prototype Development														
2	Demonstration and Refining Process														
3	Testing														
4	Submission of Progress Report														
5	Pre-SEDEX & Poster Presentation														
6	Submission of Dissertation														
7	Viva Presentation														
8	Submission of Final Report														
9	Submission of Technical Paper														

CHAPTER 4
RESULTS AND DISCUSSION

4.1 RESULTS AND DISCUSSION

The Smart Energy Consumption Management System for UTP Academic Building prototype performs as expected. There are 4 sections in this chapter, firstly is the mathematical equation used in the system; secondly the process flow diagram of the system; thirdly is the database results; fourthly is system operation and finally is the sample of data collection performed by the system. Each of these sections will be discussed and justified.

4.2 MATHEMATICAL EQUATION

The Smart Energy Consumption Management System for UTP Academic Building prototype is developed with several different mathematical equations being applied in its coding as part of its system algorithm. These mathematical equations are needed to allow the system to compute the values and numbers entered by user, hence returned the correct data for analysis. These mathematical equations are mainly being used in the "Statistics of Usage" page where this section of the system will display all the data that represents the energy consumption statistics in the building.

There has been a specific formula being derived and widely used to calculate the carbon footprints based on the type of energy consumption [18]. The formula was derived mainly for the most common behavior that leads to excessive amount of carbon footprints. Among them are the transportation and also the energy usage. **Table 4.1** shows the individual primary footprint of the most common consumptions. **Table 4.2** meanwhile shows the energy consumption calculation for common electronic devices being used.

Table 4.1: Individual Primary Carbon Footprints for Most Common Consumptions

Activities	Consumption Amount	Amount of CO_2 release in the atmosphere (kg)
Use of Electricity	1KWh	0.94
Kerosene	1 liters	2.52
LPG	1 liters	1.5
Travelling by car (LPG)	1000 liters	1500
Travelling by car (Petrol)	1000 liters	2320
Travelling by car (Diesel)	1000 liters	2630
Travelling by train by 1 person	1000 km	60

Table 4.2: Energy Consumptions Calculation per day

Appliance	Units	Power (Watt)	Consumption Rates (hours)	KWh
Fan	5	60	6	1.8
Tube Light	20	40	6	4.8
Computer	5	80	4	1.6
Laptop	5	50	10	2.5
AC	2	1000	4	1.8

Hence, from the two tables above, 2 formulas can be extracted and is being used as part of mathematical formula in the system. This formula is for computing the total carbon footprints based on amount of electricity consumption and derived as follows:

Carbon Footprints (Based on amount of electricity usage)

$$= \text{Total Electricity Usage} \times 0.94 \qquad \textbf{Equation 4.1}$$

Meanwhile, the total amount of energy consumption by the device can be derived as follows:

Total Energy Consumed by device

$$= ((\text{Power} \times \text{Hours of usage}) / 1000) \times \text{No of devices} \qquad \textbf{Equation 4.2}$$

Apart from the 2 formulas above, there are also specific formulas being used to generate the statistical report of energy usage in "Statistics of Usage" page which can be explained as in **Table 4.3**.

Table 4.3: List of Mathematical formula use to generate statistics of energy usage report

View report by	Data	Notation	Formula
Monthly	Total Energy Consumed by Device	N20	(((Power * Hours of usage) / 1000) * no of devices) * (days in month) *Where days in month = 28 or 29 or 30 or 31*
	Total Energy Consumed by building	N1	Current Meter Reading – Last Meter Reading *Where user need to select Year → Month*
	Average Energy Consumed / Week	N2	N2/4
	Average Energy Consumed / Day	N3	N2/(days in selected month)

	Total Energy Consumed by all devices in building	N4	∑N20
	Total Carbon Footprints	N5	N2*0.94
	Ideal Energy Usage	N6	N2 – N7
	Excess Energy usage	N7	N2 – N4
	Ideal Carbon Footprints	N8	N6*0.94
	Excess Carbon Footprints	N9	N7*0.94
Yearly	Total Energy Consumed by Device	N21	(((Power * Hours of usage) / 1000) * no of devices) * (365.2) *Where 365.2 = Total no of days in a year*
	Total Energy Consumed by building	N10	Energy Consumed within 12 months of the year
	Average Energy Consumed / Month	N11	N10/12
	Average Energy Consumed / Week	N12	N10/52
	Average Energy Consumed / Day	N13	N10/365.2
	Total Energy Consumed by all devices in building	N14	∑N21
	Total Carbon Footprints	N15	N10*0.94
	Ideal Energy Usage	N16	N10-N17
	Excess Energy usage	N17	N10-N14
	Ideal Carbon Footprints	N18	N16*0.94
	Excess Carbon	N19	N17*0.94

	Footprints		

4.2 PROCESS FLOW DIAGRAM

As described in earlier section, the system is consists of 4 main part including the "Main Page". Each of the pages has different functionality and hence has a different operation that occurs within them. Start with the "Main Page", user will choose on which page to go to for their preferred transaction. These pages are "Energy Usage", "Device Information Details" and "Statistics of Usage" page respectively. The component of each part has been described in details in Chapter 3. **Figure 4.1** shows the overall process flow of the system which link the "Main Page" to all other pages.

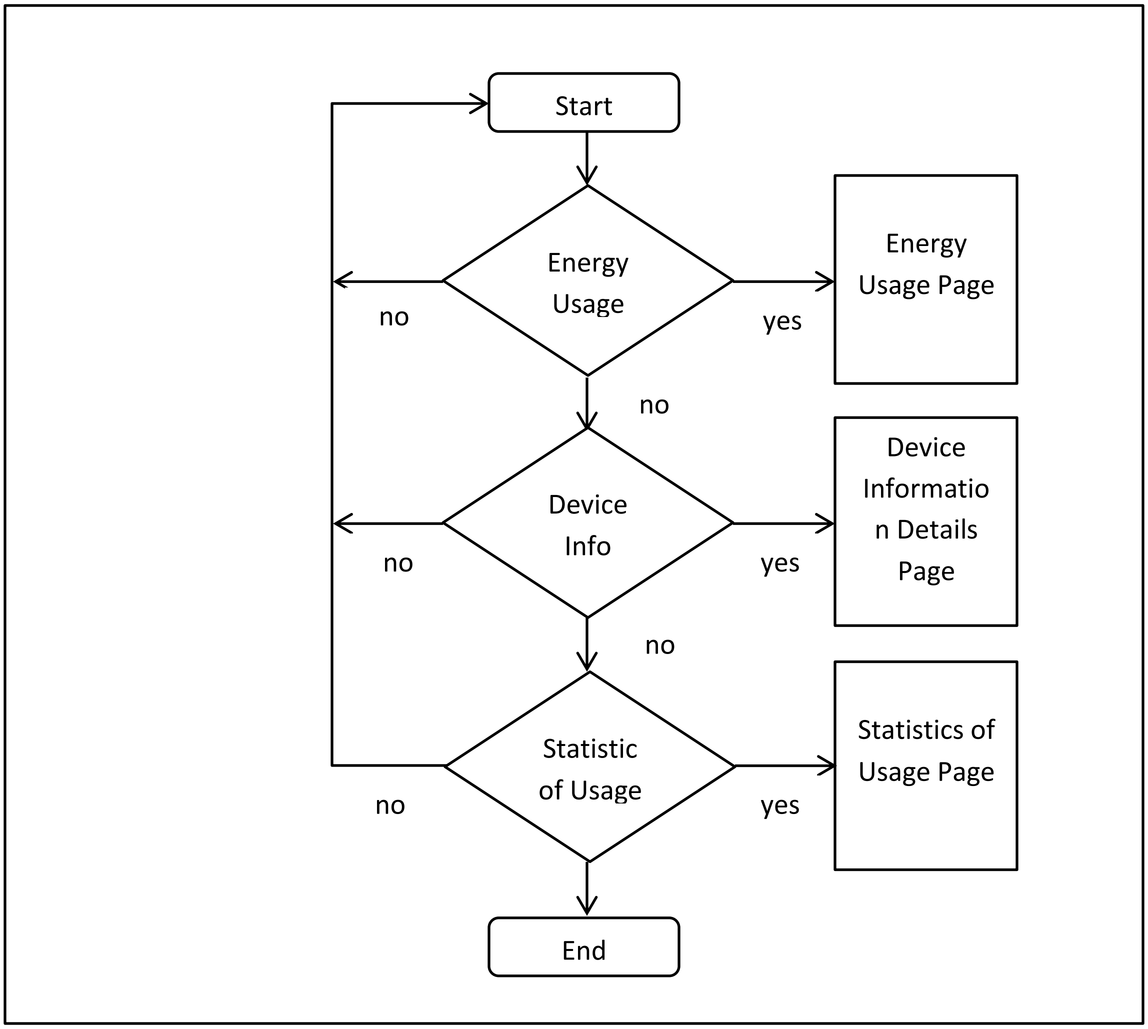

Figure 4.1: Process Flow for the whole system

The most complicated and complex process in the system occurs at the "Statistics of Usage" page. The process is complicated due to all the data need to be extracted from the system database. These data is the data that being input by the user in the other 2 page of the system. However, most of the data executed from the database will be the raw data only. Mathematical operation is performed all within the process of execution by using the data from database as its raw data and being display as a report for easier analysis by user. **Figure 4.2** shows the flow for retrieving data.

