ENERGY AUDIT ON FACULTY OF ENGINEERING AND GREEN TECHNOLOGY IN UNIVERSITI TUNKU ABDUL RAHMAN

YUN HUAN BIN

BACHELOR OF ENGINEERING (HONS.) ELECTRONIC ENGINEERING

FACULTY ENGINEERING AND GREEN TECHNOLOGY
UNIVERSITI TUNKU ABDUL RAHMAN

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

Signature	:	__________________________
Name	:	YUN HUAN BIN
ID No.	:	11 AGB 06535
Date	:	__________________________

APPROVAL FOR SUBMISSION

I certify that this project report entitled **"ENERGY AUDIT ON FACULTY OF ENGINEERING AND GREEN TECHNOLOGY (FEGT) IN UNIVERSITY TUNKU ABDUL RAHMAN (UTAR)"** was prepared by **YUN HUAN BIN** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Electronic (Hons.) of Engineering at Universiti Tunku Abdul Rahman.

Approved by,

Signature : ___________________________

Supervisor : Dr. Tan Kia Hock

Date : ___________________________

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ABSTRACT

The increase of energy demand is a concern for energy generation, many country have started marching toward of using or retrofit green technology to reduce the energy wastage, carbon footprint emission and the high costing on utility bills. In order to find out the energy consumption of the Faculty of Engineering and Green Technology (FEGT) in University Tunku Abdul Rahman (UTAR) and found a way to conserve wastage energy usage the best method is energy audit throughout FEGT building. In this paper energy audit will be carried out to collect or measure the types of electrical appliances, number of lightings, test equipment's and work load of the HVAC. Beside the numbers and condition of the electrical appliances that cause the energy consumption and energy efficiency usage, awareness of human's behaviour, occupancy of each room are also factors that cause the unwanted energy waste. The collected data and survey on energy audit will be further analyses to calculate and come up with solution to reduce the unwanted energy consumption. Methods of retrofit project and payback period may calculate accordingly to provide immediate and relatively predictable positive cash flow.

Keywords: Energy audit, energy efficiency, reduce waste energy consumption, data collection.

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LIST OF SYMBOLS, ABBREVIATIONS AND UNIT CONVERSION

%	Percent
A	Ampere, current SI unit
BTU	British thermal SI unit
C^a	Capacity of equipment (kW)
ft	Feet , distance SI unit
hr, h	Hour, time SI unit
Hz	Hertz frequency SI unit
k	Kilo, weight SI unit
LUX	Illuminance unit, one lumen per square meter
M	Mass flow rate, kg/s
m	Meter, distance SI unit
m^2	Area size, Meter squared
°C	Temperature, Celsius
Pa	Pressure, kPa
RT	Refrigerant Tonne
s	Second, time SI unit
Tonne	Weight unit equivalent 1000kg
V	Voltage SI unit
VA	Apparent power for alternating current source
W	Watt, demand power/ power
Wh	Watt-hour, energy SI unit

5S	Seiri (sort), Seiton (Set in order), Seiso (Shine), Seiketsu (Standardize) and Shitsuke (Sustain)
AC	Air Conditioning
AC	Alternating Current
AEC	Annual Energy Consumption of Equipment (MWh)
AHU	Air Handling Unit
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineering.
BIM	Building Information Modelling
CAV	Constant Air Volume
CFD	Computing Fluid Dynamic
CFL	Compact Fluorescent Lamp
EMO	Energy Management Opportunities
FEGT	Faculty of Engineering and Green Technology
FCU	Fan Coil Unit
FICT	Faculty of Information Communication and Technology
HPSV	High Pressure Sodium Vapour
HVAC	Heat, Ventilation, Air-Conditioning
LED	Light Emitting Diode
NASA	National Aeronautics and Space Administration
MEP	Mechanical, Electrical and Plumbing
OKU	Orang Kurang Upaya
RM	Ringgit Malaysia
TNB	Tenaga National Berhad
UTAR	Universiti Tunku Abdul Rahman
USA	United State of America
UH	Yearly Usage Hours of Equipment
UV	Ultraviolet
VAV	Variable-Air-Volume

1 k	= 1,000
1 M	= 1,000,000
1 W	= 3.4121402 BTU/h
1 hp	= 2540 BTU/h
1 RT	= 12000 BTU/h
1 Tonne	= 12000 Btu/h 3.517 kW
1 m^2	= 10.7639 ft^2
1 m	= 3.28084 ft
1 BTU/h	= 0.29307107 W

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Energy audit is a process of Energy Management Opportunities (EMO) where it involved many step and certain amount of time to achieve it. Every industries, Schools, office, household, hospitals etc. are all totally dependent on electricity (Rathod, D. et al., 2013). According to Krarti, M. (2000) the buildings from worldwide are responsible for over 40 percent of energy being use and related to greenhouse emission. The term “energy audit” is widely used by all over the country and have different meanings depends on the energy service company or auditors .Generally there are four types of energy audits can be distinguished as walk-through audit, utility cost analysis, standard energy audit and detailed energy audit.

An energy audit process is inspection, survey and analysis of energy flow in an industry, increase the efficiency amount of energy enter the system without much lost from the output. Energy audit is a testing and analysis of how the energy being used in the building (Singh. M, et al., 2012).

Since most of the country are very concern on energy saving, move toward green society and hire profession energy audit engineer to reduce their energy consumption or electrical bill in their building, but hiring a real profession energy audit engineer do not come with a cheap price and somehow inexperience energy audit engineer get hire which conduct poor quality energy audit can result in decrease energy savings, higher installation cost, and squandered opportunities (Avina, J. and Reshat, E. 2012)

1.2 Problem Statements

For the past few years NASA has been sending satellite probe to explore Mars and other possible planet that can sustaining human population and finding resources for development. Many scientist and geologist have declare that resources at our planet earth is in depletion process.

Is this problem have related to the energy? Well there are few factors that are related to the depletion of earth resources. Trees, Coal, Fossil Fuel, and Uranium etc. are earth resources that used to process generation of electricity for household, factories, and offices and so on.

Energy are our daily life needs, but this energy is for the use of electrical appliances that make our life easier and it come with a cost. Many people using it without concern of its effect, switching on the light, switching on Air-conditioning but unoccupied, it is waste of energy usage and causing more resources used to generate electricity.

From this project it allows me to understand more on how to reduce the unnecessary used of energy, for future construction needs, and as well may find out alternative way of sustainable energy generation.

1.3 Aims and Objectives

The objectives of the thesis are shown as following:

i) To improve energy efficiency of buildings.
ii) To reduce waste in energy use and to comply with the specifications of some regulations and standards
iii) To meet future energy efficiency construction standards.

CHAPTER 2

LITERATURE REVIEW

2.1 Energy Auditing Methods

There are several types of energy management opportunities (EMO) being implement by energy auditors or energy conservation agency, according (Malkiat Singh, 2012) a good audit orientation could provide positive results in reduction of energy billing, they have come up with energy audit that performed depends on the function and types of the building, three types of energy audit flow are preliminary energy audit, general energy audit and detailed energy audit. On the other hand (Sanjay Kumar, 2013) suggests four effective energy audit steps process listed at below.

-step1: identify all the opportunities
-step2: prioritize the activities rationally
-step3: accomplish the activities successfully
-step4: maintain the activities throughout the life of the facility

Figure 2.1 clarifies much detail of how to conduct energy audit in the flow chart.

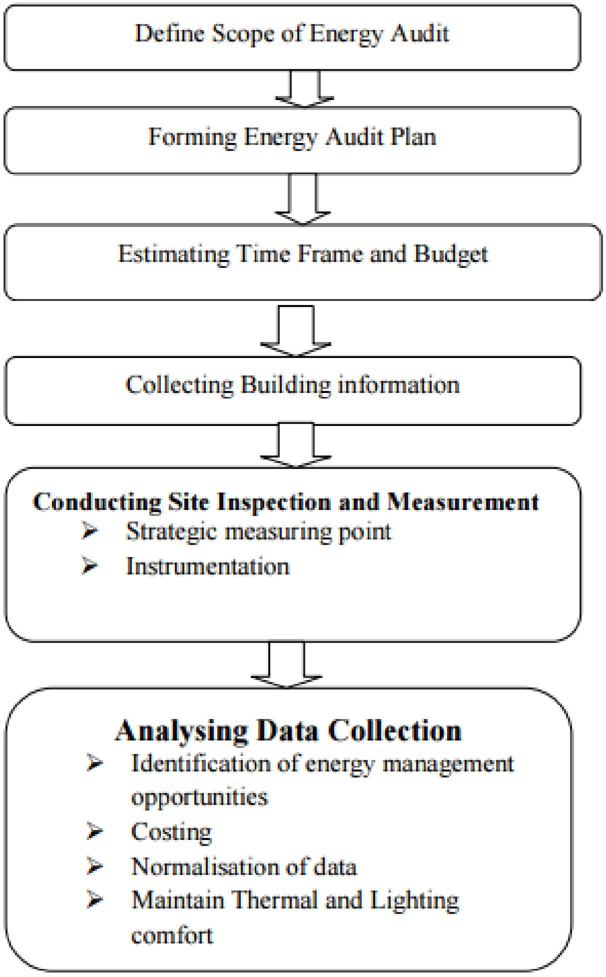

Figure 2.1: Energy audit Flow Chart

Shashank Shrivastava, (2013) performs detailed energy audit in three phase term, phase 1-pre audit, phase 2-audit phase, phase 3-post audit phase. Their process flow chart consist six steps that are contain within the detailed energy audit. Step 1 is to understand the planning and resources available and time to conduction the audit, step 2 is to start a meeting with the officers, step 3 is to collect data like electric bill and plan data, step 4 is to collect portable instrument, step 5 is to perform calculation of the data collected and prepare recommendation of how to reduce the energy usage, last step is to flow up the methodology and technical advice.

2.2 Data Collections

The calculation on the data collected and interpretation can vary as it needs to base on how much the energy auditors focus on, (WSU, 2003) had prepared energy efficiency measure guideline in a list for public agencies to follow the process. Inside the list contain envelop, lighting, HVAC, water heating, power system, refrigeration and miscellaneous equipment to look up for improved energy efficiency.

(Tang, 2012) had conduct data analysis and electricity consumption breakdown in Figure 2.2, and stated that air-conditions are always the biggest electric consumption that consume 50 percent of the electricity in the campus. The author also break down the types of lighting in that campus, the different energy consumption is list out in Table 2.1.

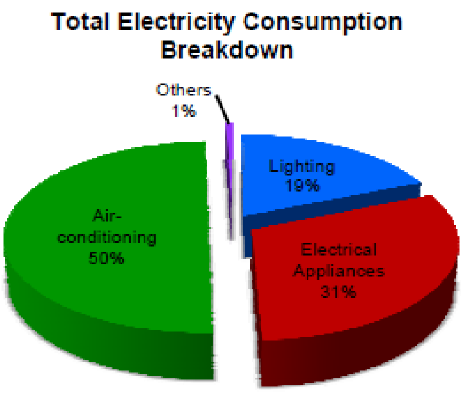

Figure 2.2: Pie chart of Total Electricity Consumption Breakdown (Tang, 2012)

Table 2.1: Energy Consumption of Different Lighting Types (Tang, 2012)

ENERGY CONSUMPTION OF DIFFERENT LIGHTING TYPES

Types of Lighting	Unit power (W)	Number of units	Total (kWh)
Fluorescent	36	2492	89.71
Stick bulb	65	834	54.21
Spiral bulb	20	439	8.78
Spotlight	50	76	3.80
Globe bulb	250	189	47.25

Lastly the author also compared the different factors and analysis on the size of the building, ambient temperature, the relationship between the number computers with the total electric consumption in a week, Figure 2.3 show the comparison of total consumption vs temperature that calculated by the author. This author's method is similar with the Bin method that was proposed by (Knebel, D.E., 1983) where it compared the weather condition with relationship to the energy consumption in the building.

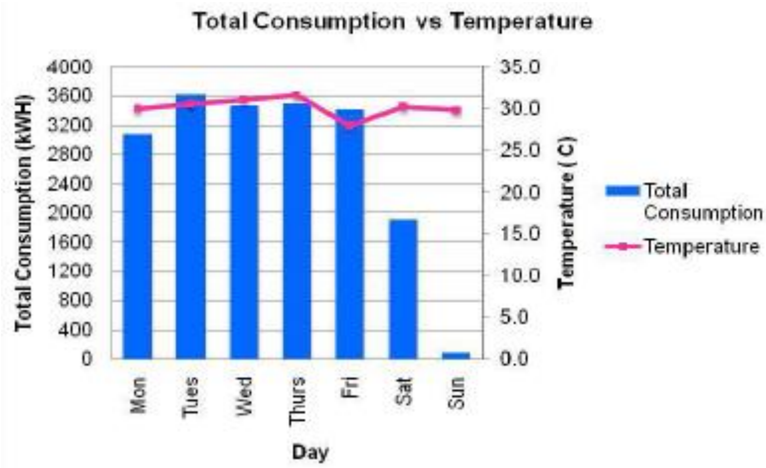

Figure 2.3: Total Consumption VS Temperature (Knebel, D.E., 1983)

(Masjuki, 2008) and (Aiman Roslizar, 2014) using the same calculation on energy intensity, compiled all the data collected from electrical appliances and estimated the energy intensity using following equation:

$AEC^a = UH^y \times C^a \times 0.001$

Where:

AEC^a - Annual energy consumption of equipment (MWh)

UH^y - Yearly usage hours of equipment

C^a - Capacity of equipment (kW)

0.001 - a factor to convert kWh to MWh

Total Energy Intensity (EI) in kWh/m^2 equation:

$$EI = \frac{\sum_i^n AEC}{TFA},$$

where:

$\sum_i^n AEC$ -Sum of energy consumption of equipments

TFA-Total floor area (m^2)

From (Masjuki, 2008) research they also found the energy intensity compared with other countries , it showed that the Malaysia building are more efficient in energy usage compared to develop country such as Japan, Shanghai, USA, and even Thailand.

2.2.1 Lighting Data Collection

In the publication, (Project(NEED), (2014-2015)) stated that the ballast type like electromagnetic type and electronic type can be identified by using flicker checker, the magnetic ballast function follows the AC input phase if the input frequency is 60Hz and the magnetic ballast will also produce 60Hz, it will create flickering effect 60 times per second. As for electronic ballast switching creates 10000Hz-20000Hz it won't create flickering effect and have better energy efficiency compare to magnetic ballast. Figure 2.4 shows the different view if use a magnetic or an electronic ballast using flicker checker.

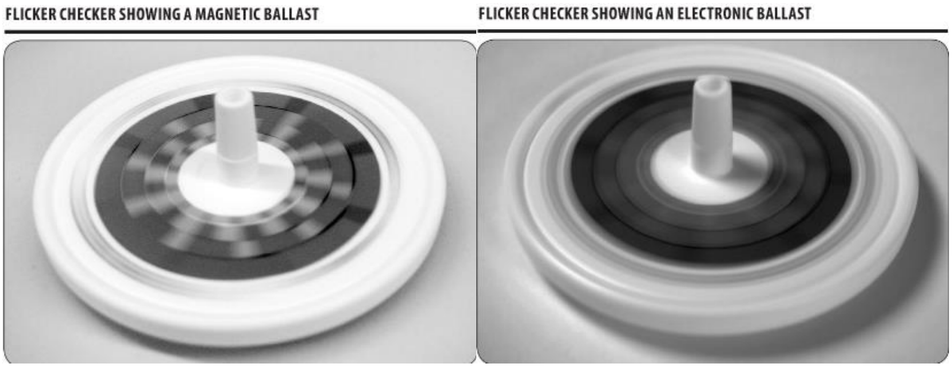

Figure 2.4: Flicker Checker left (magnetic ballast) right (electronic ballast) (Project(NEED), 2014-2015)

2.2.2 HVAC (Heat, Ventilation, Air-Conditioning)

The energy used in the United State for operating HVAC system consumes 30 percent of the total electric energy use in typical commercial building (EIA, 2006). According to (Krarti, 2000) variable-air-volume (VAV) systems types HVAC are more efficiency then the Constant Air volume (CAV) type HVAC, as variable-air-volume system only operates when needed and for instance it can turn off during unoccupied periods.

The HVAC not just uses energy to generate heat and cool but they still have parasitic energy use in the HVAC systems. Supply & return fans, condenser water pumps, chilled water pumps, cooling tower fans condenser fans etc. are the parasitic energy consumption in the HVAC system (Detlef Westphalen, 1999). It contributes total 1.5 Quads of energy being used and its break down chart is in Figure 2.5, where one quad is equivalent to 10^5 BTU.

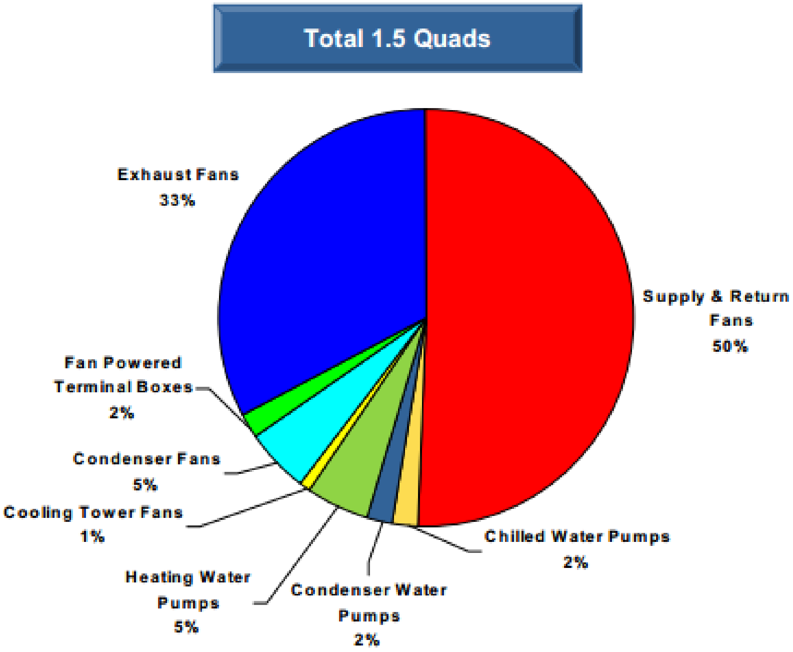

Figure 2.5: Pie Chart of various equipment energy used in HVAC

2.3 Energy Conservation Strategy

Lighting is the easiest strategy to conserve energy compared to building envelope and HVAC retrofit. (Malkiat Singh, 2012) had conducted comparison calculation between types of lighting energy consumption, and payback period. In their comparison the fluorescent tubes using conventional electromagnetic tubes and chokes replaced with electronic chocks can get payback in eight months, the halogen lamps replaced with metal halide lamps can get payback in just 4 months, they even showed that the conventional indicating lamps replaced with LED had shown much promising result on using less energy. Figure 2.6 showed the energy comparison of florescent tube using electromagnetic chokes vs electronic chokes and Figure 2.7 showed conventional indicating lamps vs LED.

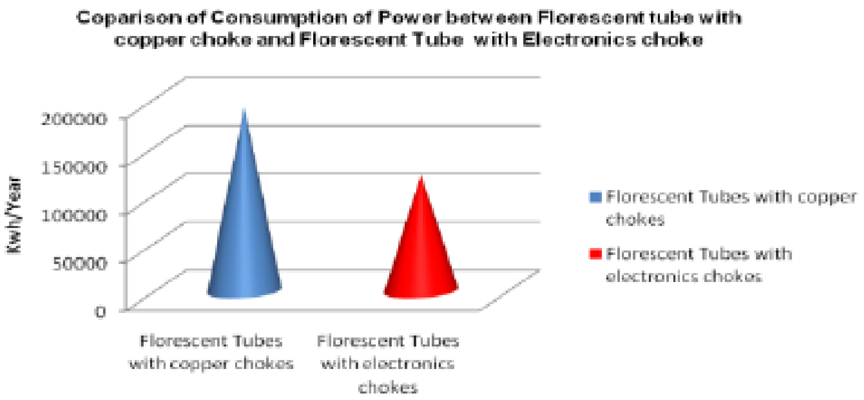

Figure 2.6: Comparison of Florescent tube using magnetic with electronic ballast

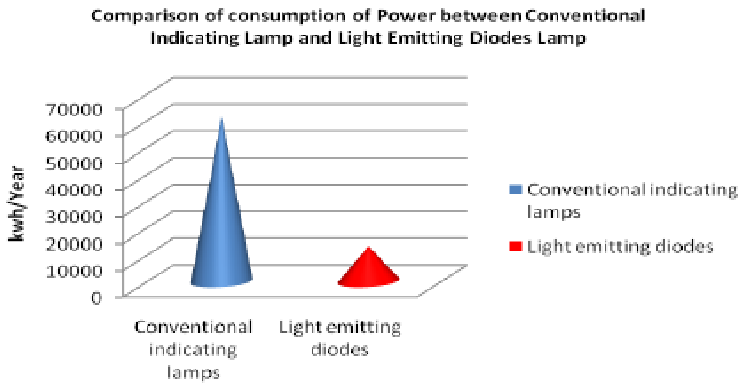

Figure 2.7: Comparison of indicating lamps with LED lamps

(Ng, S.Y. et al., 2010) proposed two approach of energy conservation in structural and non- structural. Structural is based on the technological part like all the retrofit of the equipment, and non-structural is the human behaviour that can't be "retrofit" but only can create an awareness through education on improvement in energy efficient. The behavioural, attitudes, knowledge, awareness, and skills of human being can be tremendously helpful in energy efficiency (Vesma 2002).

2.4 literature Review Conclusion

Every energy audit project has the same objectives which are reduced utility cost, innovation into green environment etc. The process of conduct energy audit are most similar in some way but there’s still has limitation due to structure auditor could conduct energy auditing whether it is a household building or an industrial building. The process of preliminary audit, general audit and post audit are most commonly used method.

As for the data arrangement and calculation each of the auditors has their own software skill to arrange the data collected, how detail is the data collected, and sophistication of the building design may limit the auditing process. The calculation for each individual equipment energy consumption are also different, each person have their range of accuracy or knowledge to perform calculation.

Most energy auditor didn’t take the opportunities to conduct building envelop analysis that will affect the energy consumption, majority are focus on the lighting, equipment and HVAC system used on the building that consume most energy. The energy audit standard aren’t being follow, the member of ASHRAE Ian Shapiro (2011) stated that if followed standard procedure provided by ASHRAE.org the common problem like monthly energy analysis, benchmarking, safeguard against overestimating saving, installed cost estimates, the expected life of the new equipment propose etc. will not be left out in the analysis and calculation.

CHAPTER 3

METHODOLOGY

3.1 Energy Audit Flow Chart

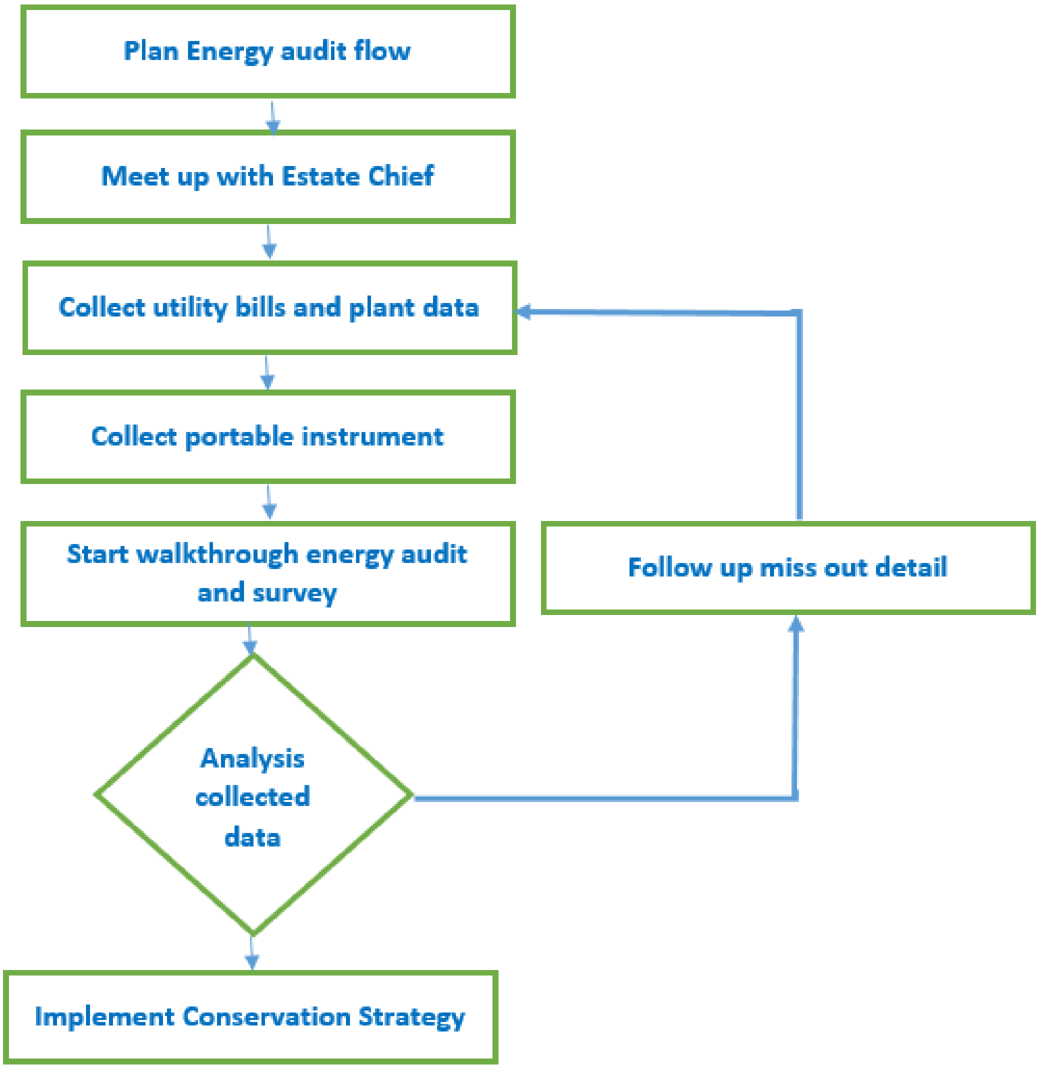

Figure 3.1: Energy audit flow chart

3.2 Gantt chart

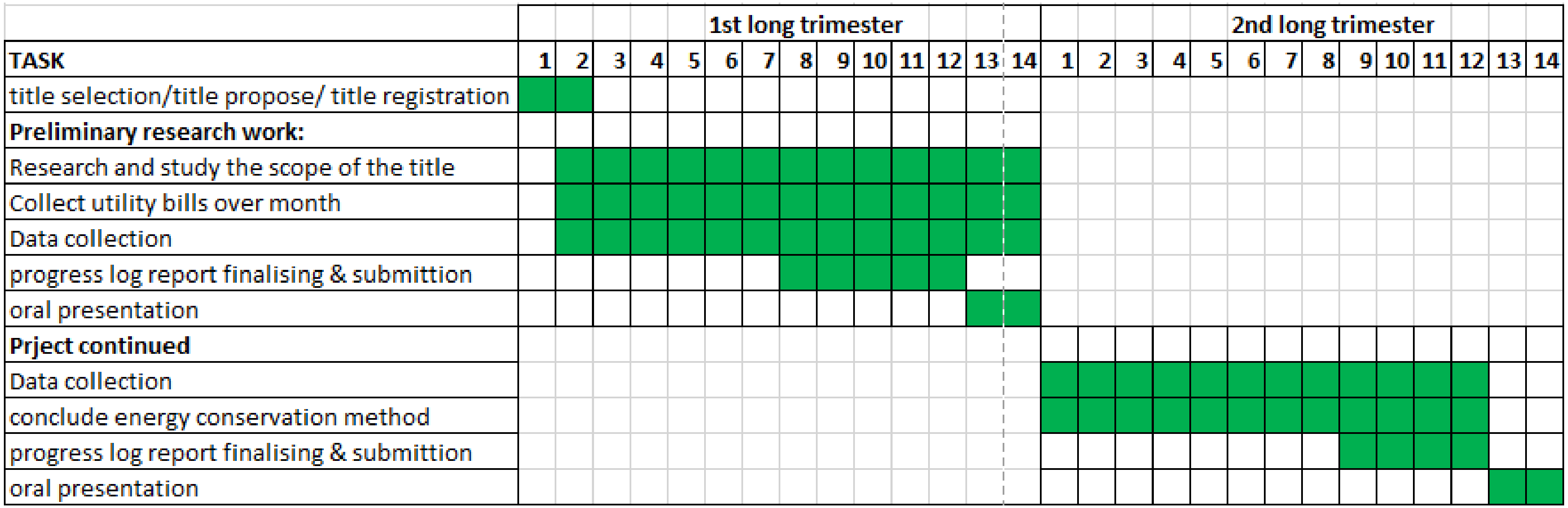

Figure 3.2: Gantt chart

3.3 Energy Audit

There are many way of doing energy auditing. Size of the building like industrial, shopping malls, schools and household etc. are different and so thus the complexity of interior design of the building. Campus building energy audit will be using method similar to industrial audit type but there are no heater or production machine calculation in my project. Majority of energy audit has been done by western country and their seasonal condition is different from our hot tropical climate. Some of the published energy audit calculation are not suitable for use such as heat return in the HVAC system, heat recycling, water boiler, and etc.

The energy audit should be in a team of minimum 2 persons for household audit, for large scale building like school building minimum should consist 4-5 persons to conduct energy audit due to safety concern such as contact with high voltage machine, and the size of the building. Average energy audit period minimum would take one year to complete, since I'm student from Electronic Engineering course we are only allow to have individual project, during duration, my project there will be time constrain and incomplete project research due to one man army. I had to request for some assistance or friends accompany me during walkthrough project research which is hazardous involving safety issue.

3.4 Selecting Measuring Tools

Measurement tools designed to collects data for the task may cost for specific measurement up to RM10, 000.00+. Before conduct of audit project, a full building survey or walkthrough survey to observe what kind of tool is required to collect data is necessary to assess the cost before actual energy audit.

Prepare check list of every measuring tools that have been borrowed and bought. Research the method and instruction of how to use each equipment, calibration are also require to be done to make sure of the accuracy of measurement. The list of the equipments utilized in the project can be seen in **Appendix A**.

Tools selected are portable type so it can be carried around, and the list of the tools need to borrow or purchase are clamp-on amp meters, laser distance measurement sensor, torch light, LUX meter, anemometer, room thermometer, modified split extension cords to measure the amps of the equipment as the equipment can't be disassemble to measure the amps flow through. The energy audit in phases will be preliminary audit and half detail audit due to some equipment are too expensive to buy, like blow door test will cost 2000+ in US dollar. Some measurement data will be extracted from the standard calculation that have been performed by the previous estate technician in UTAR; the example is shown in Figure 3.3.

Room No	Lab	DB	Equipment	Quantity	Phase	kW/unit	Circuit Number
E002A	Microprocessor Lab	DBG-PTL-A	Split Unit A/C (York)	3	1ø	3.4	2R,2B,1Y
		DBG-PTL1 (AC)	CPU + Monitor	17	3ø	0.12	1B
			Analog Osiloscope Set	16	3ø	0.035	4R,4Y,4B
			DC Power	16	3ø	0.025	5R,5Y,5B
			Digital Multimeter	16	3ø	0.02	3R,3Y,3B
			Function Generator	16	3ø	0.01	5R,5Y,5B
			Solder Device	1	[illegible]	0.03	2Y

Figure 3.3: Table of equipments energy consumption list in the lab

3.4.1 Laser Distance Measurement Meter

The laser distance measurement mostly is used for construction purpose, as for energy audit purpose the area of the room are required to measure, this meter affords measurement of length, width and the high of the room in very fast, convenient and very accurate way than a conventional measurement tape that required a lot of time and dangerous. The operation of this meter is very simple and come along with instruction manual.

Figure 3.4: Laser measurement meter

The purpose for this meter is to collect the room space or the area size of the room in meter square in order to calculate the BTU required for particular room, the calculation for the BTU is shown at bottom. The meter only measure in unit m where the conversion of meter to feet are required.

Meter square to square feet = m^2 x 10.764

1 Tonne = 1000kg

(width (feet) x length (feet))/1000kg = tonne required in that room

1 Tonne = 12000 BTU

Tonne required in that room x 12000 BTU = BTU/h required in that room

3.4.2 Anemometer

Anemometer is used to measure the wind speed and temperature of the wind, in energy audit this meter is used to measure the wind speed and temperature of air flow come out from the duct system outlet. After all data collected plotted in the floor plan, then air flow pattern can be analysed to see the abnormally portion in the duct system.

Figure 3.5: Anemometer

3.4.3 LUX Meter

LUX meter is used to measure the level of luminous or the intensity of the light that distributes from the light source. Each type of the lighting have its own power consumption and intensity. In order to find the energy efficiency of the light source, the LUX meter is needed.

Figure 3.6: LUX meter

The method to use the meter is to put it on the table height and step away few step to measure the LUX under the light source as the sensor is very sensitive to light source. There are many category of light intensity level in different types of room space or location, Figure 3.7 shows the recommended LUX level in specific room.

Building Space	Recommended Lux Level	Building Space	Recommended Lux Level
Board Room	240	Museum or Gallery	80
Car Park	40	Office	320
Church Hall or Auditorium	240	Plant Room	80
Entry Lobby	160	Public Toilet	80
Kitchen & Food Prep	240	Restaurant or Cafe	160
Laboratory	400	Retail Space	400
Library - General	240	School General Area	240
Library - Reading Room	320	Storage Areas	160

Figure 3.7: LUX level table list in different room space (Brett, 2013)

3.4.4 AC Clamp or Digital Multimeter

To measure the machine or appliances power consumption AC clamp meter can be used to measure the current supply when the appliance is operating. The clamp need to be clamped on split extension cords shown in Figure 3.9. The meter needs to clamp on either life wire or neutral wire to measure the current flow. If clamp on both wire the current will cancel out each other as the current going in and out at same value it will get zero on reading. After obtaining the current reading, it is multiply with the voltage supply, normally is 240V but for the HVAC system the voltage is 415V.

Figure 3.8: AC clamp and digital multimeter

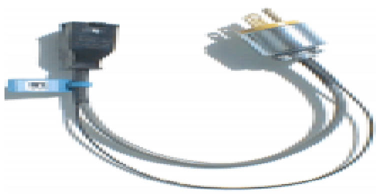

Figure 3.9: Split extension cord

Beside it can measure the power consumption the meter can be used as a thermometer using thermocouple probe provide with the model to measure room temperature.

3.4.5 Thermal Camera

To capture the thermal conduction of the building envelope the thermal camera is used to visually inspect on wall, windows, doors and ceiling. The wall thermal conduction is measured from indoor and outdoor to find the temperature different to see how well the insulation is. Besides that it can visualize the location where the cool air leaks. It is important to inspect the cool air leaks because cool air leaks means energy leaks out from the building, and the hot air entering into cool air region and when that happens the cooling unit needs to spend more energy to cool down the room temperature.

Figure 3.10: Thermal Camera

The thermal camera that I borrowed requires extension cable to power up the device as the internal battery is spoiled and can't be recharged, as a result, the memory storage is unable to store any captured picture, It needs mobile camera to capture the picture.

3.4.6 Whirling Hygrometer

Figure 3.11: Whirling hygrometer

The whirling hygrometer is used to measure the humidity in the room area. The higher the humdity percentage the better the temperature conduction, but it also can cause condensation on the window and health issue.

When using the whirling hygrometer the resevoir needs to fill up water, after that holds the handle and swing about 20-30 second. The top thermometer is to measure the dry temperature and bottom thermometer is to measure the wet temperature. The difference of the dry temperature minus the wet temperature is then used to find the percentage of humidity in the chart shown in **Appendix B**.

3.5 Walkthrough Audit

The walkthrough auditing is a most common step, walk around the FEGT building inspect, and survey the equipment available for each floor. The specification of the equipment energy or power usage and other detail like manufacturing company and the condition like filter, the life span, the output condition and etc. will be inspect and recorded. Some question will be asked for the person in charge for particular room, question like the occupancy period, period for the equipment being used, condition of the equipment, how often the equipment get maintenance and etc.

3.5.1 Steps

There are steps to follow so that the progress can proceed faster, as a student the time schedule of having class will crash with staff or lecturer free time schedule, when you are free doesn't mean the room is ready for you to do auditing.

Step 1: Understand the building structure information, get floor plan like in Appendix I, get key to unlock unoccupied room, try to get utility bill, 1-3 year energy consumption data.

Step 2: Prepare a good documentation to store various types of data as it can ease of access and do correction.

Step 3: Collect all portable tools together, as you will need to go from room to room measuring and collecting information. It will save time to go back and forward to find another tool to collect information

Step 4: Arrange the sequence of the tools use, which should be used to collect data first and which tools should use last to save the time of waiting some tools that no need operator to operate to collect data, For example like sequence of temperature probe, measure equipment's current supply, measure size of room, humidity, measure wind speed and temperature from air vent, thermal camera and lastly take a full panorama picture on the room like in Figure 3.12 so that it can view back what have miss out during the audit.

Step 5: prepare several sheets of floor plan layout of each floor and mark down different appliances, lighting types etc in different highlight color.

Figure 3.12: Panorama picture of a room

Average time to conduct energy audit in a room would took about 30 – 50 minutes depends on room size for one person, even with some assistance of one more person it would take 30 – 45 minutes, thus it is very time consuming during the process.

3.6 Data Collection and Arrangement

Annual utility bill, building layout plan indicating the size of the building, the HVAC duct system plan, and weather condition plan of Kampar area will be collected to compare the energy consumption pattern with the temperature difference. The energy calculation unit is kWh = kW x hours, as the utility bill is not only FEGT building but the whole campus of UTAR it will be slightly difficult to get accurate data to compare.

All those data collect will be store in an excel file to process the information, it is the best way using custom made list in excel file to store the data collect as there are many rooms in FEGT building, transfer to mobile device like phone or tablet to collect data when walkthrough audit process.

All the equipment has its name plate, manufacturing company, specification on the equipment and etc. will be recorded down, some of this information can be used in finding cost and energy retrofit comparison calculation and as well for the installation fees calculation.

The envelope of the building will be audited as well, as the insulation from different type of building material may affect the enthalpy process. Insulation like concrete wall, plaster wall, plaster ceiling, window glazing, and door material have different thermal penetration level. Windows and doors seal tight condition, this will affect the air-conditioning air leaking and causing more work load for the cooling unit if the windows or doors are not proper sealed.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 FEGT Building Detail

According to the information from the technician of estate department the whole university is supplied by TNB through two supply lines, each of the incoming supply line is rated 33kV with 25MVA that is apparent power for AC source. The utility bill is total energy consumption at UTAR and have no individual block utility bill. Therefore it will be difficult to compare the calculated result by block. But we are able to obtain only one whole year individual block energy consumption data shown in Table 4.1 whereby the energy management committee from UTAR that started monitoring before 2014. Beforehand UTAR has no activity on data log of individual building energy consumption.