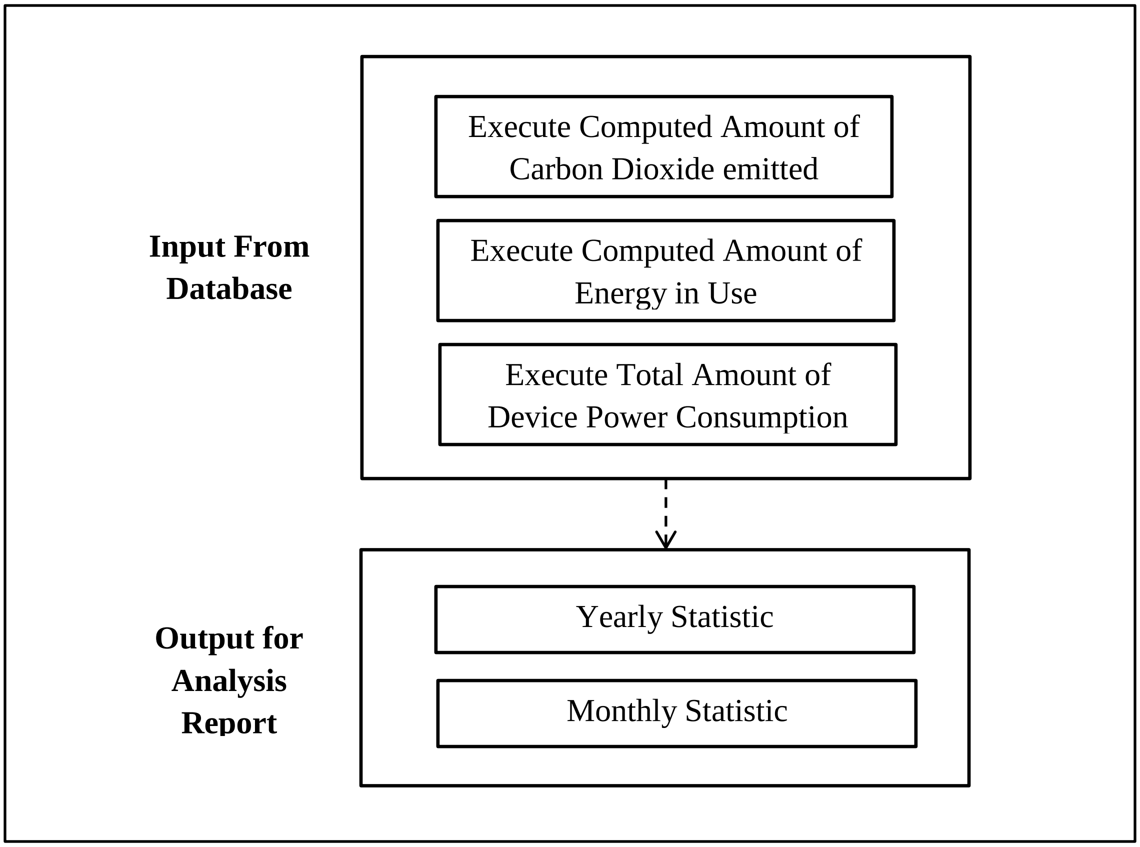

Figure 4.2: Flow of retrieving data to be display as statistics of usage

4.3 SYSTEM OPERATION

The system operation starts at the "Main Page" where in this page, it allows user to select on what kind of operation that he wish to performed. There are 3 buttons in this page labeled as *Energy Usage*, *Input Device* and *View Statistics* respectively. Click on any of this button will pop out the window for the respective system page. User shall click on *Energy Usage* button if he wished to enter the energy usage that is being obtained from the electric meter from a particular building. However, user shall click on *Input Device* button if he wished to add the details of electronic devices that had been used in the building. User will need to click on *View Statistics* button if he wished to view the statistics of the energy usage for analysis purpose.

“Energy Usage” page is the page where user will enter the electrical meter reading as the main input data. The data includes the last recorded data and current reading on the electric meter. In this section too, user need to select the building on which the data is being taken, followed by the year and month. When user click on *Save* button, all the input data will be recorded into the database and at the same time, first phase of mathematical computation occurs. This mathematical computation is to compute the total amount of energy usage within the selected month. Apart from that, by clicking the *Save* button too, another mathematical computation will occur. This time is to compute the amount of carbon footprints based on the computed total energy usage. Both values for total energy usage and carbon footprints will be stored inside the database, and at the same time the value will be shown at the page too. The *Clear* button is specifically for user to clear all the data fields if he wished to reenter the new data. The *Home* button meanwhile is for user to close the page and return back to “Main Page”.

“Device Information Details” page is the page where user will enter the information about the device being used in the building. User will first need to start by selecting the building no, followed by entering the device details such as below:

- Serial No
- Device Name
- Device Manufacturer
- Device Power
- Device Unit
- Duration of Use

After entered all the above details, user will need to click on *Add* button to store the data into database. User can edit the information of device by clicking on button *Edit*. User can also delete the stored data by clicking on *Delete* button. As for *Clear* button, it is useful if user need to clear all the data fields before entering the new set of data. User can filter and view the entire stored device according to the building no, by clicking on *View* button. Click on View button will make the system to perform another mathematical formula. This computation is to calculate the total energy consumed by all devices in the building. User can click on *Home* button to close the page and return to "Main Page".

"Statistics of Usage" page is the page where all the report is being generated and display. To view the report, user will first need to select the building no, year and month to allow the correct data to be generated.

4.4 SAMPLE OF DATA COLLECTION

The system has successfully performed all of its intended functionality. The actual data collection process has yet to be carried out due to the time constraint. However, some data have been used which exhibits the similar characteristics of the actual data. **Figure 4.3** shows the sample of data being input and stored into the system. **Figure 4.4** meanwhile shows the above data being stored inside the "Device_Inventory" database.

Building No: Block 1

Year: 2012

Month: January

==

Last Meter reading: 1988278

Current Meter reading: 1998012

Total Energy Consumption: 9734

Carbon Footprints: 9149.96

==

Device used in the building:

Block No	Device Name	Serial No	Device Manufacturer	Device Power	Device Unit	Duration of Use	Total Energy Consumption
Block 1	Computer	AAAKS1999...	90	Dell	250	8	180
Block 1	Pendarflour...	QQAO0911...	30	Philips	300	9	81
Block 1	Server	ABBJ117789	650	Western Di...	2	24	31.2
Block 1	Ventilation ...	XAAZ001272	850	York	1	12	10.2

Figure 4.3: Sample data input by user

All Access Objects

Search...

Tables

Device_Inventory

Energy_Usage

Statistics_of_Usage

Energy_Usage | Device_Inventory

serialno	blockno	dvcname	dvcmanufac	dvcpower	dvcunit	durationuse	totalenergy	Click to Add
AAAKS199901	Block 1	Computer	90	Dell	250	8	180	
QQAO091112	Block 1	Pendarflour Lig	30	Philips	300	9	81	
ABBJ117789	Block 1	Server	650	Western Digita	2	24	31.2	
XAAZ001272	Block 1	Ventilation Sys	850	York	1	12	10.2	
QASA6671333	Block 13	Computer	90	Dell	25	8	18	
AAJSHA001911	Block 17	Computer	90	Dell	20	8	14.4	
MMAS9918223	Block 21	Computer	90	Dell	30	8	21.6	
PPASH881726	Block 23	Computer	90	Dell	45	8	32.4	
BBFX112233	Block 23	Pendarflour Lig	40	Philips	220	10	88	

Figure 4.4: The added device is stored inside the "Device_Inventory" database

User has done key in all the necessary data into the system. Now is the time to check the statistics of energy usage as being generated in the "Statistics of Usage" page. **Figure 4.5** shows the print screen of the report generated to show the statistics of energy usage for Building 1, Year 2012 and Month January.

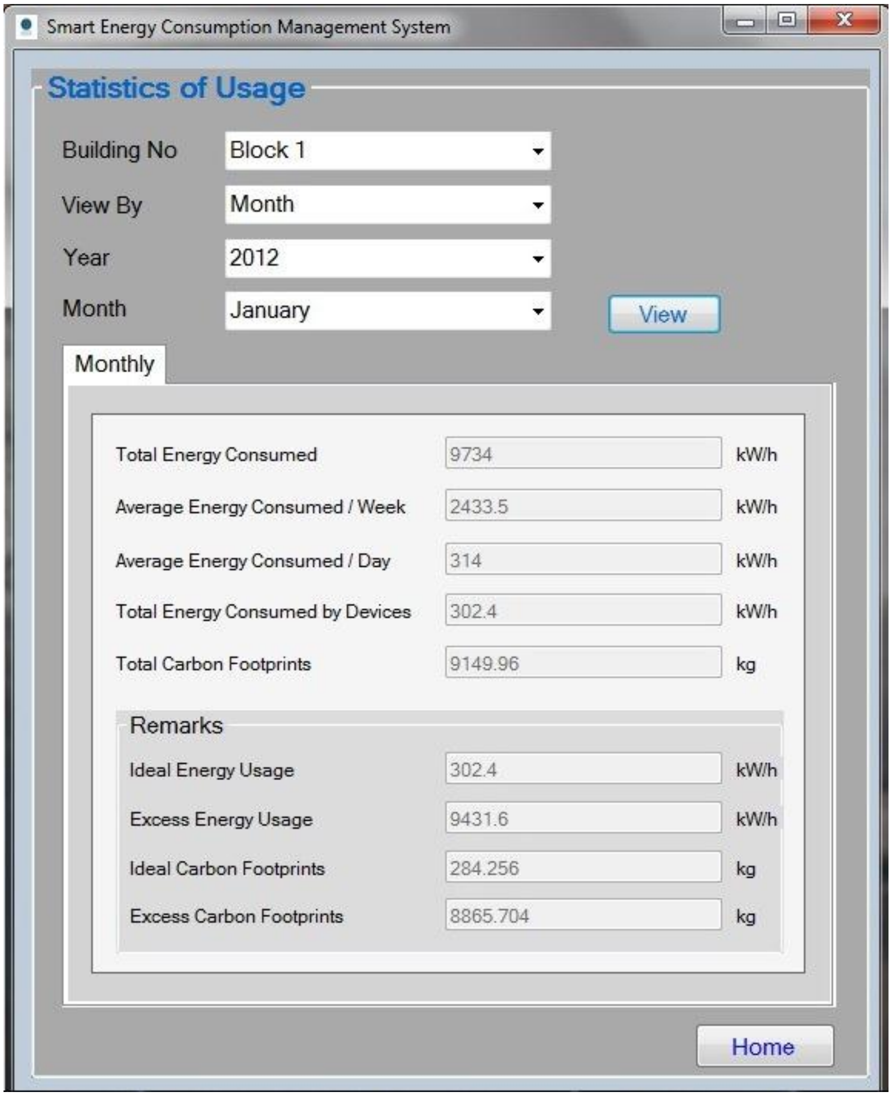

Figure 4.5: Statistics of Energy Usage Generated in the System

To ensure that the system is working well and able to perform all of its functionality, **Table 4.4** will show the in depth explanation on all the data being obtained and generated, based on the input user data. Based on the table, all the data being generated as report for statistics of usage has matched the input data, and the value is also correctly computed by using all the listed mathematical formula as in **Table 4.3**.

Table 4.4: Comparisons Between the Input Data and the Output Data being generated in the "Statistics of Usage" Page

Input Data (Entered by user)	Output Data (Report generated)	Remarks	Status
Building 1	Building 1	Building 1 is selected	Passed
Year 2012	Year 2012	Year 2012 is selected	Passed
Month January	Month January	Month January is selected	Passed
Last Meter reading: 1988278	-	Not display in report page	Passed
Current Meter reading: 1998012	-	Not display in report page	Passed
Total Energy Consumption: 9734	Total Energy Consumption: 9734	Same for both Input and Output	Passed
Carbon Footprints: 9149.96	Carbon Footprints: 9149.96	Same for both Input and Output	Passed
Total Energy Consumed by all device: 6955.2	Total Energy Consumed by all device: 6955.2	Device1 = 180 Device2 = 81 Device3 = 31.2 Device4 = 10.2 (180+81+31.2+10.2)*(31-8) = 6955.2 *Where (31-8) = 31 days in January – 8 days of weekend*	Passed

-	Average Energy Consumed / Week: 2433.5	9734/4 = 2433.5	Passed
-	Average Energy Consumed / Day: 314	9734/31 = 314	Passed
-	Ideal Energy Usage: 6555.2	9734 – 2778.8 = 6555.2	Passed
-	Excess Energy Usage: 2778.8	9734 - 6955.2 = 2778.8	Passed
-	Ideal Carbon Footprints: 6161.89	6555.2 * 0.94 = 6161.89	Passed
-	Excess Carbon Footprints: 2612.07	2778.8 * 0.94 = 2612.07	Passed

Table 4.4 above has also indicated that the system has successfully passed its entire functionality test. The comparison made has also shows that there is no mismatch data being generated, and the values are also all correct following the set mathematical formula. Therefore, with this comparison too, it is concluded that the system is working well with no issues and error for all of its intended functionality.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

A good energy consumption management system is needed to ensure a wiser way of managing energy usage. In this documentation, it explained in details about the project. Currently, Universiti Teknologi PETRONAS (UTP) does not have a system which monitors the electricity usage for its buildings, especially the academic buildings. This project is focusing only on academic building due to the fact that these are the building which consume greater amount of electricity compared to other buildings in the campus.

Much research has been conducted to study energy consumption trend in UTP. However, those researches are only meant to gather the data for further analysis and study. The root cause and factors lead towards energy over-consumption has also been identified and suggestion on proper actions to be taken for reducing energy consumption has also been found. Without we realized a simple step yet give a big impact on how energy management can be performed are actually lies on how we track the rate of energy usage.

Hence, with a smart monitoring system for all academic buildings, the energy consumption can be continuously monitored and thus gives the specific figures needed for deeper analysis on how the energy consumption problem can be solve. This project does not intent to solve the over-consumption of energy. The solution may change and varies depending on how critical is the problem. This project aims to maintain its sustainability and feasibility values where it is flexible for any kind of action to be taken to solve the energy consumption problem. This project also aims to help UTP to comply with Government policy which urged all organization and institution to practice and promote Green IT policy and reduce the total amount of energy consumption.

5.2 RECOMMENDATION

This prototype of Smart Energy Consumption Management System for UTP Academic Buildings is developed as a result from the research of the project; therefore this prototype can be improved in terms of its performance and features. The prototype can be enhanced into final product that can be used anytime and anywhere.

The Smart Energy Consumption Management System for UTP Academic Building can be enhanced by broadening its scope of usage. Currently, this prototype is only meant to be used within the UTP academic buildings. In near future, this system can be modified and enhanced to be used not only within the academic building, but anywhere in the campus. For example, this system can also be used to monitor energy usage in student's hostel and cafeteria. To ensure this system can be used in other buildings in the campus, some modification shall be made in the building selection choice, where it will include the student's hostel block. Also, it includes the option to choose cafeteria if the system is to be implemented and used in the cafeteria.

In addition, the system can also be enhanced by changing the way the data being input into the system. Current prototype require user to manually input the electrical meter reading to the system in order for the energy usage analysis to be performed. Hence, by integrating the system with an input device, it will be much easier and convenience for the user to use the system to monitor the energy consumption rate. For instance, the device will capture the electrical meter reading by itself and send the data into the system. The system will hence compute the energy analysis and display the results to the user.

Apart from that, the prototype system is a standalone system in which user will not have the flexibility of using the system if it is used as a final product. Therefore, it will be better off if the system is able to develop as a web-based product and allow all users to access the system at anytime and anywhere they wished.

REFERENCES

[1] Index Mundi "Malaysia Electricity Consumption" *Historical Data Graphs Per Year*, <http://www.indexmundi.com/g/g.aspx?c=my&v=81>

[2] Md. Azizul Bari, R. Ara Begum, A. Hamid Jaafar, R.D.Z Raja Zainal Abidin and J. Jacqueline Pereira, (2008) *Future Scenario of Residential Energy Consumption and CO_2 in Malaysia*, Institute for Environment and Development, Faculty of Economics and Management, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia

[3] R. Saidur (2009), *Energy Consumption, Energy Savings, and Emission Analysis in Malaysian Office Buildings*, Department of Mechanical Engineering, University of Malaya, Kuala Lumpur, Malaysia

[4] A. Khamis, A. Alamshah, A. Ahmad, A. Ab Rahman, M. Hendra Hairi, (2010) *Energy and Electricity Consumption Analysis of Malaysian Power Demand*, The 4th International Power Engineering and Optimization Conf. (PEOCO2010), Shah Alam, Malaysia, June 2010.

[5] Xavier, S. W. *Energy Audit Assesment Repot UTP, Malaysia.* Singapore: Honeywell Pte Ltd. 2008.

[6] Shaarani, S. M. Building Energy Efficiency of Chancellor Hall of University Technology PETRONAS. *Unpublished Journal*. 2009.

[7] Intel Corporation: Intel Ships New Eco-Friendly Intel® Xeon® Server Processors That Boost Performance <http://www.intc.com/releaseDetail.cfm?releaseid=332732> February 2012.

[8] R. Saidur, M. Hasanuzzaman, M.A Sattar, H.H Masjuki, M. Irfan Anjum, A.K.M Mohiuddin, (2007) *An Analysis of Energy Use, Energy Intensity and Emissions at The Industrial Sector of Malaysia*, Department of Mechanical Engineering, University of Malaya, Kuala Lumpur, Malaysia

[9] M.F Khamidi, A.S Khalid, R. Rahardjati, A. Idrus (2010), *Universiti Teknologi PETRONAS Retrofitting: Turning Challenges into Opportunities*, Department of Civil Engineering, Universiti Teknologi PETRONAS, Tronoh, Perak, Malaysia

[10] Malaysia, D.O.S. MALAYSIAN STANDARD Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Building (First Revision). MS 1525:2007.