Table 4.1: Energy Consumption at FEGT year 2014

Month	Consumption (KWH)	Built-up area (sq ft)	kwh/sq ft
January	82,353	144,216	0.57
February	122,637	144,216	0.85
March	140,227	144,216	0.97
April	106,839	144,216	0.74
May	108,302	144,216	0.75
June	131,087	144,216	0.91
July	139,644	144,216	0.97
August	139,364	144,216	0.97
September	81,185	144,216	0.56
October	112,815	144,216	0.78
November	141,020	144,216	0.98
December	94,356	144,216	0.65

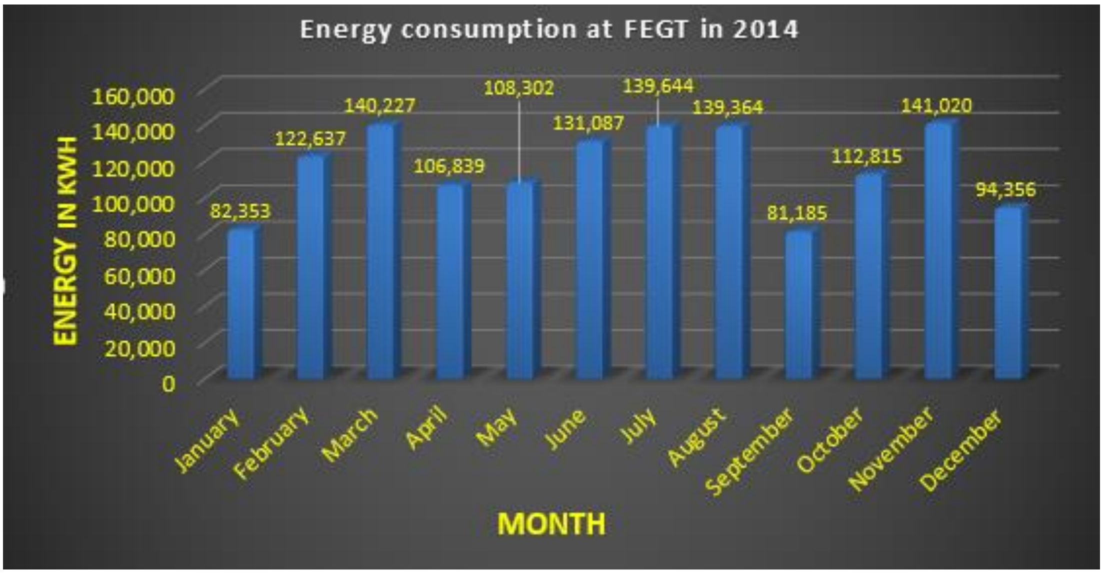

Figure 4.1: Graph of energy consumption at FEGT year 2014

UTAR utility billing is commercial category and tariff code is Tariff C1-Medium Voltage General Commercial Tariff: 034. The tariff calculation required kilowatt of maximum demand per month add with total consumption kWh per month. The calculation can be perform on http://www.tnb.com.my/residential/billing/bill-calculator.html web site , demand of the energy usage is calculated by how many total equipment's need power supply, the formula is shown at below:

-For each kilowatt of maximum demand per month: (kW * 30.30)

-For all kWh per month: (kWh * 36.50)/100

Where :

kW	= Maximum demand , 1 kW per month	= RM30.30
kWh	= Total consumption , 1 kWh per month	= RM36.50

Note* GST 6% that effective on 1 April 2015 will be calculate and add in the total amount and ICPT (Imbalance Cost Pass-Through) will be discounted every 6 month

4.2 Lighting

At UTAR FEGT building there are many lighting types being used, and there are three major types of lighting; Compact Fluorescent Light (CFL), Tube Fluorescent Light, and High Pressure Sodium Vapour Lamp. Each of this lighting have different energy consumption rate and also have different operation hour. The efficiency of each lighting is calculate in lm/Watt, the highest the number means the better efficiency of the lighting.

4.2.1 Compact Fluorescent Light (CFL)

For CFL there are also many different manufacture model being used and each has different operating life time, lumen, power rating and efficiency. For hallway and room lighting the 18 Watt CFL is commonly used but there are 3 manufacturers with different shape and life time but the efficiency and the socket type is the same. These 3 types of CFL is standardized as same type in my floor plan marking.

Table 4.2: List of Different CFL Models and Operating Specifications

Compact fluorescent light (CLF)

Manufacture	Model	Color	Life(hour)	Lumen(lm)	Power(watt)	lm/Watt
1)Philips	Master PL-C	White	10000	1200	18	66.67
2)Osram	Dulux D	White	10000	1200	18	66.67
3)Sylvania	CF-D	White	15000		18	0.00
4)Osram	Dulux T/E Plus	White	20000	3200	42	76.19
5)Sylvania	Minilynx-T Long life	Warm White	10000	900	15	60.00
6)Osram	DuluxStar Compact	Warm White	6000	600	11	54.55
7)Philips	Tornado	Warm White	8000	740	12	61.67

The shape and type of pin head of CFL can be seen from Figure 4.2 until Figure 4.8, whereas Figure 4.9 and Figure 4.10 is type of wall light fixture. In Table 4.2 the highest efficiency is Dulux T/E Plus but it is not suitable for use cause of the higher energy consumption.

Figure 4.2: Master PL-C

Figure 4.3: Dulux D

Figure 4.4: CF-D

Figure 4.5: Dulux T/E Plus

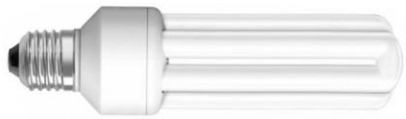

Figure 4.6: Minilynx-T Long life

Figure 4.7: Dulux Star Compact

Figure 4.8: Tornado

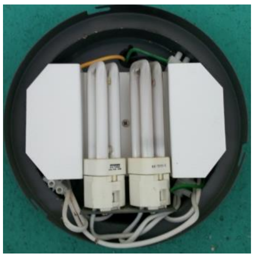

Figure 4.9: double CFL wall fixture

Figure 4.10: single CFL wall fixture

Figure 4.11: double CFL downlight fixture

There are different type of light fixture for CFL one is for down ligth and one is for wall light, the down light fixture and wall light consist two CFL bulb which consume double of energy, most of the down light and wall light using CFL bulb consist two bulbs except few new single light bulb fixture wall light used on LDK 3 and LDK 5 few months ago.

Other new faculty building not exceeds 2 year like FICT already implement single light bulb fixture and it’s efficiency is same as two light bulb fixture shown in Figure 4.11. Figure 4.9 and Figure 4.10 is a wall light fixture and there are also two types of down light fixture that consist single or double light bulb design.

4.2.2 Tube Fluorescent light

Table 4.3: List of Different Tube Fluorescent Light Models and Specifications

Fluorescent Tube

Manufacture	Model	Color	Life(hour)	Lumen(lm)	Power(watt)	lm/Watt
Philips	Life Max TLD	White	13000	2500	36	69.44
Osram	Life Max L	Warm White	20000	3350	36	93.06
Osram	DULUX L	Warm White	20000	2900	36	80.56
NCE		Yellow			40	0.00
Hitachi	D8T5	cool daylight	10000	720	8	90.00
Osram	exit light	cool daylight	10000	720	13	55.38
Osram	emergency light	cool daylight	10000	720	13	55.38
Osram	emergency light	cool daylight	10000	720	13	55.38

Figure 4.12: Normal Fluorescent tube

Figure 4.13: Dulux L

Figure 4.14: Exit light

Figure 4.15: Emergency light

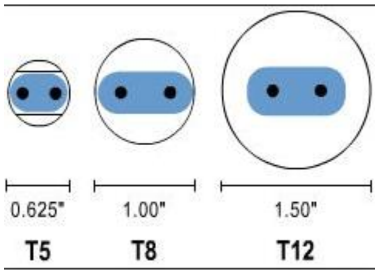

Figure 4.16: Fluorescent tube socket size

The most often use flourescent tube is T8 type socket that consume 36W energy. Flourescent tube shown in Figure 4.13 is also in office used, the Dulux L type flourescent consumed equivalent energy as the T8 type flourescent but compare to it the Dulux L type need three set to plug in the light fixture instead of T8 type only plug two tube inside the fixture. The LUX gave out from the Dulux L required three set only equivalent with the two set of T8 type which makes it inefficient .

For exit light the flourescent type used is T5 fluorescent tube and inside consists of two 18W tubes shown in Figure 4.14, some condition of the exit light is turn on 24 hours continuously and some of it are spoiled, in my calculation all being standardize using two flourescent which is 36W and turn on 21 hour according to morning 9 hours operating and night 12 hours operating.

As for emergency light most of it are spoiled, and unable to recharge, so I standardize using one fluorescent tube of 13W all light off.

4.2.3 High Pressure Sodium Vapour Lamp (HPSV)

Table 4.4: High Pressure Sodium Vapour Lamp Model Type and Specifications

Incandescent

Manufacture	Model	Color	Shape	Life(hour)	Lumen(lm)	Power(watt)	lm/Watt
Philips	SDW-T	GW	bulb	10000	2300	50	46.00
Philips	Master Color CDM-T	WW	bulb	10000	6500	70	92.86
Osram	Vialox NAV-TS super 4y			16000	15000	150	100.00

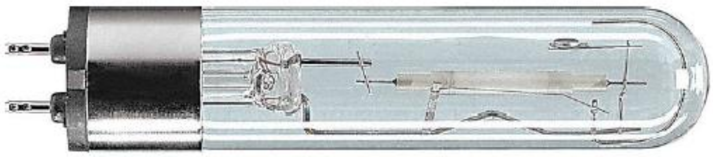

Figure 4.17: SDW-T

Figure 4.18: Master Color CDM-T

Figure 4.19: Vialox NAV-TS super4v

High pressure sodium vapour lamp used much energy and produces more heat than a CFL and the life span is almost the same CFL and fluorescent tube. HPSV are mainly used as downlight during the night time, most of it are located near the foyer near LDK 2 and second floor of FEGT. The operating hour and energy consumption can be seen on Table 4.4.

4.2.4 Outdoor Lighting

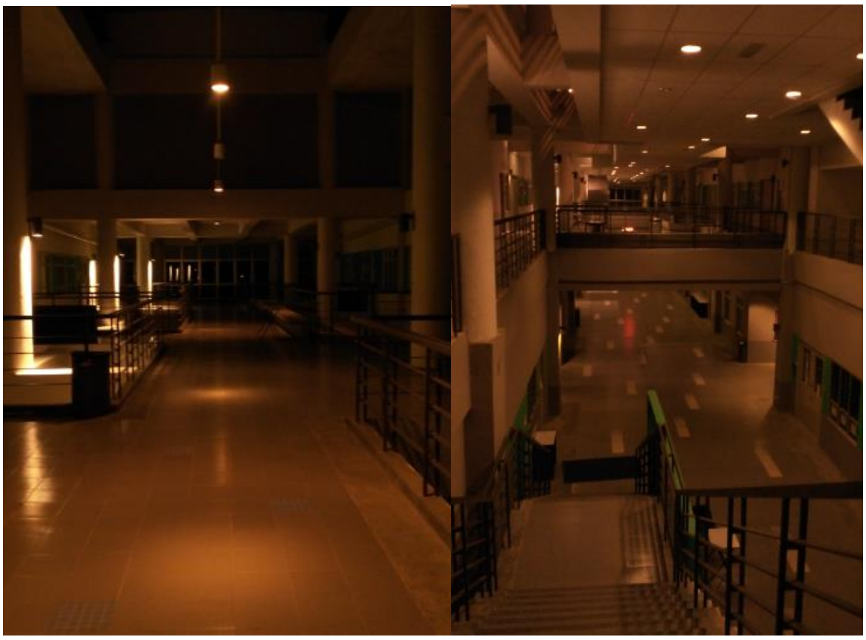

Figure 4.20: Night view in FEGT

Several types of lighting are being used at hallway or outdoor of FEGT building. During the survey on night time only certain type of lighting being turn on, according to the security guard the period of the lighting turn on time is around 7pm until moring 7am and it is automatically turn on and off. The lighting energy consumption at outdoor can be seen on Table 4.5. During week end the lighting at outdoor also will automatically turn on, so total 7 days operating time in a week.The demand power for lighting at outdoor is unable to calculate because the time for every light operate time is inconsistance.

<u>Total energy consumption:</u>

The total energy consumption is 235.11kWh per day.

A week 7 days	= 235.11kWh x 7 days	= 1645.77kWh
A month average 4 weeks	= 1645.77kWh x 4 weeks	= <u>6583kWh</u>

Column for total lighting available at all floor

Table 4.5: Outdoor Lighting Energy Consumption and Quantity

Column for total lighting available at that floor

Column for total lighting using 9 hour

Column for total lighting using 12 hour

Compact flourescent light (CLF)

	Manufacture	Model	Power(Watt)	Quantity	G	day	night	1ST	day	night	2ND	day	night	
				Total	Floor	Hour 9	Hour 12	Floor	Hour 9	Hour 12	Floor	Hour 9	Hour 12	
-	Philips	Master PL-C	18											
-	Osram	Dulux D	18	676	288	8	244	308	26	282	80		64	
-	Svlvania	CF-D	18											
	Svlvania	Minilynx-T Long life	15	17	3		3	14			0			
	Osram	DuluxStar Compact	11	11	11		11	0			0			
	Philips	Tornado	12	3	3		3	0			0			Total
				Total Watt-hour		1296	55128		4212	60912		0	13824	135372

Flourescent Tube

	Manufacture	Model	Power(Watt)	Quantity	G	day	night	1ST	day	night	2ND	day	night	
	Philips	Life Max TLD	36	22	0			21	21		1		1	
	Hitachi	D8T5	8	4	4	1		0			0			
	Osram	exit light	13	110	34	34	34	46	46	46	30	30	30	
	Osram	emergency light (x)	13	78	35			26			17			
+	Osram	emergency light(I)	13											Total
				Total Watt-hour		4050	5304		12186	7176		3510	5112	37338

High Pressure Sodium Vapor Lamp

	Manufacture	Model	Power(Watt)	Quantity	G	day	night	1ST	day	night	2ND	day	night	
+	Philips	SDW-T	50	45	32		32	0			13		13	
.	Philips	Master Color CDM-T	70	71	30			16			25		25	
	Osram	Vialox NAV-TS super 4y	150	8	8		8							Total
				Total Watt-hour		0	33600		0	0		0	28800	62400

4.2.5 LUX

Figure 4.21: Light luminance color (Energystar)

LUX level in certain room doesn’t meet the requirement shown in Figure 3.7, where office and class room should be in range of 200-300 LUX. In room E209B the average LUX is less than 200 LUX, room E209A also less than 200 LUX, this 2 room are using daylight color flourescent type lighting. Comparing between warm white color and daylight used in FEGT warm white show better illuminace level result than daylight type flourescent and both using the same 36W energy.

4.3 Cooling System

The cooling unit for FEGT building can be categorized into two types, HVAC or central AC and Split AC unit, HVAC performs cooling on large scale room space area whereas the split AC unit performs cooling on small scale room space area, but some room consists of hybrid usage of HVAC and Split AC unit for room cooling.

The rooms that using HVAC system to chilled the temperature are marks in blue colour, rooms that using split AC unit are marks in yellow colour and lastly the hybrid used of both cooling system are mark in green colour, as for those rooms that are unoccupied, and unoperated but still getting cool air supply from the HVAC system are marking red cross on the floor plan, those red cross rooms are one of the factors that causing extra energy consumption and causing inefficiency of the HVAC system. All those marking can be seen on Figure 4.22, Figure 4.23 and Figure 4.24.

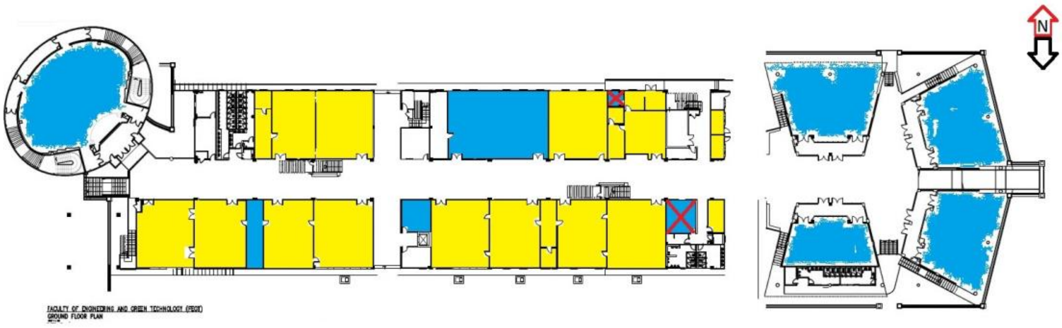

Figure 4.22: Ground floor type of cooling system used

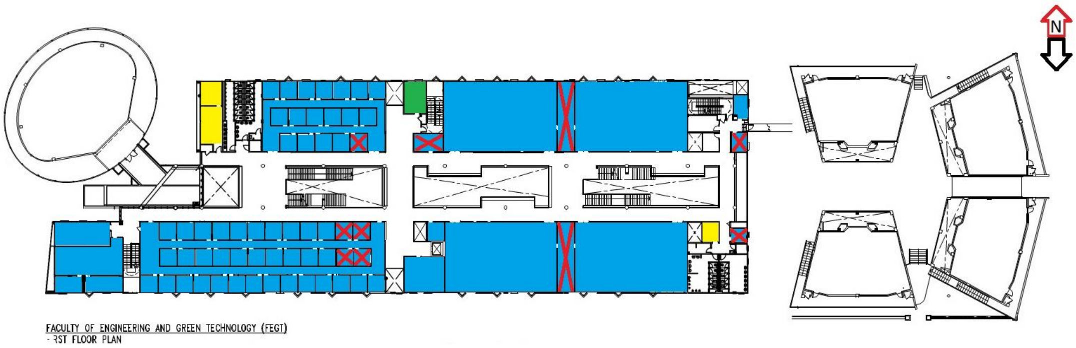

Figure 4.23: First floor type of cooling system used

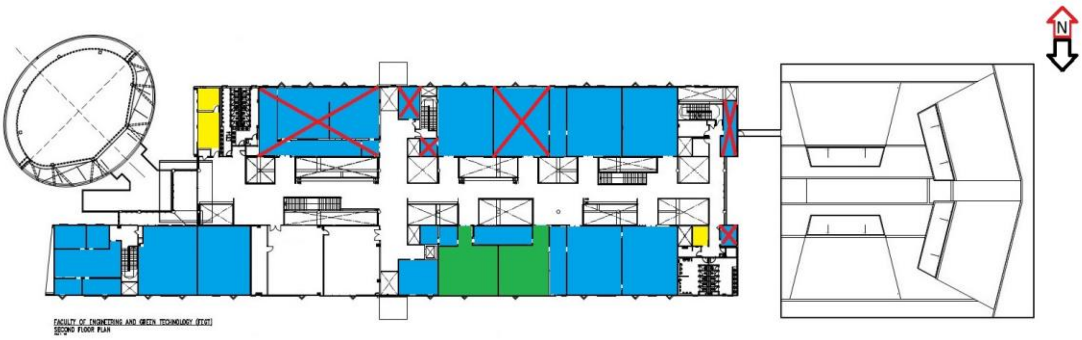

Figure 4.24: Second floor type of cooling system used

Table 4.6: Total Cooling Energy Wasted

Floor	Room no	BTU/hr required	Watt
G	E001	4166	1221
	E011B	1337	392
1st	5	1163	341
	E108	1077	316
	E110	4495	1317
	E114	1245	365
	E101	1666	488
	E103	4495	1317
	E115A	1163	341
	E115B	1163	341
	E115K	1163	341
	E115L	1163	341
2nd	E218	32203	9438
	E206	2781	815
	E207A-1	1046	307
	E207B	14989	4393
	E210	5845	1713
	E201	1198	351
Total		82358	24137

From the Red Cross room that have been marked on the Figure 4.22, 4.23 and 4.24 total cooling energy being wasted is approximate 24.137kW shown in Table 4.6.

Total wasted energy:

A day 10 hours	= 24.137kW x 10h	= 241.37kWh
A week 5 days	= 241.37kWh x 5 days	= 1206.85kWh
A month average 4 weeks	= 1206.85kWh x 4 weeks	= 4827.4kWh

4.3.1 HVAC (Heat, Ventilation and Air-conditioning)

The HVAC system used at FEGT building can separate into different zone, each zone has its own AHU (Air handling unit) located on third floor of FEGT building, the AHU pump the cool air into the building space via outlet air vent and return air from the inlet air vent. There are total of nine zone, each zone have its own AHU and the AHU only supply cool air for that zone from second floor to ground floor. Dark blue highlight indicate the location where the duct connect from second floor to ground floor.