[11] Abdul Rahman Mohamed and Keat Teong Lee (2006), Energy for sustainable development in Malaysia: Energy policy and alternative energy. *Energy Policy.* V01-34. pp-2388-2397

[12] Masjuki H.H, Jahirul M.I, Saidur R, Rahim N.A, Mekhilef S, Ping H.W, Zamaluddin M.F, *Energy and Electricity Consumption Analysis of Malaysian Industrial Sector*, Department of Mechanical Engineering and Department of Electrical Engineering, University of Malaya, Kuala Lumpur, Malaysia

[13] S.A Sulaiman, A.H Hassan (2011), *Analysis of Annual Cooling Energy Requirements for Glazed Academic Buildings*, Department of Mechanical Engineering, Universiti Teknologi PETRONAS, Tronoh, Perak, Malaysia. *Fig 1: Aerial view of the academic complex.*

[14] Ikhsan A, Abdul Rahman M.N, Abdullah H (1990), *Industrial Energy Consumption Analysis*, Faculty of Chemical and Natural Resources Engineering, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia

[15] Syzdykbayeva D (2009), *Analytical Study on Adoption of Green Computing by Malaysian Organizations*, Faculty of Science and Information System, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia

[16] Wall G (2002), *Conditions and Tools in The Design of Energy Conversion and Management Systems of a Sustainable Society*, Exergy Consultant, Solhemsgatan 46, Sweden

[17] Gerber, Aurona; Van der Merwe, Alta; Alberts, Ronell; (2007), Implications of Rapid Development Methodologies, CSITEd 2007, Mauritius, November 2007

[18] R.N. Reddy and Y.V.N.S Suvikram (2012), *Carbon Credits – A Step to Sustainable Future of the World*, Chemical Engineering Department, Institute of Technology, Nirma University, Ahmedabad, Gujarat, India

[19] Harmon R.R, Auseklis N (2009), *Sustainabme IT Services: Accessing The Impact of Green Computing Practices, Strategic Marketing Area & Engineering Computing*, Portland State University & Intel Corporation, USA

[20] Malaysia, D.O.S. MALAYSIAN STANDARD Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings (First Revision). *MS 1525:2007*.

[21] Green Building Index. GBI Assessment Criteria for Non-Residential New Construction (NRNC). Kuala Lumpur, Malaysia: Green Building Index Sdn. Bhd. April 2009.

[22] M.A Bdari, R.A Begum, A.H Jaafar, R.D.Z.R.Z Abidin, J.J Pereira (2010), *Future Scenario of Residential Energy Consumption and* CO_2 *in Malaysia*, Faculty of Economics and Management, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia

[23] A. Ikhsan, M.N Abdul Rahman and H. Abdullah (2002), *Industrial Energy Consumption Analysis*, Faculty of Chemical and Natural Resources Engineering, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia

APPENDICES

Smart Energy Consumption Management System for UTP Academic Buildings

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ABSTRACT

Over the years, Universiti Teknologi PETRONAS (UTP) has reported a high reading for its Building Energy Index (BEI). Clearly, this indicates that there are excessive amount of electricity consumption within the campus. The highest BEI comes from the academic buildings. A study conducted to identify the root cause of this issue has shown that there is no systematic system or procedure used to monitor and manage the electricity usage in the campus. Hence, this project aims to develop a system that will help to monitor the energy consumption in UTP academic buildings. The main purpose of this system is to calculate the total amount of electricity consumption, and thus computing the amount of Carbon Dioxide (CO_2) omission based on the amount of consumed electricity by a particular building. Apart from that, the system will also compute the amount of ideal and excess electricity usage for that building. This is calculated by roughly sum up the power consumption by all the available electrical devices that operate in the building. The summary report for all these data will be generated on monthly and yearly basis. With all these info being produced by this system, UTP management will be aware if there are over omitted CO_2 gas resulting from the electricity usage and also the excessively used electricity and thus take an appropriate action towards a proper way of managing its energy consumption rate to promote a Green IT concept within the campus. This system does not solve the over consumed energy and over omitted CO_2 but only provides all the necessary records and data based on the energy consumed.

Keywords: *Energy Consumption, UTP, Academic Buildings, Carbon Dioxide Emission*

I. INTRODUCTION

Demand for energy supply in Malaysia, especially electricity has risen rapidly within the last few years. Not only Malaysia, but the statistics produced by the Institute of Electrical and Electronic Engineers (IEEE) has shown the same pattern in energy consumption throughout the world. According to the studies, as per year 2011, Malaysian electricity consumption is 93.8 billion kWh compare to 5 years ago, which the studies recorded that the electricity consumption is 72.71 billion kWh [1]. A study has been conducted to access the future trend of residential energy consumption and CO_2 emissions in Malaysia and it is estimated that the CO_2 emission is 2,347,538 tonne on 2008, and predicted to increase up to 11,689,308 tonne by 2020 [2]. This large increase is due to a constant increase in electricity consumption, where the power source is mainly generated by Liquid Petroleum Gas (LPG) and other natural resource such as kerosene, coal and natural gas. Meanwhile, there is more growing concern towards the energy consumption in recent years mainly the energy used in commercial buildings. Commercial and residential building only have contributed to about half of total energy consuming in Malaysia [3]. It is estimated that about 70-300kWh/m² energy is used per-annum in commercial building [4]. Rapid growth of Malaysian economic has led towards a drastic rise in energy consumption due to the fact that everyone aims and wanted to improve their standard of living. As a results, there is a rapid increase in energy demand, and as a results, increase in the rate of CO_2 emissions.

In Universiti Teknologi PETRONAS (UTP), an energy audit assessment done by Honeywell Pte Ltd in which cooling load was monitored between 25th October 2008 – 3rd November 2008 shows that total estimated existing energy consumption of Air Handling Units (AHU) and Mechanical Ventilations (MV) fans per year in UTP is 5,576,090 kWh/Year which is equivalent to RM 1,672,827/Year at charge rate of RM0.30/kWh [5]. The BEI for the year 2007 is 287 kWh/m² and this indicates that UTP has consumed too much energy and far from practicing a good energy management [6]. This leads to a high cost need to be pay by the management due to the high amount of energy consumption. Data and facts above have raised the concern over the importance of having a proper management of electricity usage. Without a good management, apart from running out of the resources, the effect toward environment will become more costly than other effect. Having a good policy in energy usage within an organization will leads to an overall reduced in over-use of energy, which is the best step can be taken in ensuring the longer energy sustainability while lowering the rate of its negative effect towards environment. Hence, with the implementation of smart energy consumption management system within the building, it would play an important role in raising the awareness and concern over the needs of reducing the energy usage and thus reducing the rate of CO_2 emission.

A. Problem Statement

High cost need to be pay for an excessive and uncontrolled amount of energy usage by Universiti Teknologi PETRONAS (UTP). This is truly an unfavorable condition and hence, a good solution is needed to overcome this problem. High cooling demand due to insufficient devices and fixtures used are suspected to be the main cause. Besides that, human behaviors towards energy consumption too were suspected to contribute toward an inefficient amount of energy usage. Even though UTP have its own Gas District Cooling (GDC) plant to supply electricity to all its buildings, excessive usage of electricity will still results in high energy consumption which will give bad impact towards environment. It results in high emission of CO_2 gases and caused a greenhouse effect. Narrowing the root cause, the excessive usage of electricity is mainly due to human behavior itself. The usage of electrical equipment is without proper control and monitor. UTP management has seen this as a serious issue and proper action need to be taken. In compliance with international and government policy which encourage an efficient energy consumption to support Green IT campaign, UTP requires a smart system which helps to monitor the energy usage within the campus.

Managing energy consumption reflecting how UTP can continuously monitoring its electricity usage, most importantly within its own academic buildings where it is identified as main building which consume the biggest amount of electricity. This is due to several high-tech devices being used including devices running for 24 hours a day, mainly for research and learning purpose that is not being turned off even if it is not in use. UTP management team may have not alerted that all of these practices are actually contributing towards a massive electricity usage and thus results in a big amount of CO_2omission into environment. Without a proper system to manage the energy consumption, years from now, UTP might emerged as one of the biggest contributor towards the greenhouse effect results from an uncontrolled and excessive amount of energy usage.

B. Objective

The objectives of this project are as outlined below.

6. To record the electricity usage in academic buildings.
7. To compute the amount of CO_2 omission for that particular building based on the amount of electricity usage.
8. To generate complete report for electricity usage, CO_2 omission, ideal electricity usage, excess electricity usage, ideal CO_2 omission rate, and excess CO_2 omission rate on monthly and yearly basis.
9. To record and store all electronic devices being used in the academic buildings.
10. To ensure the reports generated will give clear analysis of electricity consumption in academic building for UTP management to decide on proper action to be taken.

C. Scope of Study

The scope of study of the project is Universiti Teknologi PETRONAS (UTP) academic buildings. Overall, there are 16 academic blocks in UTP and each block is referred to as Block 1, Block 2, Block 3, Block 4, Block 5, Block 13, Block 14, Block 15, Block 16, Block 17, Block 18, Block 19, Block 20, Block 21, Block 22 and Block 23. Each academic block is a 4-level building structures, in which the 4^{th} level of each building is specifically allocated as lecturer's office, whereas for 1^{st}, 2^{nd} and 3^{rd} level, it is used as lecture rooms, computer laboratories, engineering laboratories, meeting rooms and research centers.

II. LITERATURE REVIEW

A. Energy and Electricity Consumption Analysis of Malaysian Industrial Sector

This research paper [7] was written by Masjuki H.H et al., from Department of Mechanical Engineering and Electrical Engineering, University of Malaya, Malaysia is about the analysis of energy and electricity consumption by the industrial sector in Malaysia. The research main parameters are power rating, operation time of energy consuming equipment, source of energy consumption, production figure, peak tariff usage behavior and also power factor [8]. The most important data collected was the power rating and operating time for each machines and equipment used for productions. With all the data collected, the team have come out with an approaches used to estimate the specific energy consumption (SEC) for each machines and equipment. The SEC of each sector is represented by SEC from the audited industries of the particular sector. Such methodology and estimation of energy consumption will be very useful for other research or study which related to the energy consumption management and the invention of devices which used to calculate the energy usage. This study has concluded that majority of factories are still operating by using the old equipment which are not efficient and consume large amount of energy.