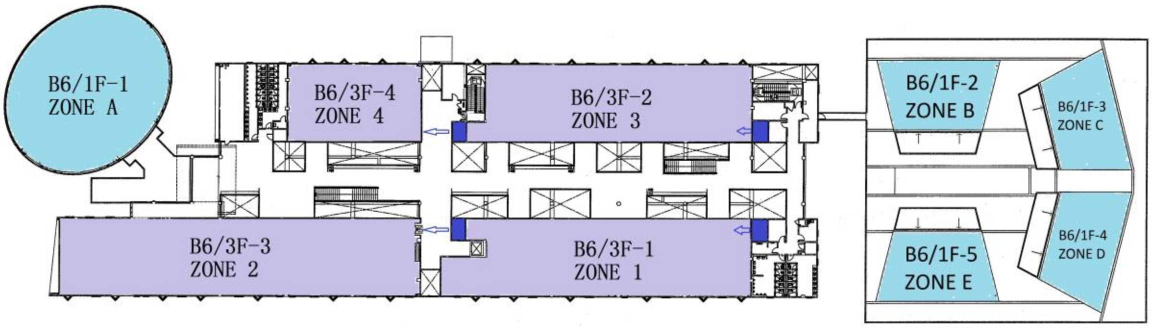

Figure 4.25: AHU zone marking floor plan

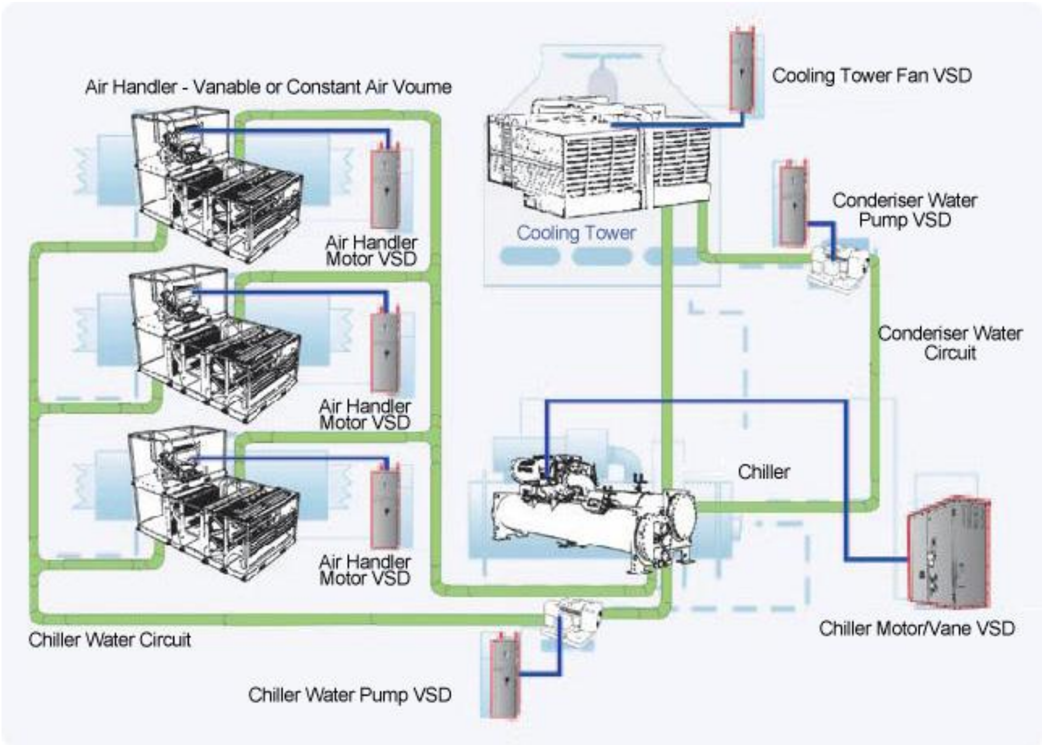

Figure 4.26: Equipments in the HVAC system (ENERGYLAND)

The equipments in the HVAC system consist of AHU air return motor/air supply motor, Chiller water pump, Compressor Motor, Cooling tower fan motor, damper control motor and other equipments locate inside the duct. Each of this equipment are parasitic energy consumption (Detlef Westphalen, 1999) needed to calculate.

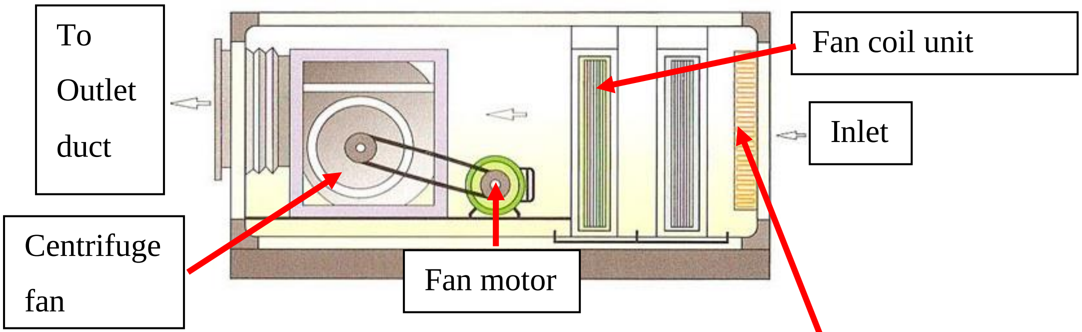

Figure 4.27: AHU internal section

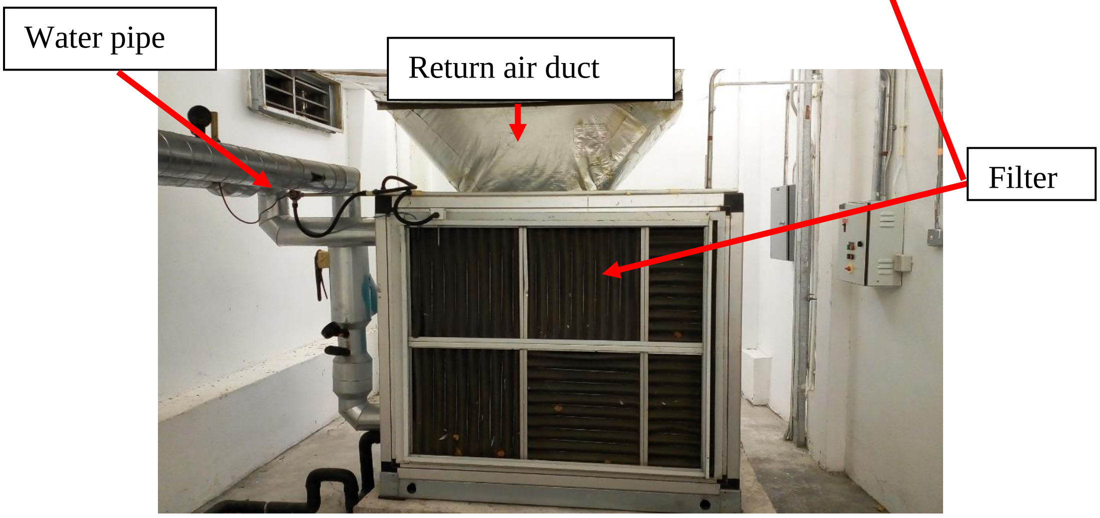

Figure 4.28: AHU filter

Type of AHU used in FEGT is shown in Figure 4.27 and Figure 4.28, and the internal part of AHU can be seen on Figure 4.30. According to the technician the filter is washed every one month, the motor belt that spin the centrifuge fan consist of three and if either one is broken all three will be changed to a new one together,

Coolant that used to cool down the temperature is water coolant, to control the temperature increase and decrease is by controling the water pressure from the water pipe manually, there is a pressure gauge and thermomter on the inlet or outlet water pipe shown in Figure 4.29 to check the water pressure and water temperature.

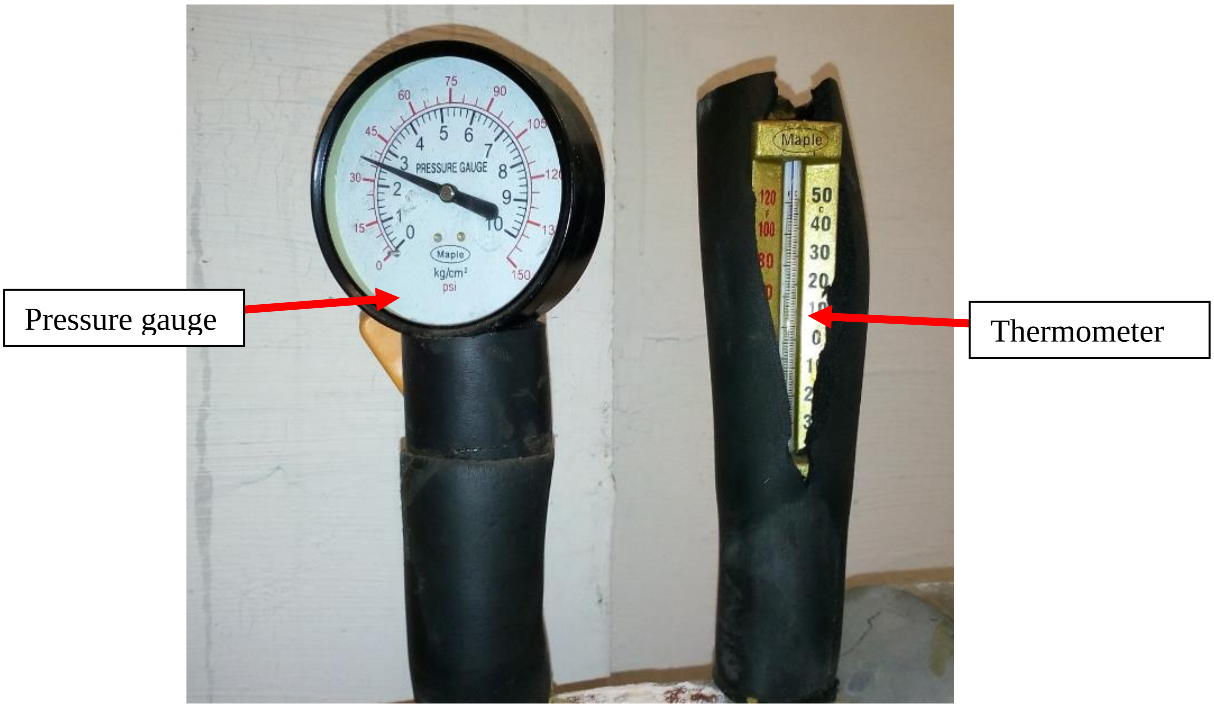

Figure 4.29: Water inlet or outlet pressure gauge

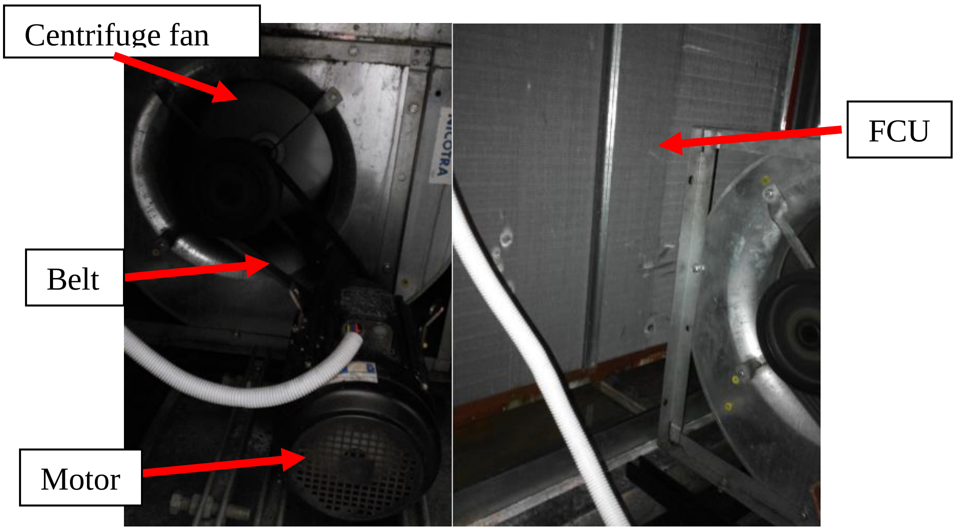

Figure 4.30: AHU internal view of motor, centrifuge fan and fan coil unit

The information of the AHU motor can be seen on the label (Figure 4.31). There are three water pump motors (Figure 4.32) that pump the coolant from AHU to condenser unit, but only two motors are operating while the other one is back up.

Figure 4.31: AHU information lable

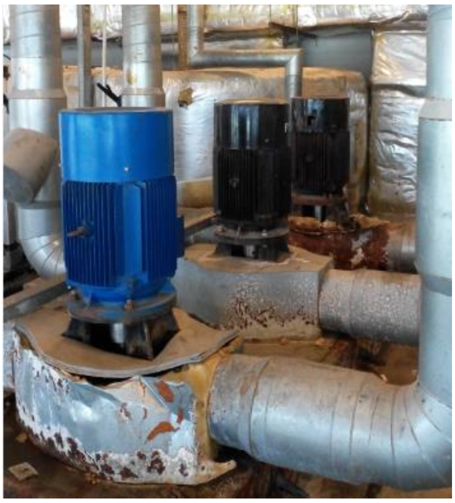

Figure 4.32: Water pump for HVAC

Figure 4.33: AHU room

Figure 4.34: HVAC condenser units

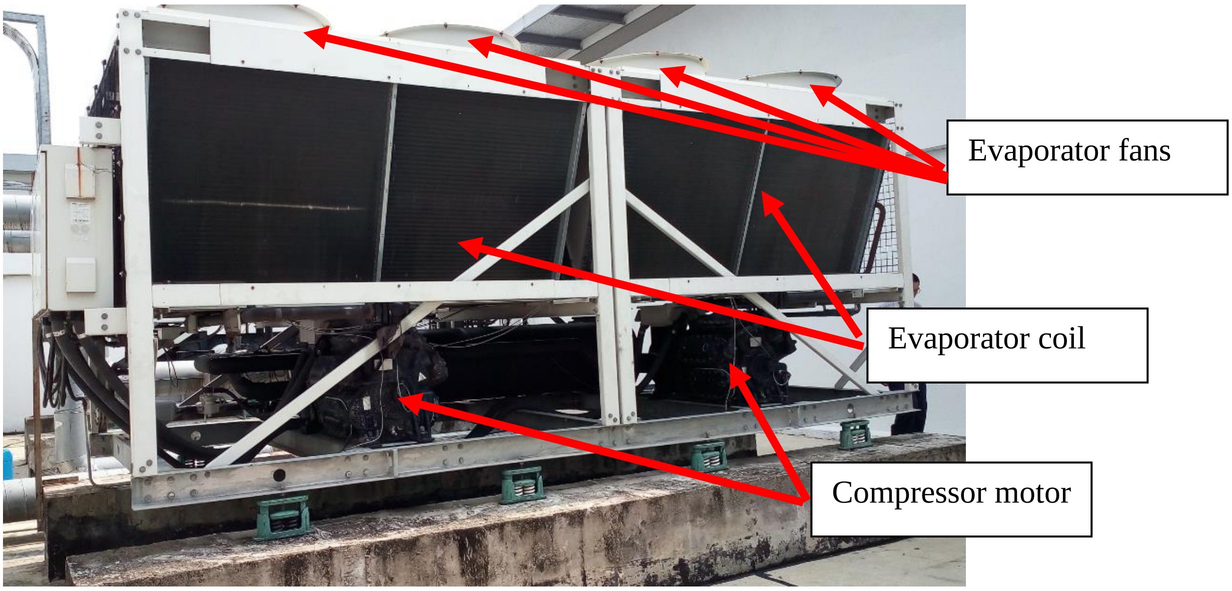

Figure 4.35: HVAC condenser unit (side view)

The location of the AHU unit is above on third floor of each zone, and the condenser unit is located at center of third floor. Total energy consumption of HVAC can be seen in Table 4.7. There are other unknown parasitic equipment in the building that is hard to reach and to collect data.

Table 4.7: HVAC Equipment Energy Consumption

AHU

Unit tag	Hall	Model	Fan motor	Fan type	RPM	Volt	Return temperature
B6/1F-1	EDK1	YDM 40x50(8R/12F)	**7.5Kw**	500(FC)	823	415	26.5
B6/1F-2	EDK2	YDM 30x50(8R/10F)	**4Kw**	400(FC)	1010	415	24.5
B6/1F-3	EDK3	YDM 30x50(8R/10F)	**4Kw**	400(FC)	1010	415	26.9
B6/1F-4	EDK4	YDM 30x50(8R/10F)	**4Kw**	400(FC)	1010	415	24.5
B6/1F-5	EDK5	YDM 30x50(8R/10F)	**4Kw**	400(FC)	1010	415	25.4

B6/3F-1	Zone 1	YDM 40x80(6R/12F)	11Kw	630(BC)	1298	415	22.9
		YDM 40x80(6R/12F)	7.5Kw	630(FC)	428	415	
		Total Watt:	**18.5kw**				
B6/3F-2	Zone 2	YDM 50x70(6R/12F)	15Kw	630(BC)	1338	415	23.3
		YDM 50x70(6R/12F)	7.5Kw	630(FC)	438	415	
		Total Watt:	**22.5kw**				
B6/3F-3	Zone 3	YDM 40x80(6R/12F)	11Kw	630(BC)	1298	415	23.9
		YDM 40x80(6R/12F)	7.5Kw	630(FC)	428	415	
		Total Watt:	**18.5kw**				
B6/3F-4	Zone 4	YDM 40x50(6R/12F)	7.5Kw	500(BC)	1523	415	22.3
		YDM 40x50(6R/12F)	4Kw	500(FC)	543	415	
		Total Watt:	**11.5kw**				

	Power(W)	quantity	used	backup	Total kw
AHU Coolant Pump Motor	22kw	3	2	1	44kw
Compressor motor	22kw	4	4		88kw
Evaporator fan	2.24kw	16	16		35.84kw
					167.84kw

Total

Demand Watt	**262.34kW**
10 hour	2623.4kWh
5 days:	13117kWh
Month:	**52468kWh**

4.3.1.1 Damper

The damper operation cutaway can be seen in Figure 4.36, it used to control the velocity and volume of the air flow from the AHU unit. The damper use in FEGT duct system is in Figure 4.37 that is manual control instead of mechanical control type to control the damper blade.