B. Energy Consumption, Energy Savings and Emission Analysis in Malaysia

This journal was written by R. Saidur from the Department of Mechanical Engineering, University of Malaya. The objective of this journal is to study the estimated amount of energy being consumed in office and commercial buildings in Malaysia. This study is focusing only on the office and commercial buildings within Malaysia in comparisons of the residential buildings. This research has also figured out that the pattern of energy usage in Malaysia is largely affected by changes in economic trend of Malaysia itself. This research has also come out with a statistics of energy uses in Malaysia, where the highest percentage is the industrial sector with 48%, followed by commercial sector with 32%, then residential with 19% while others with 1%. Besides that, this research has also stressed out the importance of managing and reducing the energy usage as it contributed towards a huge amount of CO_2 emissions. R. Saidur also suggest that the most cost-effective ways towards achieving this is by having a smart way of managing the electricity usage within the commercial and office buildings.

C. Universiti Teknologi PETRONAS Energy Retrofitting: Turning Challenges into Opportunities

This research paper was written by M.F Khamidi, A.S Khalid, R Rahadjati, and A Idrus from the Department of Civil Engineering, Universiti Teknologi PETRONAS. The objective of this research is to plan a project which helps to reduce UTP cooling load and energy consumption, thus being in line with Government calls for energy efficiency. The scope of study for the research is the electricity consumption within the UTP campus, mainly in academic buildings; Block 13, 14 and Pocket C. The study done estimated that UTP is consuming too large amount of energy which has contributed towards a worrying negative effect on environment. High electricity usage requires a huge amount of energy to generate the electricity in which this results in high emission rate of CO_2 gas [9]. Other implication is huge cost need to be pay by UTP management due to high electricity usage. Energy audit assessment report done between 25th October 2008 – 3rd November 2008 by Honeywell Pte Ltd estimated that energy consumption for all Air Handling Units (AHU) and Mechanical Ventilation (MV) that serve the academic buildings is 5,576,090 kWh/Year. This equals to RM1,672,827/Year at RM0.30/kWh. This research also identified what is the main challenge faced when it comes to energy saving. The main challenge is human attitudes where the low level of awareness among the students and staffs of UTP leads towards inefficient usage of electricity. Khamidi et al. concluded that UTP electricity usage is so high that action needs to be taken in order to reduce the amount of energy consumption.

III. METHODOLOGY

A. Software Process Model

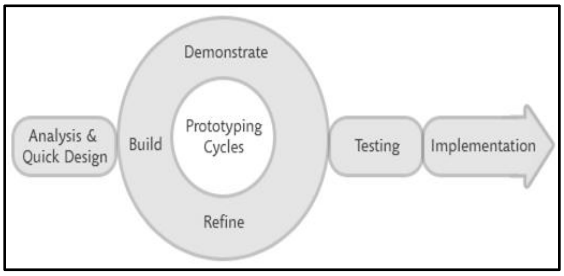

Figure 1: Rapid Application Design (RAD) Model

In this project, the software process model that being used is Rapid Application Development (RAD) method as shown in **Figure 1** [10]. This methodology is chosen due to the time constrain of this project which in total is 9 months. This methodology is also chosen due to the possibility of there might be functionality and performance compromising in order to allows a faster development process. The benefits of using this methodology is it allows any changes to be made during the development phase if there is needs to review and recheck at any other phase of project development. This is important as it provides flexibility throughout completing the project such as debugging process.

B. System Architecture

Figure 2 shows the complete system architecture of the project prototype. The system prototype has 4 pages, namely Main Page, Energy Usage, Device Information, and Statistics of Usage. When the program is execute, the Main Page will be displayed first, which gives option for user to choose which transaction to perform. In Energy Usage page, user will enter the amount of electricity being used, based on the value recorded by the electric meter reading. Data recorded will be save and store in the system database. In Device Information page, user will enter the details of the electrical devices being used in the building. The information details will also be stored into the system database. In Statistics of Usage page, user will be able to view the statistics of energy being used based on the Building No, Year and Month.

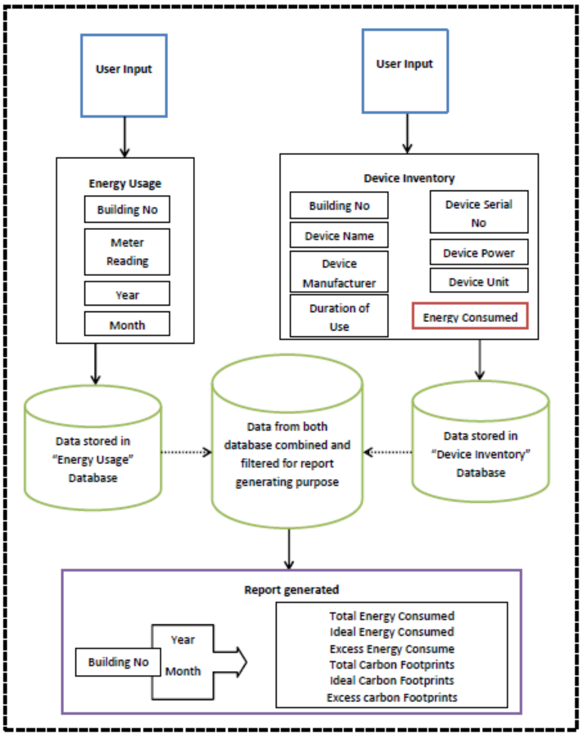

Figure 2: System Architecture

C. Development Tools Required

- Electric Meter Reading
- Microsoft Visual Studio 2010 Ultimate Edition
- Microsoft Access 2010 Professional Plus Edition
- Platform Windows 7 Ultimate 32Bit

IV. RESULTS AND DISCUSSION

The Smart Energy Consumption Management System for UTP Academic Building prototype performs as expected. There are 5 sections in this chapter, firstly is the mathematical equation used in the system; secondly the process flow diagram of the system; thirdly is the database results; fourthly is system operation and finally is the sample of data collection performed by the system. Each of these sections will be discussed and justified.

A. *Mathematical Equation*

The Smart Energy Consumption Management System for UTP Academic Building prototype is developed with several different mathematical equations being applied in its coding as part of its system algorithm. These mathematical equations are needed to allow the system to compute the values and numbers entered by user, hence returned the correct data for analysis. These mathematical equations are mainly being used in the "Statistics of Usage" page where this section of the system will display all the data that represents the energy consumption statistics in the building. There are two main mathematical formulas being used in the system which can be described as below:

1. *Carbon Footprints (Based on amount of electricity usage) = Total Electricity Usage × 0.94*
2. *Total Energy Consumed by device = ((Power × Hours of usage) / 1000) × No of devices*

Apart from the 2 formulas above, there are also specific formulas being used to generate the statistical report of energy usage in "Statistics of Usage" page which can be explained as in **Table 1**.

Table 4: List of other Mathematical Formulas used

View report by	**Data**	**Notation**	**Formula**
Monthly	Total Energy Consumed by Device	N20	(((Power * Hours of usage) / 1000) * no of devices) * (days in month) *Where days in month = 28 or 29 or 30 or 31*
	Total Energy Consumed by building	N1	Current Meter Reading – Last Meter Reading *Where user need to select Year → Month*
	Average Energy Consumed / Week	N2	N2/4
	Average Energy Consumed / Day	N3	N2/(days in selected month)
	Total Energy Consumed by all devices in building	N4	∑N20
	Total Carbon Footprints	N5	N2*0.94
	Ideal Energy Usage	N6	N2 – N7
	Excess Energy usage	N7	N2 – N4
	Ideal Carbon Footprints	N8	N6*0.94
	Excess Carbon Footprints	N9	N7*0.94
Yearly	Total Energy Consumed by Device	N21	(((Power * Hours of usage) / 1000) * no of devices) * (365.2) *Where 365.2 = Total no of days in a year*
	Total Energy Consumed by building	N10	Energy Consumed within 12 months of the year
	Average Energy Consumed / Month	N11	N10/12
	Average Energy Consumed / Week	N12	N10/52
	Average Energy Consumed / Day	N13	N10/365.2
	Total Energy Consumed by all devices in building	N14	∑N21
	Total Carbon Footprints	N15	N10*0.94
	Ideal Energy Usage	N16	N10-N17
	Excess Energy usage	N17	N10-N14
	Ideal Carbon Footprints	N18	N16*0.94
	Excess Carbon Footprints	N19	N17*0.94

B. *Process Flow Diagram*

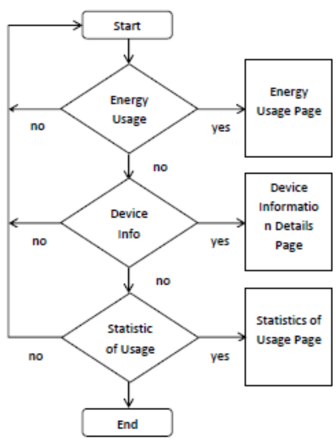

Figure 3: Process Flow Diagram

C. *System Operation*

The system operation starts at the "Main Page" where in this page, it allows user to select on what kind of operation that he wish to performed. There are 3 buttons in this page labeled as *Energy Usage*, *Input Device* and *View Statistics* respectively. Click on any of this button will pop out the window for the respective system page. User shall click on *Energy Usage* button if he wished to enter the energy usage that is being obtained from the electric meter from a particular building. However, user shall click on *Input Device* button if he wished to add the details of electronic devices that had been used in the building. User will need to click on *View Statistics* button if he wished to view the statistics of the energy usage for analysis purpose.