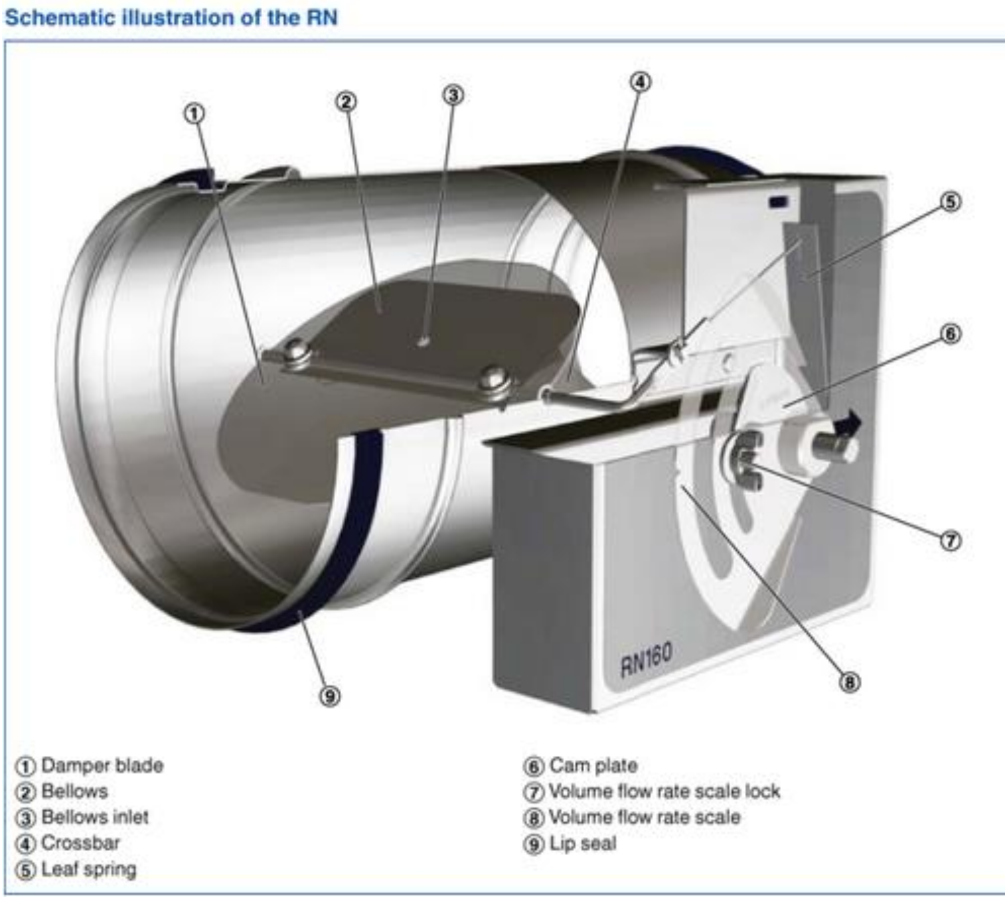

Figure 4.36: Damper Cutaway

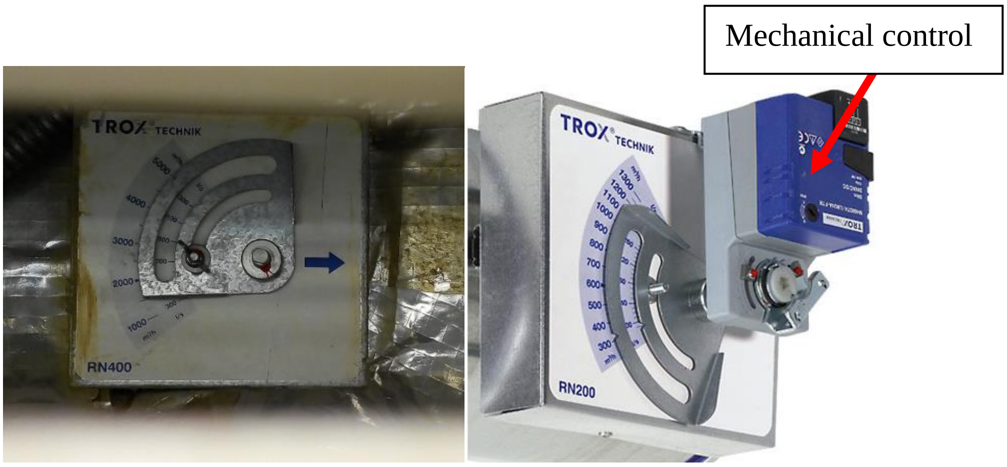

Figure 4.37: Manual control (left), machanical control (right)

Figure 4.38:HVAC electric air flow on off control

Besides velocity control using damper, the duct system also consist of HVAC electrical air flow on-off control shown in Figure 4.38, whether it still function or not the status is unknown, but for sure the dampar on off control that still functions are at room E213 and E214.

4.3.1.2 Outlet Vent Grille Types

The vent grille is used to evenly distribute the cool air into the room space, at FEGT building got three types of outlet vent grille. The square vent grille are mostly used in lecturer rooms at E115, E116 and E124, round design vent grille mostly implement on lecture hall in all EDK, fan design vent grille mostly implement on office rooms, class rooms and certain lecture rooms.

Figure 4.39: Fan design

Figure 4.40: Round design

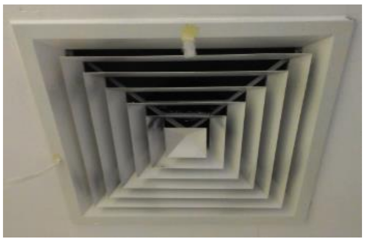

Figure 4.41: Square Design

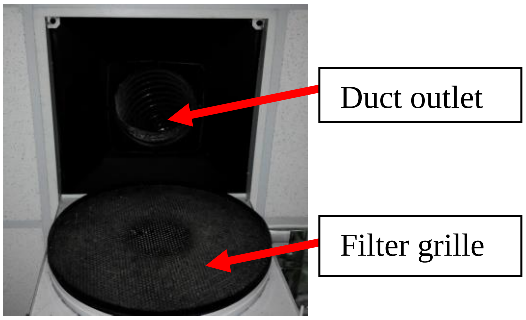

Figure 4.42: Dust clogged grilled

Figure 4.43: Return vent grilled

The most effective air distribution are square and round design vent grille because the design have no internal filter grille, whereas the fan design type have internal filter grille that can clog by dust and block the cool air distribute to the room space and make it inefficient.

When the air vent grille is block, the temperature in the room doesn't meet the requirement motor of AHU will increase it speed to supply more cool air into the room space. The velocity from the duct outlet maximum can reach 5 m/s to 6 m/s but most the of air vent that I have measured the velocity the minimum air flow speed only 0.3 m/s to 1.5 m/s, this indicate that there is a problem in the duct system or the air vent grille.

4.3.2 Split AC (Air-Conditioning)

There are several types of indoor air-conditioning, mostly all UTAR building used split AC to cool ground floor small space room, the cooling load information can be obtain from the condenser unit outside the room(outdoor unit) shown in Figure 4.46.

Figure 4.44: Split AC information lable

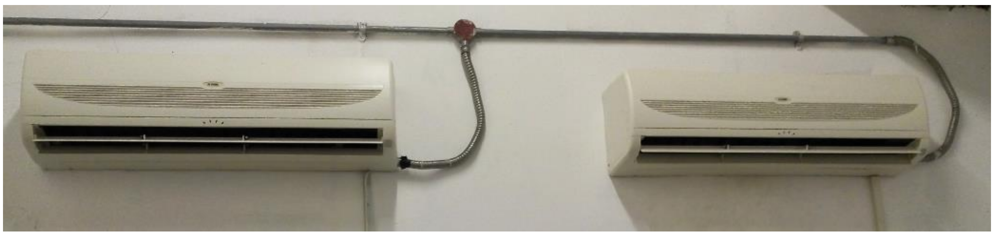

Figure 4.45: Indoor air exchange unit

Table 4.8: All Types Split AC Information Used in FEGT

Type	Model	Power(W)	Current(A)	Refrigerant weight(kg)	weigh(kg)	btu/hr	Quantity	All operate(W)
1	YSL09C-AMHOB	894	3.84	0.575		3050.45	2	1788
2	YSL15C3-AMPOK	1180	5.16	0.6	29	4026.33	6	7080
3	YSL15C-AMPOH	1240	5.6	0.75	34	4231.06	7	8680
4	YSL20C3-AMHOB	1793	7.87	0.83	57	6117.97		
5	YSL20C3-AMHOB	1813	7.96	0.83	57	6186.21	3	5439
6	YSL28C-AMHOB	2475	0.82	1.75		8445.05	3	7425
7	YSL25C-AMFOD	2654	11.8	1.1		9055.82	2	5308
8	YSL30B-AFCA	2939	14.1	1.96		10028.29	15	44085
9	YSL30C2-AMM0B	3133	13.6	2	70	10690.24	4	12532
10	YSL35C-AFFD	3200	5.2	2		10918.85	1	3200
							Total	95537

Figure 4.46: Outdoor condenser unit

Figure 4.47: Timer control

All the types of split AC unit located under ground floor and few above first floor are listed on Table 4.8. If all the split AC unit turns on total energy consumption will be 95.54kW. Certain area like SDF, EWG1,EGG1, CCR1 and CCR2 have two split units, but only operate at one time, each of this room split AC unit have timer like in Figure 4.47 or Figure 4.48 to change the indoor air exchange unit work task after 12 hour continuous everyday.

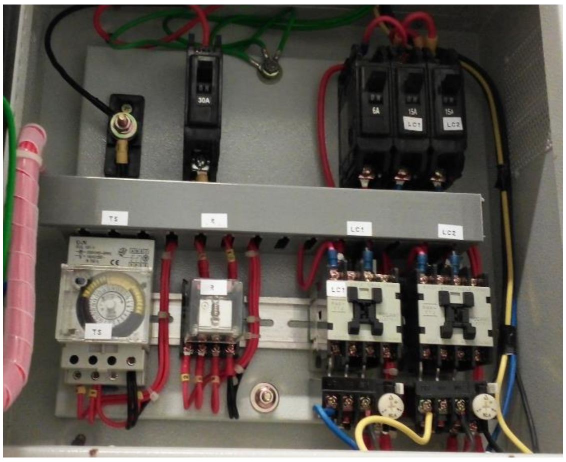

Figure 4.48: Switch box timer control

Table 4.9: Percentage of Addition Require or Extra BTU For Cooling.

G-floor

Room no	Split quantity	Supply (Watt)	BTU supply	Watt required	BTU required	Addition BTU required (%)
SDF	1	1180	4026	622	2124	-90
E002	3	8817	30084	5070	17300	-74
E002B	3	8817	30084	7770	26514	-13
E003	1	1654	5644	1527	5209	-8
E003A	1	894	3050	447	1525	-100
E004A	3	8817	30084	7761	26482	-14
E004B	3	8817	30084	8103	27649	-9
E012A	2	6139	20947	7545	25744	19
E012B	2	5878	20056	6736	22983	13
E014A	1	3133	10690	4270	14570	27
E014B	2	6266	21380	4711	16074	-33
EWG1	1	1180	4026	375	1281	-214
EGG1	1	1180	4026	359	1225	-229
E011	1	1813	6186	2720	9282	33
E011C	1	1180	4026	484	1650	-144
E011AA	1	1180	4026	959	3271	-23
E010	3	7425	25335	8241	28120	10

E018B	2	6266	21380	8287	28275	24
E018A	2	3626	12372	8287	28275	56
E017	1	2654	9056	1550	5288	-71
E017A	1	894	3050	517	1763	-73

1st Floor

Room no	Split quantity	Power(W)	BTU supply	Watt required	BTU required	Addition BTU required (%)
CCR1	1	1240	4231	364	1241	-241
E107	1	1180	4026	991	3381	-19
E122	1	1240	4231	1175	4009	-6
E123	1	1240	4231	808	2758	-53

2nd floor

Room no	Split quantity	Power(W)	BTU supply	Watt required	BTU required	Addition BTU required (%)
E217	1	1240	4231	794	2710	-56
E216	1	1240	4231	1181	4030	-5
CCR2	1	1240	4231	364	1241	-241

I have calculated the room space BTU/hr requirement for the room that using split AC unit to see how efficient the split AC unit deliver, in Table 4.9 shows the percentage of addition require or extra BTU have been supply to the room. Percentage in negative figure mean extra cooling BTU have supply to the room and the percentage in positive figure mean required addition cooling BTU to that room, the percentage highlighted in yellow indicate that room is overused of addition energy to cool down the room, where else the positive percentage that more than 25% still required addition cooling BTU, as less than 25% still acceptable.

4.3.3 Room Temperature

The supply temperature from HVAC system is controlled by DISTECH control unit/Variable Speed Drive (VSD) show in Figure 4.9, the temperature data from AHU and FCU thermocouple is sent to DISTECH control unit and temperature monitoring interface, the DISTECH control unit automatically manages the fan speed of AHU to control the air flow, it can be manually set a fix desired temperature for each zone by controlling the chiller water pressure.

According to the technician the zone temperature is set from 20 ℃ – 22 ℃ according to zone space size and complain from staffs or students. As more occupant occupied the room space the cooling load also increase thus the temperature is reset manually by the technician.

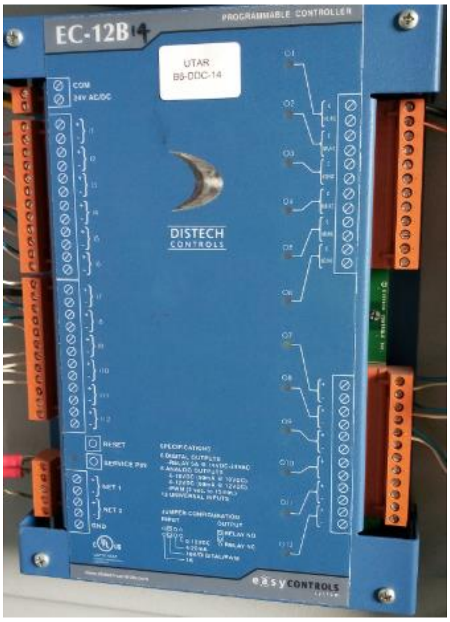

Figure 4.49: DISTECH Control module/VSD

The temperature monitoring interface is located at ground floor SDF room beside OKU toilet or near female toilet, the control interface can be seen in Figure 4.50 and Figure 4.51. The main monitoring interface is located somewhere at heritage building according to technician.

The temperature data that I have collect only from the room that are using HVAC system, as for the room that using split AC unit it can manually adjusted so I have ignored collecting the room temperature data. Most of the room that using HVAC system the temperature is range from 18.5 ℃ to 25 ℃, but the temperature from the outlet can be range from 13 ℃ to 21 ℃.

Figure 4.50: Fan coil unit (FCU) interface monitoring

Figure 4.51: Air Handling unit (AHU) interface monitoring

4.3.4 Humidity

The humidity that have collected from the rooms that using HVAC is from 50% to 75%. At Kampar it most often raining even not in raining season, the humidity will be higher, and when sunny day and raining day the humidity will be different.

4.4 Other Appliances and Equipment’s

4.4.1 Printers

The printer consist two types. Heavy duty and small scale printers. Small scale usually used at some lecture and staff room but only big scale printer that often used and the location of the photocopy machine is located at E116M, E120 and near E124R., the heavy duty printer also serves as photocopy machine, the small scale energy I have ignored to collect the energy consumption as most of it are power off and use it when needed, but for the heavy duty printer we have 3 units, the energy consumption of the printer is shown in Table 4.10.

Table 4.10: Photocopy Machine Energy Consumption

Model	**Unit**	**Volt**	**Current(A)**	**Power(W)**	**Remark**
Sharp AR-M355U	3	240	3.84	921.6	Warming up
			5	1200	Working
			0.5	120	Sleep mode

The energy consumption for this printer is not included in the total energy consumption as the period of use is inconsistence.

4.4.2 Water Dispenser Unit

Table 4.11: Water Dispenser Location and Measured Energy Consumption

G-floor, Near EDK5 site	Hot	Cool	Standby	malfunction
Current(A)	3.24	1.74	-	-
Power(watt)	777.6	417.6	-	-
Total	1195.2W			

G-floor, Near EDK1 site	Hot	Cool	Standby	malfunction
Current(A)	2.97	-	0.11	-
Power(watt)	712.8	-	26.4	-
Total	739.2W			

1st floor, Near EDK5 site	Hot	Cool	Standby	malfunction
Current(A)	2.88	1.7	-	-
Power(watt)	691.2	408	-	-
Total	1099.2W			

1st floor, Near EDK1 site	Hot	Cool	Standby	malfunction
Current(A)	3.33	0.13	-	4.7
Power(watt)	799.2	31.2	-	1128
Total	1159.2W			

2nd floor, Near EDK5 site	Hot	Cool	Standby	malfunction
Current(A)	2.8	1.6	-	-
Power(watt)	672	393.6	-	-
Total	1065.6W			

2nd floor, Near EDK1 site	Hot	Cool	Standby	malfunction
Current(A)	2.9	1.74	-	-
Power(watt)	696	417	-	-
Total	1113W			

Table 4.12: Actual Output Data from Different Model

Model(yamada)	Actual Specification	
	Hot	Cool
NWD 700	800W	205W
KSW-291	800W	160W
W500	800W	145W

The water dispenser operation time is inconsistence as the machine Itself have sensor control, inside the dispenser have two reservoir that contain cool and hot water, when the reservoir is depletion the water start fill in and during that moment the machine operate to heat up or chilled down the water temperature for storing. Even though when no one is filling up or drink the temperature inside the reservoir will become warm and the machine will start to operate.

There are six water dispensers at FEGT, two on each floor near toilet and the condition and energy consumption data can be seen in Table 4.11, the actual specification that I found on the internet is shown in Table 4.12.

The period that I used for the calculation is 12 hour as some water dispenser unit facing malfunction and continued to consume the energy, and I'm using 5 days and 4 weeks to calculate a month energy consumption. The total energy used per month is 1529kWh a month.

<u>Total energy consumption:</u>

Total Watt	= 6371.4/ 1000	= 6.37kW	(demand)
A day 12 hours	= 5.0862kW x 12hr	= 76.46kWh	
A week 5 days	= 76.46kWh x 5 days	= 382.284kWh	
A month average 4 weeks	= 382.284kWh x 4 weeks	= <u>1529.136kWh</u>	

4.4.3 Network Splitter Module

The network splitter module or server unit that connect all the internet cable are located on CCR room first floor and second floor while other are also located on E005, E105, E205 and SDF room. This module require constant cooling to perform nicely and power must always on unless under maintenance. So I'm unable to measure the energy consumption. During the survey and data collection I found that the Split AC unit on CCR room doesn't operate as the lightning strike have cause the switch trip off and were not reset.

Figure 4.52: Network Splitter Module

4.4.4 Computers and Laptops

The number of computers and monitors energy consumption is standardised into 200W and for laptops all standardised to 70W. There are total 95 computers and 7 laptops used on ground floor, 86 computers and 3 laptops used on first floor, 16 computers and 5 laptops used on second floor. If all the computer is being used the total energy consumption will be 364kWh per day.

<u>Total energy consumption:</u>

(200W x 197 units + 70W x 15)	= 40450W/ 1000	= 40.45kW (demand)
A day 9 hours	= 40.45kW x 9h	= 364kWh
A week 5 days	= 364kWh x 5 days	= 1820.25kWh
A month average 4 weeks	= 1820.25kWh x 4 weeks	= <u>7281kWh</u>

4.4.5 Projectors

The projector have different brand, model and energy consumption, most of the projector is mount on the ceiling and unable to measure each energy consumption, I'm only able to measure the energy consumption on portable projector which is different brand than the projector mount on ceiling. According to the information label on the projector, the label current supply is 2.7A but when I measured the current flow with the clamp meter when power on it only supply 1.01A max

Figure 4.53: Projector information label

For calculating the total energy consumption on the projector all the energy used is standardized to 240W and period of usage follows the room occupied period.

<u>Total energy consumption:</u>

(240W x 21 units)	= 5040W/ 1000	= 5.04kW	(demand)
A day 9 hours	= 5.04kW x 9h	= 45.36kWh	
A week 5 days	= 45.36kWh x 5 days	= 226.8kWh	
A month average 4 weeks	= 226.8kWh x 4 weeks	= <u>907.2kWh</u>	

4.4.6 Exhaust Fans

The exhaust fan can be categorized into two types, fume exhaust and room exhaust, fume exhaust requires more energy than a normal room exhaust. There are seven fume exhaust used by bioengineering lab elsewhere normal exhaust mostly located on the ceiling of each toilet and some located in some bioengineering lab to extract contaminated air. The operation period is from 8am until 6pm total of 9 hours duration.

Figure 4.54: Fume exhaust fan

Figure 4.55: Indoor exhaust fan

Table 4.13: Exhaust Fans Energy Consumption and Quantity

Exhaust fan	Power	Quantity
Normal exhaust	70W	18
Fume pump motor	1500W	7

Total energy consumption:

(70W x 18) + (1500W x 7) = 11760W/ 1000 = 11.76kW (demand)

A day 9 hours = 11.76kW x 9h = 105.84kWh

A week 5 days = 105.84kWh x 5 days = 529.2kWh

A month average 4 weeks = 529.2kWh x 4 weeks = 2116.8kWh

4.4.7 Elevator

Elevator used at FEGT just only one unit, the elevator is contracted by some company and the detail of the energy consumption by the elevator is confidential.

Figure 4.56: Elevator maximum weight carry notice

There are few information that I can collect from the elevator ,that is, the maximum weight it can carry 890kg and I'm able to measure the acceleration and the height the elevator can reach.

The time from ground floor to first floor required average of 2.5 second and from ground floor to second floor average is 5 second. Distance from ground floor to second floor is 9 meter and from ground floor to first floor is 4.5 meter. It took 1.8m/s to reach floor to floor.