"Energy Usage" page is the page where user will enter the electrical meter reading as the main input data. The data includes the last recorded data and current reading on the electric meter. In this section too, user need to select the building on which the data is being taken, followed by the year and month. When user click on *Save* button, all the input data will be recorded into the database and at the same time, first phase of mathematical computation occurs. This mathematical computation is to compute the total amount of energy usage within the selected month. Apart from that, by clicking the *Save* button too, another mathematical computation will occur. This time is to compute the amount of carbon footprints based on the computed total energy usage. Both values for total energy usage and carbon footprints will be stored inside the database, and at the same time the value will be shown at the page too. The *Clear* button is specifically for user to clear all the data fields if he wished to reenter the new data. The *Home* button meanwhile is for user to close the page and return back to "Main Page".

"Device Information Details" page is the page where user will enter the information about the device being used in the building. User will first need to start by selecting the building no, followed by entering the device details such as below:

- Serial No
- Device Name
- Device Manufacturer
- Device Power
- Device Unit
- Duration of Use
-

After entered all the above details, user will need to click on *Add* button to store the data into database. User can edit the information of device by clicking on button *Edit*. User can also delete the stored data by clicking on *Delete* button. As for *Clear* button, it is useful if user need to clear all the data fields before entering the new set of data. User can filter and view the entire stored device according to the building no, by clicking on *View* button. Click on View button will make the system to perform another mathematical formula. This computation is to calculate the total energy consumed by all devices in the building. User can click on *Home* button to close the page and return to "Main Page".

"Statistics of Usage" page is the page where all the report is being generated and display. To view the report, user will first need to select the building no, year and month to allow the correct data to be generated. All the data can be export into MS Excel file for external record keeping purpose and also for printing.

D. User Interface

Figure 4: Main Page Interface

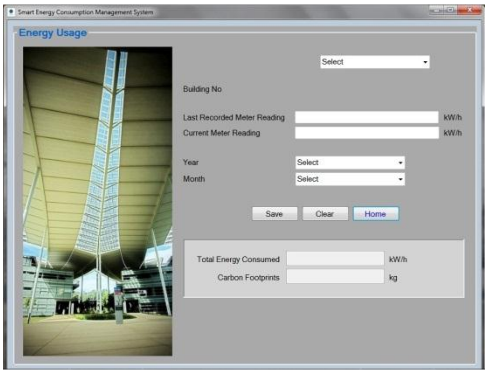

Figure 5: Energy Usage Page Interface

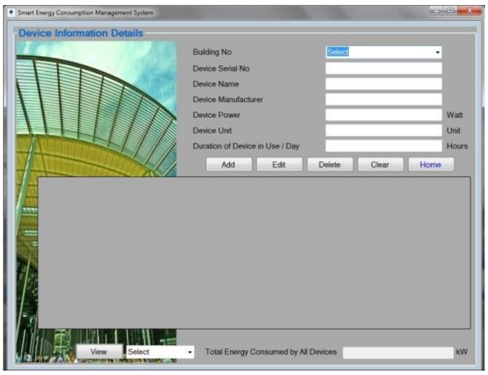

Figure 6: Device Information Page Interface

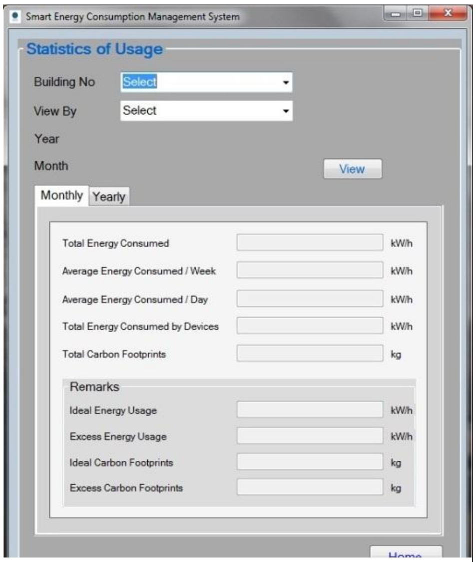

Figure 7: Statistics of Usage Page Interface

V. CONCLUSION

Smart Energy Consumption Monitoring System for UTP Academic Buildings will help in continuous monitoring process of energy usage within the academic buildings. This project does not intent to solve the over-consumption of energy as the solution of the problem may change and varies depending on how critical is the problem. This project aims to maintain its sustainability and feasibility values where it is flexible for any kind of action to be taken to solve the energy consumption problem. This project will also help UTP to comply with Government policy which urged all organization and institution to practice and promote Green IT policy and reduce the total amount of energy consumption.

This prototype of Smart Energy Consumption Management System for UTP Academic Buildings is developed as a result from the research of the project; therefore this prototype can be improved in terms of its performance and features. The prototype can be enhanced into final product that can be used anytime and anywhere. In addition, the system can also be enhanced by changing the way the data being input into the system. Apart from that, the prototype system is a standalone system in which user will not have the flexibility of using the system if it is used as a final product. Therefore, it will be better off if the system is able to develop as a web-based product and allow all users to access the system at anytime and anywhere they wished.

VI. ACKNOWLEDGEMENT

First and foremost, the writer would like to take this opportunity to express his greatest gratitude and appreciation to project supervisor, Prof. Dr. Alan Oxley, who had continuously monitored his progress throughout the duration of the project. His constructive comments, advices, and suggestions have guided the project towards its successful final outcome. This gratitude also dedicated towards Universiti Teknologi PETRONAS (UTP) especially the committee of Final Year Project of Computer Information Sciences (CIS) department for excellent organization and management of this course. Last but not least; the writer would also like to express his acknowledgement to the participant of interview, especially the management of UTP for their feedback and kind cooperation which have helped a lot in developing, improving and implementation of the system prototype.

REFERENCES

[1] Index Mundi “Malaysia Electricity Consumption” *Historical Data Graphs Per Year*, <http://www.indexmundi.com/g/g.aspx?c=my&v=81>

[2] Md. Azizul Bari, R. Ara Begum, A. Hamid Jaafar, R.D.Z Raja Zainal Abidin and J. Jacqueline Pereira, (2008) *Future Scenario of Residential Energy Consumption and CO_2 in Malaysia*, Institute for Environment and Development, Faculty of Economics and Management, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia

[3] R. Saidur (2009), *Energy Consumption, Energy Savings, and Emission Analysis in Malaysian Office Buildings*, Department of Mechanical Engineering, University of Malaya, Kuala Lumpur, Malaysia

[4] A. Khamis, A. Alamshah, A. Ahmad, A. Ab Rahman, M. Hendra Hairi, (2010) *Energy and Electricity Consumption Analysis of Malaysian Power Demand*, The 4th International Power Engineering and Optimization Conf. (PEOCO2010), Shah Alam, Malaysia, June 2010.

[5] Xavier, S. W. *Energy Audit Assesment Repot UTP, Malaysia.* Singapore: Honeywell Pte Ltd. 2008.

[6] Shaarani, S. M. Building Energy Efficiency of Chancellor Hall of University Technology PETRONAS. *Unpublished Journal*. 2009.

[7] Masjuki H.H, Jahirul M.I, Saidur R, Rahim N.A, Mekhilef S, Ping H.W, Zamaluddin M.F, *Energy and Electricity Consumption Analysis of Malaysian Industrial Sector*, Department of Mechanical Engineering and Department of Electrical Engineering, University of Malaya, Kuala Lumpur, Malaysia

[8] S.A Sulaiman, A.H Hassan (2011), *Analysis of Annual Cooling Energy Requirements for Glazed Academic Buildings*, Department of Mechanical Engineering, Universiti Teknologi PETRONAS, Tronoh, Perak, Malaysia. *Fig 1: Aerial view of the academic complex.*

[9] Wall G (2002), *Conditions and Tools in The Design of Energy Conversion and Management Systems of a Sustainable Society*, Exergy Consultant, Solhemsgatan 46, Sweden

[10] Gerber, Aurona; Van der Merwe, Alta; Alberts, Ronell; (2007), Implications of Rapid Development Methodologies, CSITEd 2007, Mauritius, November 2007