<u>Calculation of how much energy consume by elevator from ground to top floor-lift empty</u>

Force to lift 890kg: 890kg x 9.81	=8730.9N
Work done (joule)	= force x distance
8730.9N x 9m	= 970.1 joule
Power	= 970.1/5 second
	= 194.02 joule/s
	= <u>**194.02W or 0.194kW**</u>

4.4.8 Lab Equipments

At FEGT there are petrochemical engineering, environmental engineering, industrial engineering and electronic engineering laboratories. There are many types of lab equipments being used in these courses. Because of time constrain I'm unable to collect the lab equipment energy consumption data.

4.4.9 Water Pump

The water pump and the compress water tank is used to supply the water plumbing on the washroom, there are four motors but only three operated and one use as backup. One single pump consume 1.1kW of energy and standardize the operate time to 9 hours.

Figure 4.57: Water pump

<u>Total energy consumption:</u>

1.1kW x 3 units		= 3.3kW	(demand)
A day	= (1.1kW x 3 units) x 9h	= 29.7kWh	
A week 5 days	= (29.7kWh x 5 day)	= 148.5kWh	
A month average 4 weeks	= (148.5kWh x 4)	= <u>594kWh</u>	

4.5 Building Envelope

The building envelope is a shell of the building that shield the room space from bottom of the building until top of the building, the heat from penetrate from the wall, heat from the window, heat from the infiltration air, heat from equipment, heat from lighting and heat from peoples are cooling load or heat gain. This cooling load is the heat energy required to remove from the cooling space.

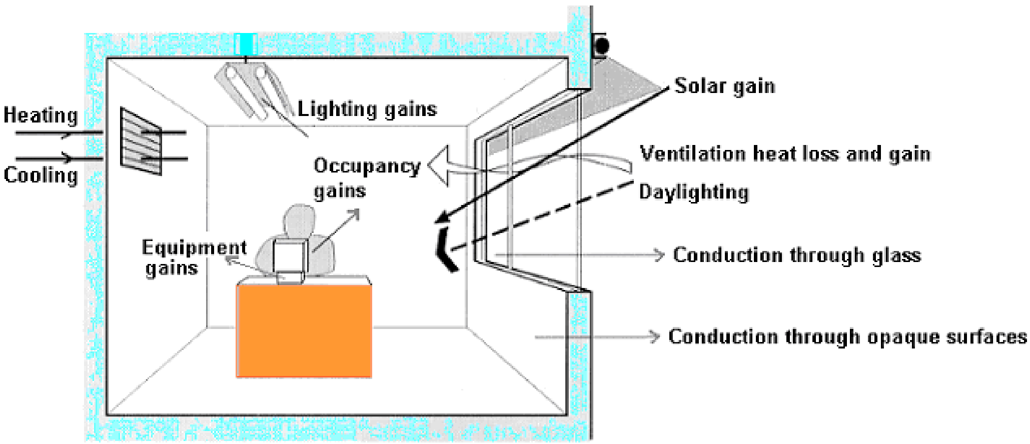

Figure 4.58: Cooling load types

4.5.1 Wall

On the thermal image the average temperature on the room that supply with HVAC cooling is 24 ℃ which is internal wall temperature, for the outdoor wall temperature average temperature is 27 ℃ -28 ℃ at noon time, which is about 0.11%-0.14% percent heat penetration.

4.5.2 Windows

The windows on the building is not well laminated with a good UV protection glazing which allow heat radiation penetrate floor tile and double the heat element. On Figure 4.59 the simulation on the left portion show a good UV protection glazing layer and the right show a low quality UV protection glazing layer, the right glazing allow heat radiation heat up the floor tile or wall and increase the room temperature. On Learning Complex 1 of UTAR some of the glazing is laminate with thicker UV protection laminate.

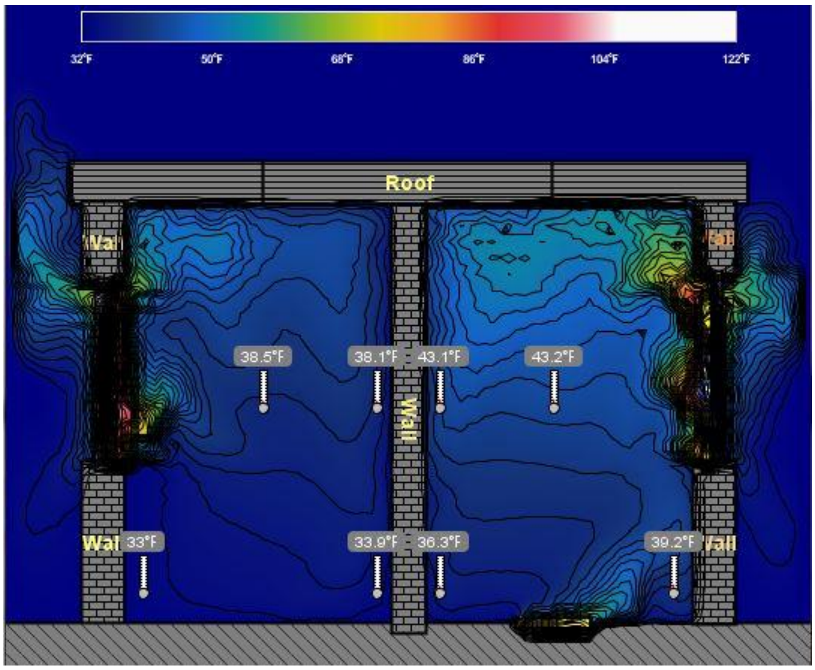

Figure 4.59: Simulation on window glazing

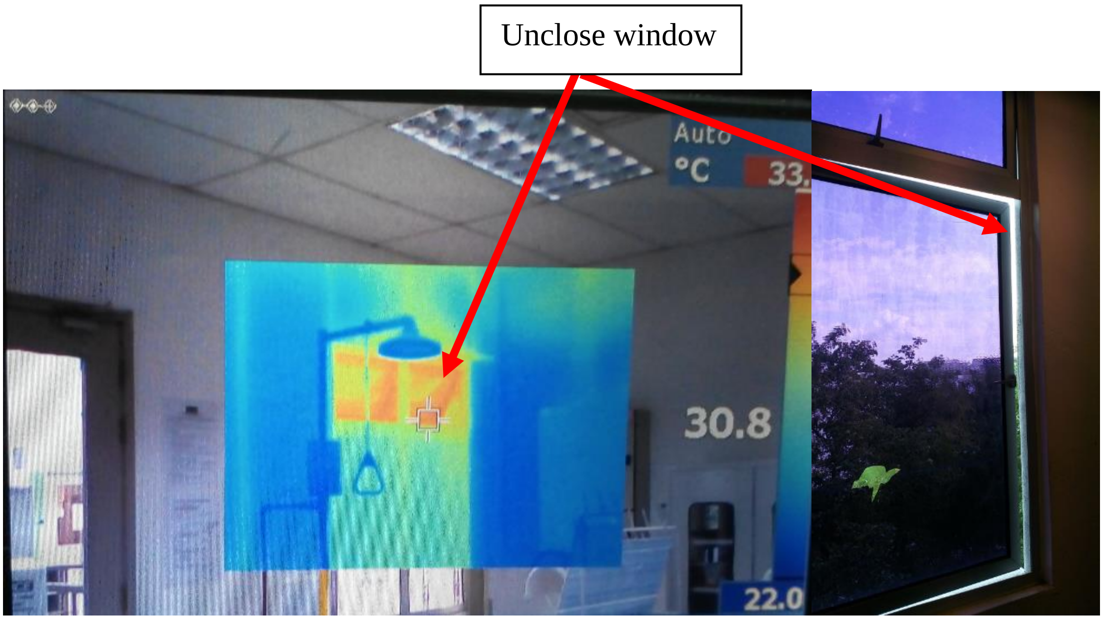

Figure 4.60: Thermal image on open window

Most of the room space temperature in FEGT is chilled down by HVAC system when the temperature is unable to adjusted, the student, lecturer or staff personel will open a gap on the windows or door to warm up the cool temperature. After using the room the windows will be left unclose and unconcern. When open up the window the hot air from outsite will penetrate the room space and when the return air temperature rise the AHU detect the changes it will increse the fan work to supply the set temperature to specific room space. In the thermal image, the hot air temperature from outdoor is from 27 ℃ - 32 ℃ depend on the outdoor temperature change.

4.5.3 Ceiling

Ceiling condition for some unoccupied room are damaged and continued of cooling air supply from HVAC, the temperature from that open cover can reach from 27 ℃ – 29 ℃ during noon time, this is another factor for cooling load that can increase energy consumption.

Figure 4.61: uncover ceiling / spoiled ceiling

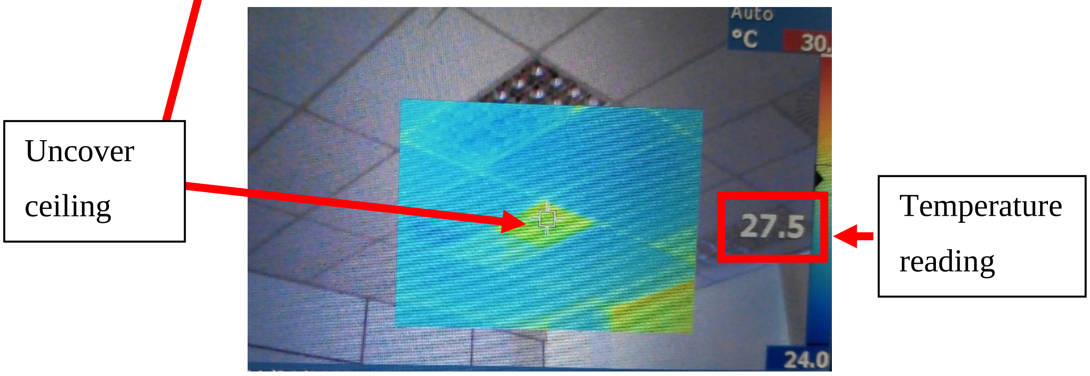

Figure 4.62: Thermal image on uncover ceiling

4.5.4 Light Fixture

Light fixture without light on also can become one factor for cooling load increase as the temperature from the upper ceiling that is made of concrete, the heat from the concrete penetrates through the metal part of the light fixture and the temperature can reach up to 28 ℃, when the lighting is on the temperature can exceed 40 ℃ where it become addition BTU need to be cool down. The Figure 4.62 show simulation on how is the light fixture temperature propagate throughout the room space.

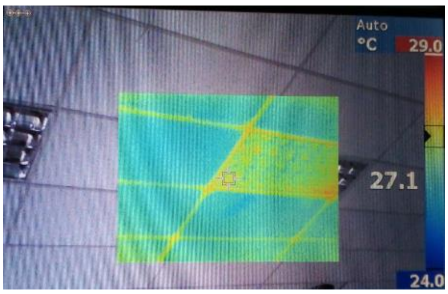

Figure 4.63: Thermal image on light fixture without turning on the light

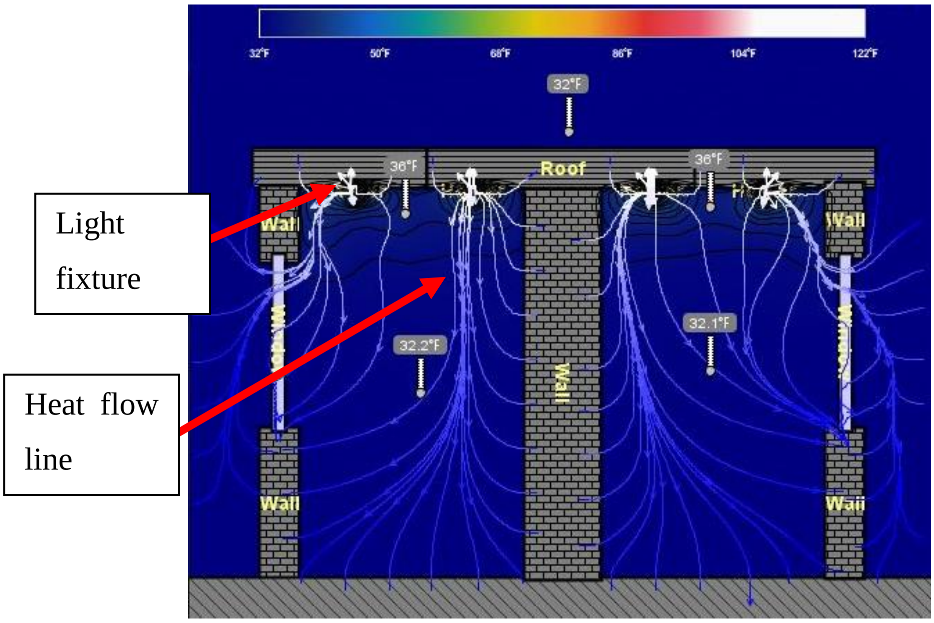

Figure 4.64: Simulation on light fixture temperature flow

4.5.5 Doors

The doors at FEGT are mainly made from wood and glass panel, the insulation is not sufficient to block the hot air penetration, this has become cooling load for the HVAC and split AC units. The door gap in Figure 4.65 shows that the temperature reach 28.7 ℃

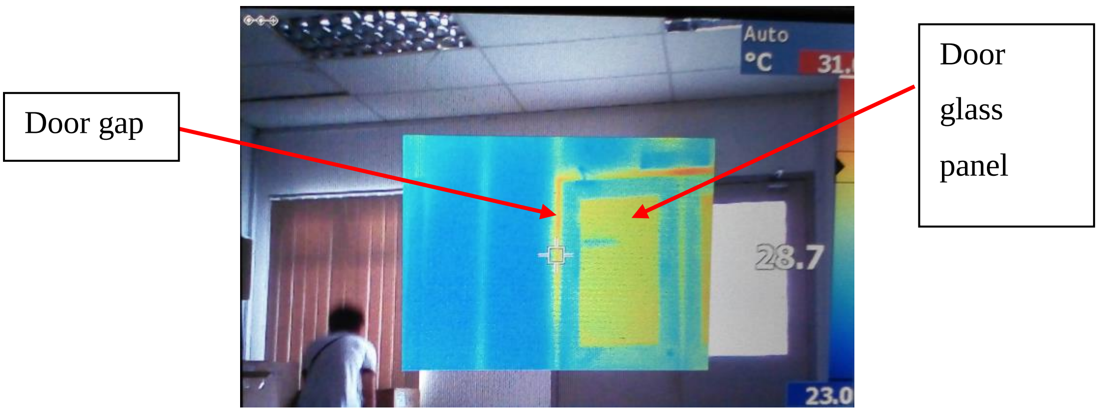

Figure 4.65: Door thermal image

4.5.6 Landscape

The landscape outside the building have already implement on reducing the temperature around the building, in Figure 4.66 the tree is almost as tall as the building that can block the direct sunlight to the side of the wall.

Figure 4.66: Side view of FEGT building

4.6 Overall Energy Consumption

Table 4.14: Lighting, Cooling, Equipments Monthly Total Energy Consumption

Light energy consumption

Period	month
Location	kWh
Outdoor	4,702.2
G-floor	7421
1st-floor	4,543.4
2nd-floor	2,444.8
Total	19,111.4

Cooling system

Period	month
Type	Kwh
AHU’s	52,468
Split unit’s	17,196.6
Total	69,664.6

Equipment’s

Period	month
All Location	kWh
Water dispensers	1,529.2
PC’s	7281
Projectors	907.2
Exhaust’s	2,116.8
Water pump’s	594
Total	12,428.2

Table 4.15: Overall energy consumption

Period	month
Type	**kWh**
Lighting	19,111.40
Cooling System	69,664.60
Equipments	12,428.20
Other	39,159.80

Others
Printer
Splitter
Elevator
Lab equipment

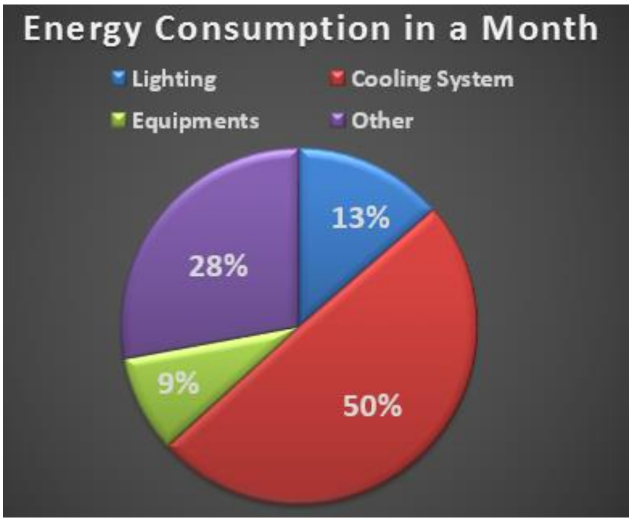

Figure 4.67: Pie chart of Energy consumption in a month

After combining all the energy consumption data and taking average monthly energy consumption from Table 4.1 about 140,364kWh subtracted all the energy consumption on Table 4.14, we get 39,159.8kWh energy consume by printers, splitter units, elevator, lab equipment's and other unknown factors like building envelope cooling load, and other parasitic equipment's that can't be measured.

From Figure 4.67, we can see that the HVAC consume 50% energy which is the highest, lighting consume 13% energy, equipments consume 9%, and 28% energy consume by other equipment's and some extra load factors not yet being calculated or measured.

CHAPTER 5

RECOMMENDATIONS AND CONCLUSION

5.1 Recommendation

5.1.1 Software Energy Simulation

Software like Autodesk Revit consist BIM (Building Information Modelling), MEP (Mechanical, Electrical and Plumbing) design, CFD (Computing Fluid Dynamic) analysis tools. Whether analysis, and energy analysis simulation (Autodesk, 2011) is very useful before implementing any real retrofit project, in the simulation we able to see how much energy is consumed in the building and can implement change in the MEP design to see the energy improvement outcome before proceed to the retrofit project. Figure 5.1 show how the light illuminance distribution in the simulation.

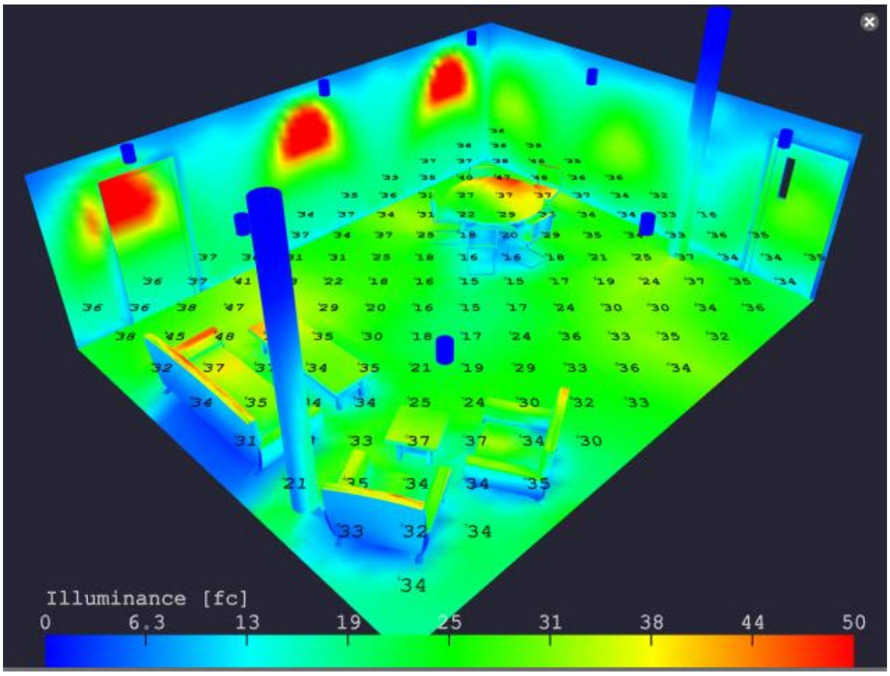

Figure 5.1:Revit simulation on lighting LUX (Fosu, 2013).

5.1.2 LED (Light Emitting Diode)

LED is more costly then CFL, but LED consume less energy, have higher efficiency, longer life span, better luminous even from time to time, dimmable to suit personal needs and using electronic ballast instead of magnetic ballast. The LED fixture also produce less heat than CFL, and its seal tight prevent bugs infiltration on the lens cover that can affect the luminous fate from time to time.

Figure 5.2: Comparison between LED, CFL and Incandescent bulb

Beside implementation LED on downlight it also can implement on exit sign light, it only draws as little as 1.8W energy and able to meets emergency aggress standard of building codes (Wilson, 2012).

As for payback period estimate can be returned after 3-4 years and the life span is more than 4 years.

5.1.3 Occupancy Sensor

Since most of the people have unconcern behaviour to turn off the appliances the occupancy sensor can reduce energy consumption by automatic turn on and off the switch for lighting, cooling unit and damper control when present of people inside the room. It might be able to save about 10%-20% of the energy consumption.

5.1.4 Timer

The timer control that are similar to the timer used on CCR room and chemical storage room are also able to reduce unnecessary over time usage, a digital type timer that allow to set schedule of the class available during that day is more efficiency on control of the energy consumption.

5.1.5 Rain Water Harvesting System

Since Kampar area often has a rain not during the raining season compare to other zone I can recommend rain water harvesting system to collect the rain water to make roof sprinkling/spray system (Program, 2003) during hot day to decrease the cooling load for the HVAC and Split AC unit. The cost for the project require further research and discussion.

5.1.6 Housekeeping

During the walkthrough audit I found that most of the HVAC vent grilled is clogged by a thick dust to prevent smooth air flow, this should be the responsibility of the staff or the person that used that room doing house keeping them self instead or waiting cleaner to clean the clogged air vent.

Most of the big company have 5S program culture that are Seiri (sort), Seiton (Set in order), Seiso (Shine), Seiketsu (Standardize) and Shitsuke (Sustain) (Everspark, 1990). This 5S program is normally used at Japanese company as they are the first country to develop this program and now even some of the western company also adopt this good culture to do housekeeping in a year or even in every week period. It is a good way to promote green environment, but in UTAR we do not have this kind of program. As this is not a good practice to be in an education firm even though FEGT that bear the name of green technology?

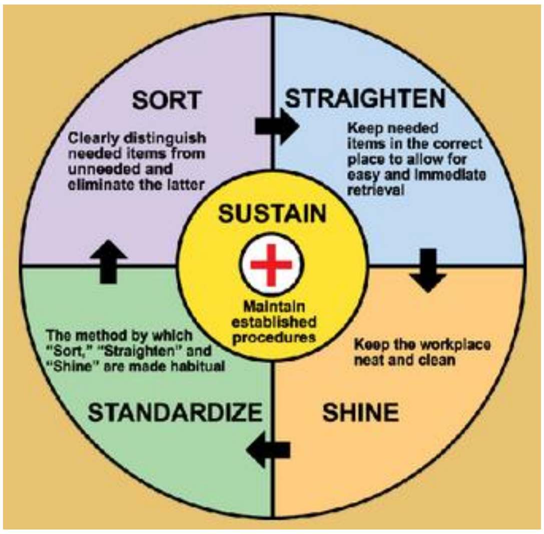

Figure 5.3: 5S program (Everspark, 1990)

5.1.7 HVAC Iris Damper

Iris damper allow to control the desire air flow velocity and volume enter individual room space, it can be installed on the outlet of the duct system that supply to that individual room.

Figure 5.4: Iris damper

5.1.8 Data logger

Data logger would be best device to collect more precise daily use information on room temperature, humidity level, energy consumption on individual room, weather condition, numbers of occupancy and period of occupied,. With data logger it will be easier to analyse the factors that causing inefficient energy consumption and come up with retrofit projects or necessary actions.

5.2 Conclusion

In conclusion, energy audit can be further split into subproject, such as project on lighting, cooling system, building envelope, smart energy grid control and CFD simulation on energy efficiency.

Energy audit is a sophisticated work that can’t be done for single person it need a group or team to make the energy saving objectives complete as it required tremendous amount of time to analyse the collected data, come up with a solution on solving extra energy consumption and to improve the efficiency of the building.

The UTAR also have counter measure on reducing energy consumption by using cool air from the room instead of outdoor air return to AHU unit to recycle the cooling process, from that process the energy consumption won’t be increase.

The major factors that cause inefficiency energy use of the building are improper control the distribution of the energy and human behaviour.

As for my project progress are incomplete and less accuracy due to insufficient building information, undetailed floor plan, the lack authority to survey certain part of the area and secure more detail on HVAC system.

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APPENDICES

Appendix A : Tools list

LASER DISTANCE MEASUREMENT METER

Brand name : PULSEIIPOWER

Model name : HILTI PD42

Serial number : UTAR TLA30001750

Purpose : Measure the distance

Status : borrowed from E017

ANEMOMETER

Brand name : PROVA

Model name : AVM-05

Serial number : S/N 10150186

Purpose : Measure the wind speed flow of the air-conditioning ventilation system and
Outlet temperature

Status : borrowed from E017

LUX METER

Brand name : MASTECH

Model name : MS6610

Serial number : 10110003399

Purpose : Measure light illumination level

Status : borrowed from E017

AC CLAMP MULTIMETER

Brand name : AMPROBE

Model name : ACD-41PQ

Serial number : 130701166

Purpose : To measure the current and power usage of equipment and electric cable

Status : borrowed from Dr Soh Chit Shiong

THERMAL CAMERA

Brand name : FLUKE

Model name : Ti25

Purpose : To measure wall temperature, to find cool air leaking area, hot air infiltration the building and visual inspection on heat generate from the equipment.

Status : borrowed from E003

WHIRLING HYGROMETER

Brand name : ZEAL

Model name : P2520

Purpose : To measure the humidity or water moisture level in the air

Status : borrowed from E013

INTELLIGENT DIGITAL MULTIMETER

Brand name : TENMA

Model name : 72-7730A

Purpose : To measure room temperature and other electrical measurement

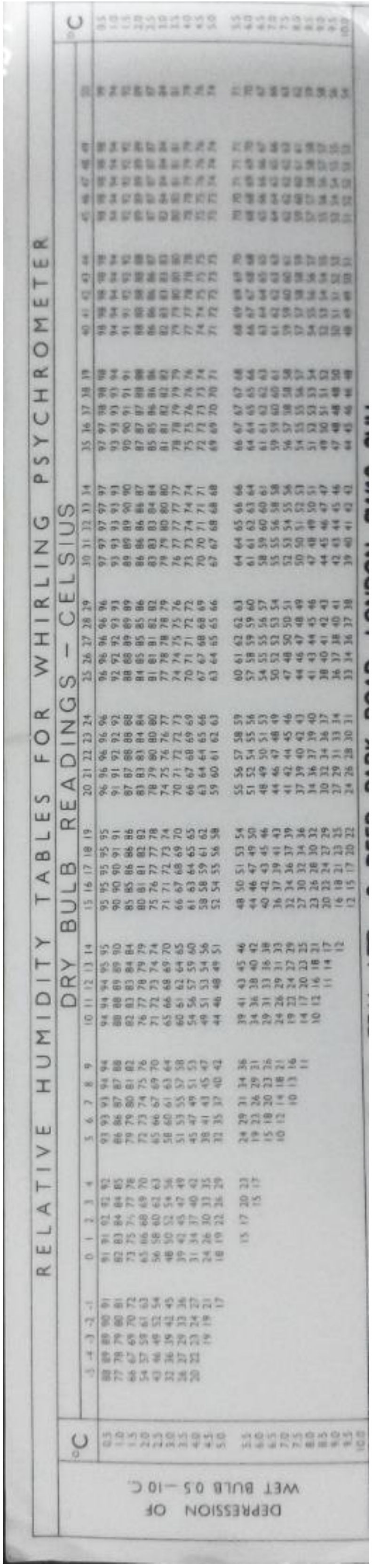
Status : borrowed from Dr Tan Kia Hock

LADDER

Purpose : To extend the height to collect data from high place

Status : borrowed from E017

Appendix B : Humidity percentage chart



Appendix C : HVAC Information

Table: HVAC Equipment Energy Consumption

AHU

Unit tag	Hall	Model	Fan motor	Fan type	RPM	Volt	Return temperature ℃
B6/1F-1	EDK1	YDM 40x50(8R/12F)	**7.5Kw**	500(FC)	823	415	26.5
B6/1F-2	EDK2	YDM 30x50(8R/10F)	**4Kw**	400(FC)	1010	415	24.5
B6/1F-3	EDK3	YDM 30x50(8R/10F)	**4Kw**	400(FC)	1010	415	26.9
B6/1F-4	EDK4	YDM 30x50(8R/10F)	**4Kw**	400(FC)	1010	415	24.5
B6/1F-5	EDK5	YDM 30x50(8R/10F)	**4Kw**	400(FC)	1010	415	25.4
B6/3F-1	Zone 1	YDM 40x80(6R/12F)	11Kw	630(BC)	1298	415	22.9
		YDM 40x80(6R/12F)	7.5Kw	630(FC)	428	415	
		Total Watt:	**18.5kw**				
B6/3F-2	Zone 2	YDM 50x70(6R/12F)	15Kw	630(BC)	1338	415	23.3
		YDM 50x70(6R/12F)	7.5Kw	630(FC)	438	415	
		Total Watt:	**22.5kw**				
B6/3F-3	Zone 3	YDM 40x80(6R/12F)	11Kw	630(BC)	1298	415	23.9
		YDM 40x80(6R/12F)	7.5Kw	630(FC)	428	415	
		Total Watt:	**18.5kw**				
B6/3F-4	Zone 4	YDM 40x50(6R/12F)	7.5Kw	500(BC)	1523	415	22.3
		YDM 40x50(6R/12F)	4Kw	500(FC)	543	415	
		Total Watt:	**11.5kw**				

	Power(W)	quantity	used	backup	Total kw
AHU Coolant Pump Motor	22kw	3	2	1	44kw
Compressor motor	22kw	4	4		88kw
Evaporator fan	2.24kw	4	4		8.96kw
					140.96kw

Demand Watt	**235.46kW**
10 hour	2354.6kWh
5 days:	11773kWh
Month:	**47092kWh**

Appendix D : Split air-conditioning units

Type	Model	Power(W)	Current(A)	Refrigerant weight(kg)	weigh(kg)	BTU/h	Quantity	All operate(W)
1	YSL09C-AMHOB	894	3.84	0.575		3050.45	2	1788
2	YSL15C3-AMPOK	1180	5.16	0.6	29	4026.33	6	7080
3	YSL15C-AMPOH	1240	5.6	0.75	34	4231.06	7	8680
4	YSL20C3-AMHOB	1793	7.87	0.83	57	6117.97		
5	YSL20C3-AMHOB	1813	7.96	0.83	57	6186.21	3	5439
6	YSL28C-AMHOB	2475	0.82	1.75		8445.05	3	7425
7	YSL25C-AMFOD	2654	11.8	1.1		9055.82	2	5308
8	YSL30B-AFCA	2939	14.1	1.96		10028.29	15	44085
9	YSL30C2-AMM0B	3133	13.6	2	70	10690.24	4	12532
10	YSL35C-AFFD	3200	5.2	2		10918.85	1	3200
							Total	95537

Consumption period	Watt
one day(10hour)	859833
5 day	4299165
month	17196660

Color for highlight/marking in floor plan

Appendix E : Lighting Types

Compact fluorescent light (CLF)

	Manufacture	Model	Color code	Color	Shape	Socket	Life(hour)	Lumen(lm)	Power(watt)	Remark
	Philips	Master PL-C	830	white	4 single tube	2 pin	10000	1200	18	
-	Osram	Dulux D	830	white	2 long u tube	4 pin	10000	1200	18	
-	Svlvania	CF-D	830	white	2 long u tube	2pin	15000		18	
	Osram	Dulux T/E Plus	830	white	3 long u tube	4 pin	20000	3200	42	
	Svlvania	Minilynx-T Long life	827	warm white	3 short u tube	Screw	10000	900	15	
	Osram	DuluxStar Compact	827	warm white	3 short u tube	Screw	6000	600	11	
	Philips	Tornado	827	warm white	Spiral tube	Screw e27	8000	740	12	

Fluorescent Tube

	Manufacture	Model	Color code	Color	Shape	Socket	Life(hour)	Lumen(lm)	Power(Watt)	Remark
	Philips	Life Max TLD	54/765	white	1.2m	T8	13000	2500	36	
	Osram	Life Max L	830	warm white	1.2m	T8	20000	3350	36	
	Osram	DULUX L	830	warm white	Long U	2G11	20000	2900	36	
	NCE			yellow	1.2m	T8			40	UV room light
	Hitachi	D8T5	-	Daylight	short tube	T5	10000	720	8	Lift light
	Osram	PR-213	765	cool daylight	20 inch	T5	10000	720	13	Exit light
	Osram	EM33	765	cool daylight	20inch	T5	10000	720	13	emergency light
+	Osram	EM33R	765	cool daylight	20inch	T5	10000	720	13	emergency light

High Pressure Sodium Vapor Lamp

	Manufacture	Model	Color code	Color	Shape	Socket	Life(hour)	Lumen(lm)	Power(watt)	Remark
+	Philips	SDW-T	825	Golden white	bulb	E6	10000	2300	50	downlight
.	Philips	Master Color CDM-T	830	warm white	bulb	G12	10000	6500	70	downlight
	Philips	Tango IP65		warm white					150/250	Sport light
	Osram	Vialox NAV-TS super 4y			tube		16000	15000	150	bicycle parking

Outdoor Lighting Quantity used and operating period

				Total	Floor	Hour	Hour	Floor	Hour	Hour	Floor	Hour	Hour	
	Compact fluorescent light (CLF)					9	12		9	12		9	12	
	Manufacture	**Model**	**Power(watt)**	**Quantity**	**G**	**day**	**night**	**1ST**	**day**	**night**	**2ND**	**day**	**night**	
-	Philips	Master PL-C	18											
-	Osram	Dulux D	18	676	288	8	244	308	26	282	80		64	
-	Svlvania	CF-D	18											
	Svlvania	Minilynx-T Long life	15	17	3		3	14			0			
	Osram	DuluxStar Compact	11	11	11		11	0			0			
	Philips	Tornado	12	3	3		3	0			0			**Total**
				Total Wh		1296	55128		4212	60912		0	13824	**135372**

Fluorescent Tube

	Manufacture	Model	Power(watt)	Quantity	G	day	night	1ST	day	night	2ND	day	night	
	Philips	Life Max TLD	36	22	0			21	21		1		1	
	Hitachi	D8T5	8	4	4	1		0			0			
	Osram	exit light	13	110	34	34	34	46	46	46	30	30	30	
	Osram	emergency light (x)	13	78	35			26			17			
+	Osram	emergency light(I)	13											**Total**
				Total Wh		4050	5304		12186	7176		3510	5112	**37338**

High Pressure Sodium Vapor Lamp

	Manufacture	Model	Power(watt)	Quantity	G	day	night	1ST	day	night	2ND	day	night	
+	Philips	SDW-T	50	45	32		32	0			13		13	
.	Philips	Master Color CDM-T	70	71	30			16			25		25	
	Osram	Vialox NAV-TS super 4y	150	8	8		8							**Total**
				Total Wh		0	33600		0	0		0	28800	**62400**

Total Wh	235110	12 hours a day
	1645770	7 days a week
	6583080	month

80

Appendix F : FEGT overall floors data collection tables

G-Floor Data

Room no	Purpose	Door status	Fluorescent	CFL	PC	Laptop	Exit light	Projector	Exhaust	Split unit	Occupied period(hr)	Occupancy	Area size	Tonne required
SDF	AHU CONTROL ROOM	KEY FROM ESTATE	3	0	1	1	0	0	0	1180	0	0	16.44	0.18
ETG1	TOILET(OKU)		1	0	0	0	0	0	0	0	0	0	0.00	0.00
ETG2	TOILET(FEMALE)		5	8	0	0	0	0	1	0	10	0	0.00	0.00
ETG3	TOILET(MALE)		5	8	0	0	0	0	1	0	10	0	0.00	0.00
E001	STORE ROOM	KEY FROM FGO	8	0	0	0	0	0	0	0	0	0	32.26	0.35
E002	FYP PROJECT LAB		42	0	0	0	1	0	0	8817	9	3	120.00	1.29
E002B	MICROPROCESSOR LAB		28	0	15	0	1	0	0	8817	9	20	112.36	1.21
E003	STAFF ROOM		8	0	2	0	0	0	0	2654	9	3	26.39	0.28
E003A	STAFF ROOM		0	0	1	0	0	0	0	894	9	1	7.16	0.08
E004A	DIGITAL LAB		28	0	23	0	1	0	0	8817	9	20	112.12	1.21
E004B	ANALOGUE LAB		42	0	23	0	1	0	0	8817	9	20	121.15	1.30
E006	STAFF ROOM		8	0	0	2	0	0	0	0	9	2	30.77	0.33
E005	STAFF ROOM	KEY FROM FGO	4	0	0	0	0	0	0	0	0	0	30.71	0.33
E012A	BIOCHEM LAB		32	0	0	0	1	0	0	6139	9	15	129.63	1.40
E012B	EV LAB		28	0	0	0	1	0	0	5878	9	15	108.25	1.17
E013	STAFF ROOM		8	0	3	0	0	0	0	0	9	3	33.60	0.36
E014A	PE LAB		28	0	0	0	1	1	0	3133	9	0	112.80	1.21

E014B	ANALATICAL LAB		42	0	0	0	1	0	0	6266	9	0	124.44	1.34
ERG1	CHEMICAL STORE	KEY FROM E017	1	0	0	0	0	0	1	0	0	0	13.32	0.14
EWG1	CHEMICAL STORE	KEY FROM E017	2	0	0	0	0	0	0	1180	0	0	9.91	0.11
EGG1	CHEMICAL STORE	KEY FROM E017	2	0	0	0	0	0	0	1180	0	0	9.48	0.10
ELV	UNKNOWN	KEY FROM ESTATE	0	0	0	0	0	0	0	0	0	0	0.00	0.00
EUG2	EMPTY	KEY FROM E017	0	0	0	0	0	0	0	0	0	0	0.00	0.00
E011	PCB LAB		22	0	0	4	1	0	0	1813	9	4	53.28	0.57
E011D	PCB LAB		8	0	0	0	0	0	1	0	0	0	13.72	0.15
E011C	PCB LAB		8	0	0	0	0	0	0	1180	0	0	12.78	0.14
E011B	PCB LAB		2	0	0	0	0	0	0	0	0	0	10.35	0.11
E011A	PCB LAB		2	0	0	0	0	0	0	0	0	0	8.41	0.09
E011AA	PCB LAB		6	0	0	0	0	0	0	1180	9	2	16.04	0.17
E010	POWER LAB		42	0	1	0	1	0	0	7425	9	20	124.80	1.34
E009	LECTURE ROOM		74	52	1	0	2	1	0	0	9	150	214.52	2.31
E008	STORE ROOM	KEY FROM E017	8	0	0	0	0	0	0	0	0	0	37.32	0.40
E007	STAFF ROOM	KEY FROM FGO	10	0	0	0	0	0	0	0	0	0	27.76	0.30
EUG1	UTILITY ROOM	UNKNOW	0	0	0	0	0	0	0	0	0	0	0.00	0.00
E018B	CM LAB		42	0	0	0	1	1	0	6266	9	20	126.00	1.36
E018A	VLSI LAB		30	0	16	0	1	0	0	3626	9	20	126.00	1.36
E017	STAFF ROOM		6	0	3	0	0	0	0	2654	9	3	27.00	0.29
E017A	STAFF ROOM		2	0	1	0	0	1	0	894	9	1	9.00	0.10
ETG6	TOILET(OKU)		0	2	0	0	0	0	0	0	0	0	0.00	0.00
ETG5	TOILET(FEMALE)		14	10	0	0	0	0	1	0	10	0	0.00	0.00
ETG4	TOILET(MALE)		14	8	0	0	0	0	1	0	10	0	0.00	0.00
E016	STAFF ROOM	KEY FROM FGO	4	0	0	0	0	0	0	0	0	0	18.30	0.20