USER INTERFACE

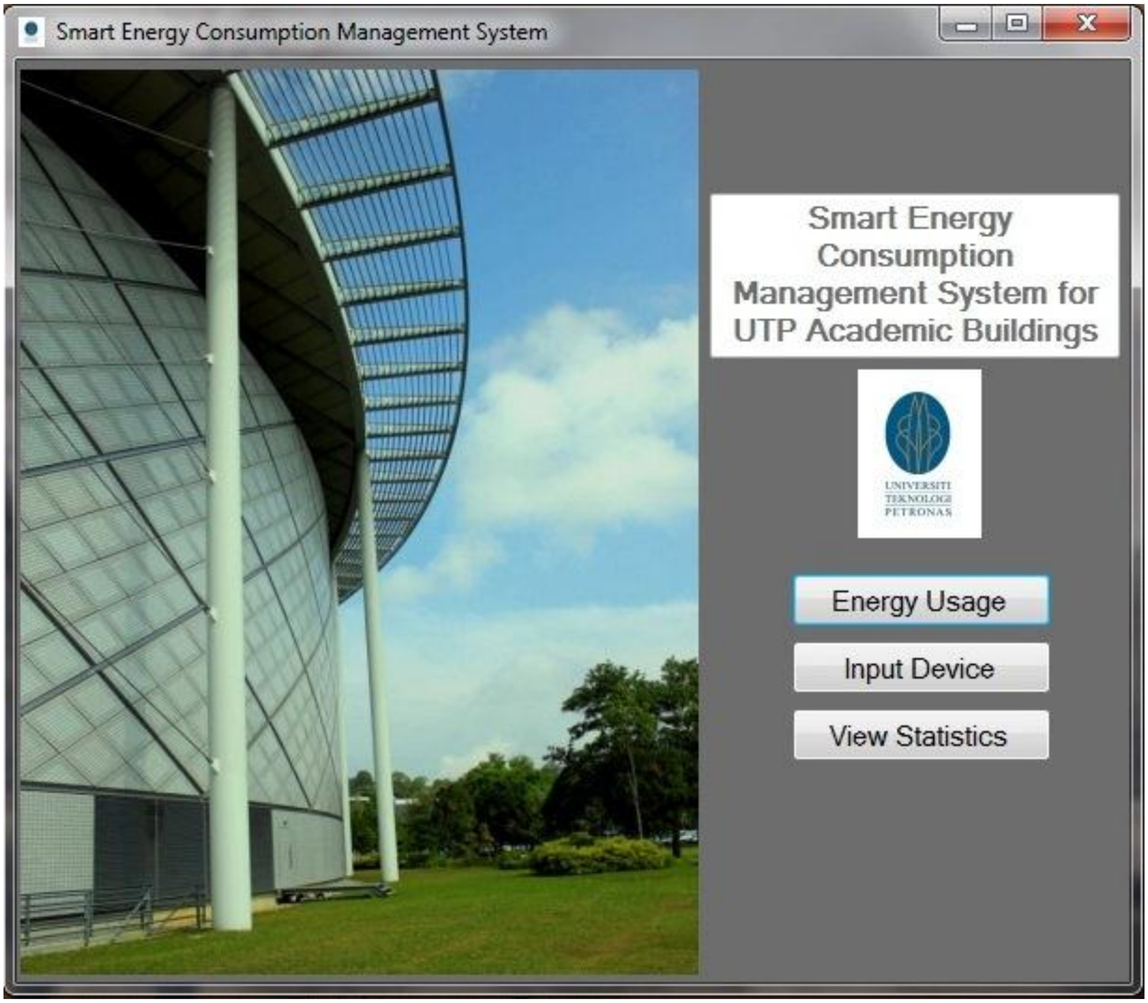

Figure 7.1: Main Page Interface

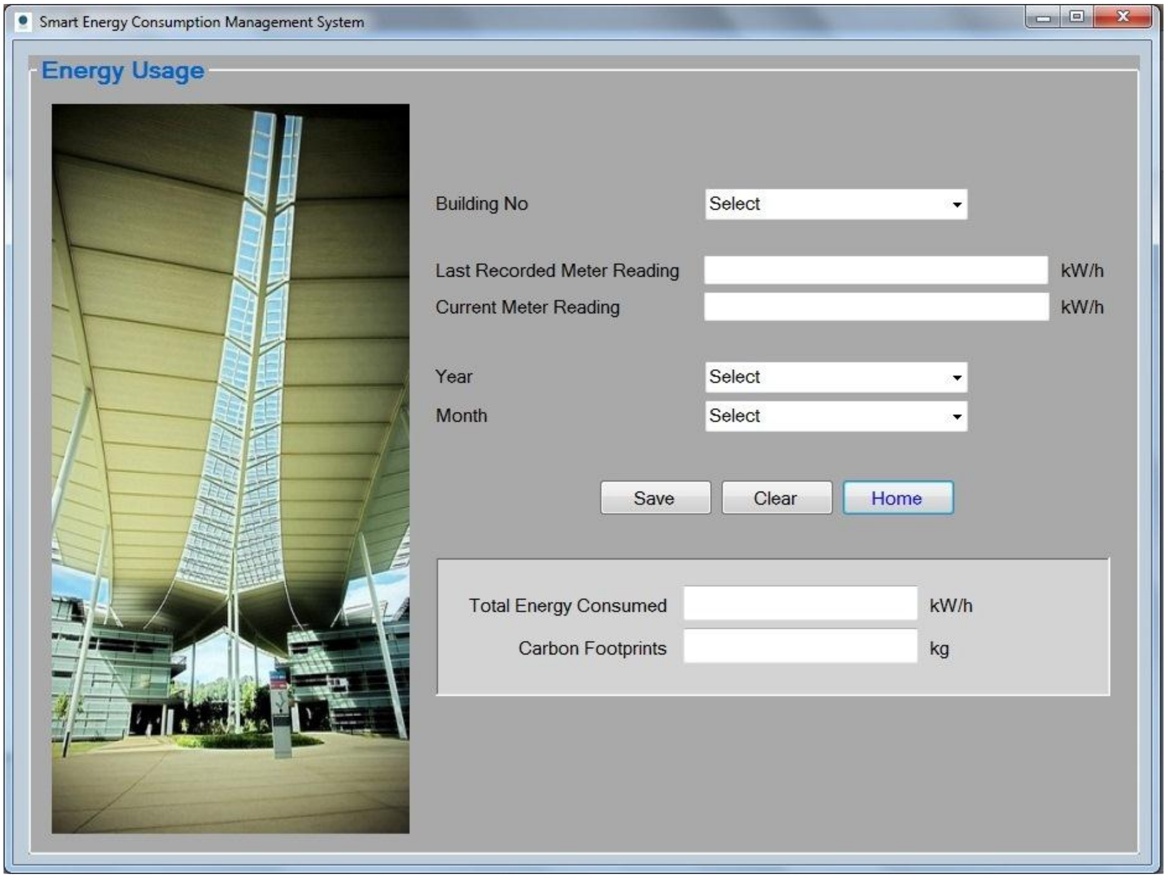

Figure 7.2: Energy Usage Interface

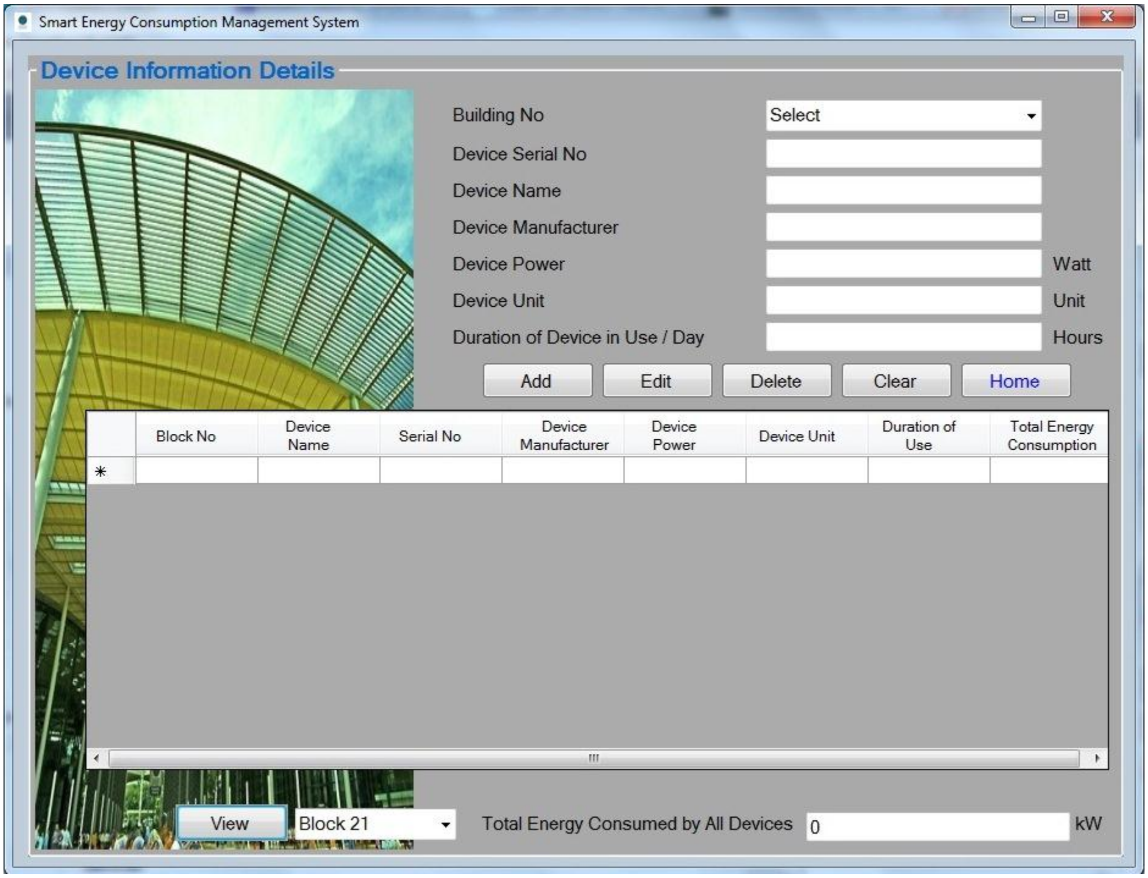

Figure 7.3: Device Information Details Interface

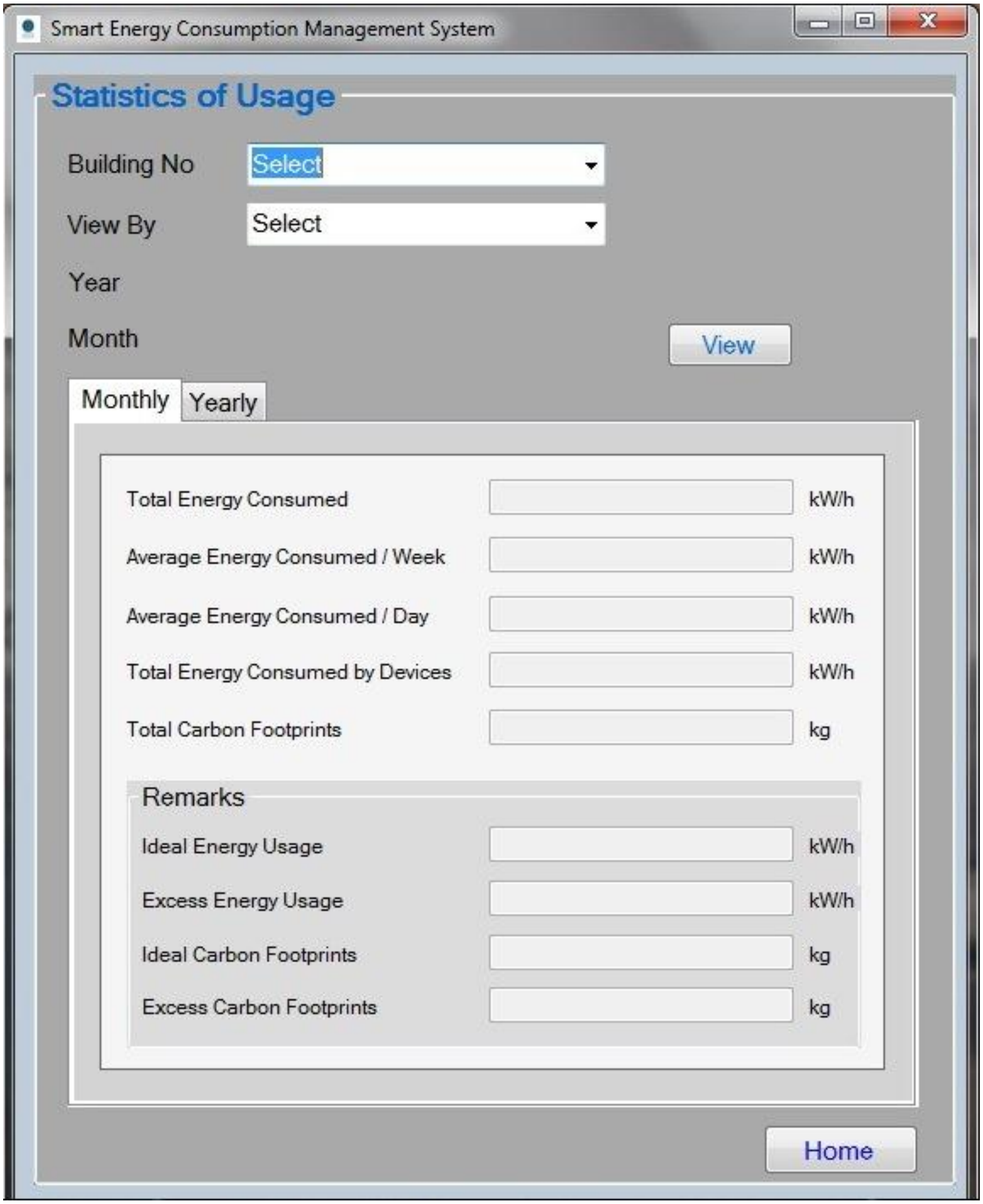

Figure 7.4: Statistics of Usage Interface

recordID	blockno	lastreading	currentreading	year_record	month_reco	energyconsmp	carbonfootp	Click to Add
19	Block 1	1988278	1998012	2012	January	9734	9149.96	
20	Block 1	2109876	2115642	2012	February	5766	5420.04	
21	Block 1	2213445	2311905	2012	March	98460	92552.4	
22	Block 1	2323449	2341905	2012	April	18456	17348.64	
23	Block 1	2343449	2365503	2012	May	22054	20730.76	
24	Block 13	6343449	6365503	2012	January	22054	20730.76	
25	Block 13	6353449	6365098	2012	February	11649	10950.06	
26	Block 13	6363889	6365628	2012	March	1739	1634.66	
27	Block 13	6373211	6380008	2012	April	6797	6389.18	
28	Block 13	6383211	6395578	2012	May	12367	11624.98	
29	Block 16	5346611	5395578	2012	January	48967	46028.98	
30	Block 16	5395578	5400973	2012	February	5395	5071.3	
31	Block 16	5400973	5411209	2012	March	10236	9621.84	
32	Block 16	5411209	5420091	2012	April	8882	8349.08	
33	Block 16	5420091	5431114	2012	May	11023	10361.62	
34	Block 21	9200786	9210081	2012	January	9295	8737.3	
35	Block 21	9210081	9226678	2012	February	16597	15601.18	
36	Block 21	9226678	9231009	2012	March	4331	4071.14	
37	Block 21	9231009	9240011	2012	April	9002	8461.88	
38	Block 21	9240011	9251245	2012	May	11234	10559.96	

Figure 7.5: Data Stored in *Energy_Usage* Database

serialno	blockno	dvcname	dvcmanufac	dvcpower	dvcunit	durationuse	totalenergy(	Click to Add
AAAKS199901	Block 1	Computer	90	Dell	250	8	180	
ABBJ117789	Block 1	Server	650	Western Digita	2	24	31.2	
QQAO091112	Block 1	Pendarflour Lig	30	Philips	300	9	81	
SML12209	Block 1	Laser Jet Printe	100	Canon	6	10	6	
XAAZ001272	Block 1	Ventilation Sys	850	York	1	12	10.2	
*								

Figure 7.6: Data Stored in Device_Inventory Database

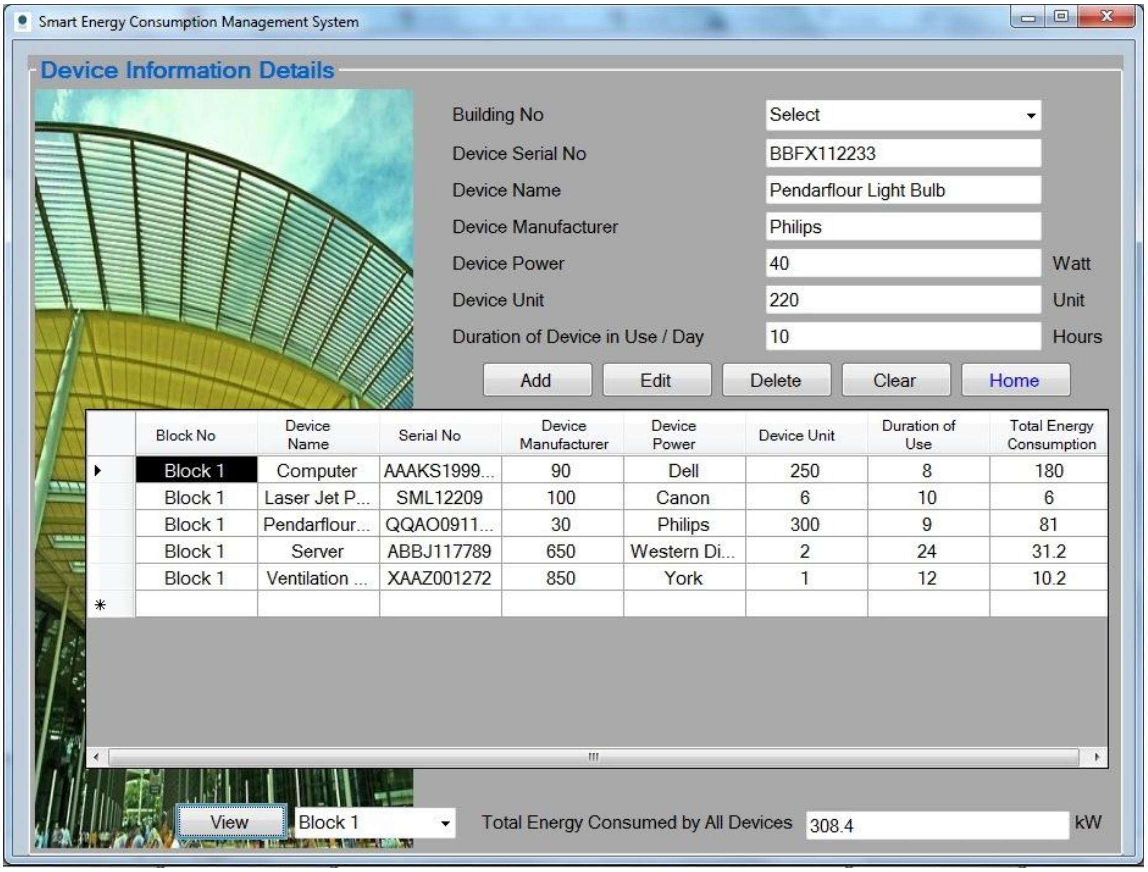

Figure 7.7: View the Device Stored in Database by filtering (Block 1)