E015	STAFF ROOM	KEY FROM FGO	8	0	0	0	0	0	0	0	0	0	23.40	0.25
EDK1	LEC HALL		70	140	1	0	5	1	0	0	9	250	0.00	0.00
EDK2	LEC HALL		35	94	1	0	4	1	0	0	9	150	0.00	0.00
EDK3	LEC HALL		35	94	1	0	4	1	0	0	9	150	0.00	0.00
EDK4	LEC HALL		35	94	1	0	4	1	0	0	9	150	0.00	0.00
EDK5	LEC HALL		35	94	1	0	4	1	0	0	9	150	0.00	0.00
EDK5TM	TOILET		2	6	0	0	0	0	1	0	10	0	0.00	0.00
EDK5TF	TOILET		0	6	0	0	0	0	1	0	10	0	0.00	0.00
	Total		**839**	**616**	**95**	**7**	**35**	**9**	**8**	**88810**				

G-Floor Data Continued

Room no	BTU required	Temp(ºC)	Humidity	Total power(W)	Light power(W)	Demand Watt
SDF	2124	21.5	69	1180	0	1180
ETG1	0	0	0	0	0	0
ETG2	0	0	0	3940	3240	394
ETG3	0	0	0	3940	3240	394
E001	4166	22.1	63	0	0	0
E002	17300	0	0	96435	13842	19532
E002B	26514	0	0	118899	9306	22028
E003	5209	0	0	30078	2592	5996
E003A	1525	0	0	9846	0	1988
E004A	26482	0	0	133526.16	9423	23653
E004B	27649	0	0	137981.79	13959	24148
E006	5174	23.3	78	3969	2709	441
E005	3967	0	0	0	0	0
E012A	25744	0	0	69093	10602	13816
E012B	22983	0	0	65471.22	9306	13153
E013	6140	0	0	7992	2592	888
E014A	14570	0	0	43034.04	9423	7915
E014B	16074	0	0	73476	13842	14430
ERG1	1720	0	0	0	0	0
EWG1	1281	0	0	0	0	0
EGG1	1225	0	0	0	0	0
ELV	0	0	0	0	0	0
EUG2	0	0	0	0	0	0
E011	9282	23.2	0	28359	7362	4964
E011D	1773	0	0	0	0	0
E011C	1650	0	0	0	0	0
E011B	1337	0	0	0	0	0
E011A	1086	0	0	0	0	0
E011AA	3271	0	0	12564	1944	2576
E010	28120	0	0	82701	14076	16614
E009	117709	22	76	36828	32868	4092
E008	4821	0	0	0	0	0
E007	3585	0	0	0	0	0
EUG1	0	0	0	0	0	0
E018B	28275	0	0	75636	13842	14670
E018A	28275	20.5	59	74628	9954	11918
E017	5288	23.7	69	31230	1944	6124
E017A	1763	22.2	68	12654	648	2300
ETG6	0	0	0	0	0	36
ETG5	0	0	0	7540	6840	754
ETG4	0	0	0	7180	6480	718

E016	2364	0	0	0	0	0
E015	3023	0	0	0	0	0
EDK1	150000	0	0	62082	58122	6898
EDK2	90000	0	0	31464	27504	3496
EDK3	90000	0	0	31464	27504	3496
EDK4	90000	0	0	31464	27504	3496
EDK5	90000	0	0	31464	27504	3496
EDK5TM	0	0	0	2500	1800	250
EDK5TF	0	0	0	1780	1080	178
				1360399	**371052**	**236032**

1St Floor data

	Room no	Purpose	Room status	Fluorescent	CLF	PC	Laptop	Exit light	Projector	Exhaust	Split unit	Occupied period	Occupancy	Meter square	Tonne required
	JANATOR	EMPTY		0	0	0	0	0	0	0	0	0	0	0.00	0.00
	ETF1	TOILET(OKU)		0	2	0	0	0	0	0	0	0	0	0.00	0.00
	ETF2	TOILET(FEMALE)		10	8	0	0	0	0	1	0	10	0	0.00	0.00
	ETF3	TOILET(MALE)		5	8	0	0	0	0	0	0	10	0	0.00	0.00
	CCR1	Server Room		1	0	0	0	0	0	0	1240	0	0	9.61	0.10
	E101	EMPTY	Key From FGO	2	0	0	0	0	0	0	0	0	0	12.90	0.14
	E102	Class Room		76	52	1	0	2	1	0	0	9	150	234.36	2.52
	E103	EMPTY	Key From FGO	8	0	0	0	0	0	0	0	0	0	34.80	0.37
	E104	Class Room		77	52	1	0	2	1	0	0	9	150	232.56	2.50
	E105	STAFF ROOM		12	0	2	3	0	0	0	0	9	6	42.61	0.46
	E106	Dr Tan		2	0	1	0	0	0	0	0	9	8	9.90	0.11
19	E115A	LECTURE ROOM		4	0	1	0	0	0	0	0	0	0	9.00	0.10
20	E115B	LECTURE ROOM		4	0	1	0	0	0	0	0	0	0	9.00	0.10
21	E115C	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
22	E115D	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
23	E115E	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
24	E115F	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
25	E115G	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
26	E115H	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
27	E115I	LECTURE ROOM		4	0	18	0	0	0	0	0	9	1	9.00	0.10
28	E115J	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
29	E115K	LECTURE ROOM		4	0	1	0	0	0	0	0	0	0	9.00	0.10

30	E115L	LECTURE ROOM		4	0	1	0	0	0	0	0	0	0	9.00	0.10
31	E115M	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
32	E115N	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
33	E115P	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
34	E115Q	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
35	E115R	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
36	E115S	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
37	E115T	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
38	E116A	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
39	E116B	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
40	E116C	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
41	E116D	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
42	E116E	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
43	E116F	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
44	E116G	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
45	E116H	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
46	E116I	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
47	E116J	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
48	E116K	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
49	E116L	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
50	E116M	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
51	E116N	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
52	E116P	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
53	E116Q	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
54	E116R	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10

55	E116S	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
56	E116T	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
	E120	FEGT FGO		15	0	3	0	0	0	0	0	9	3	57.13	0.61
	E121	MEETING ROOM		11	16	1	0	0	1	0	0	0	0	38.46	0.41
	E120A	STAFF ROOM		4	0	0	0	0	0	0	0	9	0	19.72	0.21
	E120B	STAFF ROOM		4	0	0	0	0	0	0	0	9	0	13.34	0.14
	E113	STAFF ROOM		2	0	1	0	0	0	0	0	9	1	9.99	0.11
	E114	STAFF ROOM	Key From FGO	2	0	0	0	0	0	0	0	0	0	9.64	0.10
	E112	STAFF ROOM	Lock Unknow	0	0	0	0	0	0	0	0	0	0	0.00	0.00
	EUF1	UNKNOWN		0	0	0	0	0	0	0	0	0	0	0.00	0.00
	E111	Class Room		60	34	1	0	2	1	0	0	9	150	232.20	2.50
	E110	EMPTY	Key From FGO	8	0	0	0	0	0	0	0	0	0	34.80	0.37
	E109	LECTURE ROOM		78	48	1	0	2	1	0	0	9	150	231.36	2.49
	E108	STAFF ROOM		2	0	0	0	0	0	0	0	0	0	8.33	0.09
	E107	Prof Ong		5	0	0	0	0	0	0	1180	9	1	21.53	0.23
	1	Dr Yip		0	8	1	0	0	0	0	0	9	1	9.00	0.10
	2	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
	3	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
	4	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
	5	LECTURE ROOM		0	8	1	0	0	0	0	0	0	0	9.00	0.10
	6	LECTURE ROOM		2	0	1	0	0	0	0	0	9	1	9.00	0.10
	7	LECTURE ROOM		2	0	1	0	0	0	0	0	9	1	9.00	0.10
	8	LECTURE ROOM		2	0	1	0	0	0	0	0	9	1	9.00	0.10
	9	LECTURE ROOM		2	0	1	0	0	0	0	0	9	1	9.00	0.10

10	Mr Lee		2	0	1	0	0	0	0	0	9	1	9.00	0.10
11	Mr Daniel		2	0	1	0	0	0	0	0	9	1	9.00	0.10
12	Dr Yup		0	8	1	0	0	0	0	0	9	1	9.00	0.10
13	Dr Soh (HOD)		0	8	1	0	0	0	0	0	9	1	9.00	0.10
14	Dr Loh		0	8	1	0	0	0	0	0	9	1	9.00	0.10
15	Dr Toh		0	8	1	0	0	0	0	0	9	1	9.00	0.10
16	LECTURE ROOM		0	8	1	0	0	0	0	0	9	1	9.00	0.10
17	Dr Yeong		0	8	1	0	0	0	0	0	9	1	9.00	0.10
18	Dr Nisar		0	8	1	0	0	0	0	0	9	1	9.00	0.10
ETF6	TOILET(OKU)		0	2	0	0	0	0	0	0	0	0	0.00	0.00
ETF5	TOILET(FEMALE)		14	10	0	0	0	0	1	0	10	0	0.00	0.00
ETF4	TOILET(MALE)		14	8	0	0	0	0	1	0	10	0	0.00	0.00
E122	Dr Lee		6	0	0	0	0	0	0	1240	0	0	31.04	0.33
E123	Dr Lee		4	0	1	0	0	0	0	1240	9	1	16.70	0.18
	Total		**454**	**600**	**86**	**3**	**8**	**5**	**3**	**4900**				

1st Floor Data continued

Room no	Purpose	BTU/h required	Temp(ºC)	Humidity %	Total consumption(W)	Light consume(W)	Demand Watt
JANATOR	EMPTY	0	0	0	0	0	0
ETF1	TOILET(OKU)	0	0	0	0	0	0
ETF2	TOILET(FEMALE)	0	0	0	5740	5040	574
ETF3	TOILET(MALE)	0	0	0	3240	3240	324
CCR1	Server Room	1241	0	0	1240	0	1240
E101	EMPTY	1666	22	69	0	0	0
E102	Class Room	120272	20.5	75	37710	33750	4190
E103	EMPTY	4495	23.5	63	0	0	0
E104	Class Room	120039	22.5	69	38034	34074	4226
E105	STAFF ROOM	9103	23.5	69	10035	4005	1115
E106	Dr Tan	6079	22.8	77	2565	765	285
E115A	LECTURE ROOM	1163	0	0	0	0	0
E115B	LECTURE ROOM	1163	0	0	0	0	0
E115C	LECTURE ROOM	1763	0	0	3096	1296	344
E115D	LECTURE ROOM	1763	0	0	3096	1296	344
E115E	LECTURE ROOM	1763	0	0	3096	1296	344
E115F	LECTURE ROOM	1763	0	0	3096	1296	344
E115G	LECTURE ROOM	1763	0	0	3096	1296	344
E115H	LECTURE ROOM	1763	0	0	3096	1296	344
E115I	LECTURE ROOM	1763	0	0	3096	1296	344
E115J	LECTURE ROOM	1763	0	0	3096	1296	344
E115K	LECTURE ROOM	1163	0	0	0	0	0
E115L	LECTURE ROOM	1163	0	0	0	0	0
E115M	LECTURE ROOM	1763	0	0	3096	1296	344
E115N	LECTURE ROOM	1763	0	0	3096	1296	344
E115P	LECTURE ROOM	1763	0	0	3096	1296	344
E115Q	LECTURE ROOM	1763	0	0	3096	1296	344
E115R	LECTURE ROOM	1763	0	0	3096	1296	344
E115S	LECTURE ROOM	1763	0	0	3096	1296	344
E115T	LECTURE ROOM	1763	0	0	3096	1296	344
E116A	LECTURE ROOM	1763	0	0	3096	1296	344
E116B	LECTURE ROOM	1763	0	0	3096	1296	344
E116C	LECTURE ROOM	1763	0	0	3096	1296	344
E116D	LECTURE ROOM	1763	0	0	3096	1296	344
E116E	LECTURE ROOM	1763	0	0	3096	1296	344
E116F	LECTURE ROOM	1763	0	0	3096	1296	344
E116G	LECTURE ROOM	1763	0	0	3096	1296	344
E116H	LECTURE ROOM	1763	0	0	3096	1296	344
E116I	LECTURE ROOM	1763	0	0	3096	1296	344
E116J	LECTURE ROOM	1763	0	0	3096	1296	344
E116K	LECTURE ROOM	1763	0	0	3096	1296	344

E116L	LECTURE ROOM	1763	0	0	3096	1296	344
E116M	LECTURE ROOM	1763	0	0	3096	1296	344
E116N	LECTURE ROOM	1763	0	0	3096	1296	344
E116P	LECTURE ROOM	1763	0	0	3096	1296	344
E116Q	LECTURE ROOM	1763	0	0	3096	1296	344
E116R	LECTURE ROOM	1763	0	0	3096	1296	344
E116S	LECTURE ROOM	1763	0	0	3096	1296	344
E116T	LECTURE ROOM	1763	0	0	3096	1296	344
E120	FEGT FGO	9180	23	68	10494	5094	1166
E121	MEETING ROOM	4968	22	70	0	0	0
E120A	STAFF ROOM	2547	21.2	74	1413	1413	157
E120B	STAFF ROOM	1723	21.7	68	1296	1296	144
E113	STAFF ROOM	1890	23.7	70	2448	648	272
E114	STAFF ROOM	1245	22.7	69	0	0	0
E112	STAFF ROOM	0	0	0	0	0	0
EUF1	UNKNOWN	0	0	0	0	0	0
E111	Class Room	119993	22.3	70	29610	25650	3290
E110	EMPTY	4495	23.5	63	0	0	0
E109	LECTURE ROOM	119884	0	0	37710	33750	4190
E108	STAFF ROOM	1077	22	0	0	0	0
E107	Prof Ong	3381	0	0	12240	1620	2540
1	Dr Yip	1763	0	0	3096	1296	344
2	LECTURE ROOM	1763	0	0	3096	1296	344
3	LECTURE ROOM	1763	0	0	3096	1296	344
4	LECTURE ROOM	1763	0	0	3096	1296	344
5	LECTURE ROOM	1163	0	0	0	0	0
6	LECTURE ROOM	1763	0	0	2448	648	272
7	LECTURE ROOM	1763	0	0	2448	648	272
8	LECTURE ROOM	1763	0	0	2448	648	272
9	LECTURE ROOM	1763	0	0	2448	648	272
10	Mr Lee	1763	0	0	2448	648	272
11	Mr Daniel	1763	0	0	2448	648	272
12	Dr Yup	1763	0	0	3096	1296	344
13	Dr Soh (HOD)	1763	0	0	3096	1296	344
14	Dr Loh	1763	0	0	3096	1296	344
15	Dr Toh	1763	0	0	3096	1296	344
16	LECTURE ROOM	1763	0	0	3096	1296	344
17	Dr Yeong	1763	0	0	3096	1296	344
18	Dr Nisar	1763	0	0	3096	1296	344
ETF6	TOILET(OKU)	0	0	0	0	0	0
ETF5	TOILET(FEMALE)	0	0	0	7540	6840	754
ETF4	TOILET(MALE)	0	0	0	7180	6480	718
E122	Dr Lee	4009	0	0	0	0	2696

E123	Dr Lee	2758	0	0	14256	1296	2824
	Total				**376759**	**227169**	**47817**

2^{nd} Floor Data

Room number	Purpose	Room status	Fluorescent tube	CFL	PC	Laptop	Exit light	Projector	Exhaust	Split unit(W)	Occupied period	Occupancy	Area, m^2	Tonne require
ETS1	TOILET(OKU)		0	2	0	0	0	0	0	0	0	0	0.00	0.00
ETS2	TOILET(MALE)		10	8	0	0	0	0	1	0	10	0	31.42	0.34
ETS3	TOILET(FEMALE)		5	8	0	0	0	0	1	0	10	0	0.00	0.00
E201	Empty Room	Key From FGO	2	0	0	0	0	0	0	0	0	0	9.28	0.10
E202A	TELECOMUNICATION LAB		44	0	0	0	1	0	0	0	9	15	120.00	1.29
E202B	VLSI LAB		42	0	0	0	0	0	0	0	9	15	110.04	1.18
E203	STAFF ROOM		8	0	4	0	0	0	0	0	9	2	34.80	0.37
E204A	CISCO NETWORKING LAB		30	0	2	0	0	0	0	0	0	0	109.95	1.18
E204C	DATA LAB		12	0	0	0	0	0	0	0	0	0	35.16	0.38
E204B	DATA COMMUNICATION LAB		36	0	2	0	0	0	0	0	9	15	107.48	1.16
E204D	IE Lab		4	0	2	0	0	0	0	0	9	1	11.18	0.12
E204E	IE Lab		2	0	0	0	0	0	0	0	0	0	0.00	0.00
E205	STAFF ROOM		15	0	0	5	0	0	0	0	9	6	43.03	0.46
E211A	IB FYP LAB	Key From Dean	40	0	0	0	1	0	0	0	0	0	120.38	1.30
E211B	NETWORK/IMAGING LAB	Key From Dean	30	0	0	0	1	0	0	0	0	0	113.40	1.22
E212	Empty Room	Key From Dean	7	0	0	0	0	0	0	0	0	0	40.56	0.44
E213	LECTURE ROOM		30	0	1	0	1	1	0	0	9	50	40.56	0.44
E214	LECTURE ROOM		30	0	1	0	1	1	0	0	9	50	123.60	1.33
E215	DEAN DEPARTMENT		0	0	0	0	0	0	0	0	9	1	0.00	0.00
E215A	DEAN DEPARTMENT		0	0	0	0	0	0	0	0	9	1	0.00	0.00
E215B	DEAN DEPARTMENT		0	0	0	0	0	0	0	0	9	1	0.00	0.00
E215C	DEAN DEPARTMENT		6	0	1	0	0	0	0	0	9	1	24.00	0.26

E215D	DEAN DEPARTMENT		4	0	0	0	0	0	0	0	9	1	13.88	0.15
E210	STAFF ROOM	Key From Dean	6	0	1	0	0	0	0	0	0	0	45.25	0.49
EUS1	UNKNOWN	-	0	0	0	0	0	0	0	0	0	0	0.00	0.00
EUS2	UNKNOWN	-	0	0	0	0	0	0	0	0	0	0	0.00	0.00
E209B	COMPUTING LAB		40	0	0	0	1	0	1	0	9	0	117.60	1.27
E209A	ENTERPRISE/ DATABASE LAB		30	0	0	0	1	0	2	0	9	0	115.20	1.24
E208	STAFF ROOM		8	0	2	0	0	0	0	0	9	2	34.92	0.38
E207B	Empty Room		30	0	0	0	1	0	0	0	0	0	116.04	1.25
E207A	SOFTWARE ENGINEERING LAB		40	0	0	0	1	0	0	0	9	0	118.80	1.28
E207A-1	ELECTRICAL ROOM		2	0	0	0	0	0	0	0	0	0	8.10	0.09
E206	Empty Room	Key From Dean	5	0	0	0	0	0	0	0	0	0	21.53	0.23
E218B	Empty Room	Key From Dean	30	0	0	0	1	0	0	0	0	0	81.77	0.88
E218A	Empty Room	Key From Dean	10	0	0	0	0	0	0	0	0	0	38.06	0.41
E218C	Empty Room	Key From Dean	26	0	0	0	1	0	0	0	0	0	78.16	0.84
E218D	Empty Room	Key From Dean	14	0	0	0	0	0	0	0	0	0	51.33	0.55
ETS6	TOILET(OKU)		0	2	0	0	0	0	0	0	0	0	0.00	0.00
ETS5	TOILET(FEMALE)		14	10	0	0	0	0	1	0	10	0	0.00	0.00
ETS4	TOILET(MALE)		14	8	0	0	0	0	1	0	10	0	0.00	0.00
E217	STAFF ROOM	Key From FGO	4	0	0	0	0	0	0	1240	0	0	16.80	0.18
E216	STAFF ROOM	Key From FGO	6	0	0	0	0	0	0	1240	0	0	31.20	0.34
CCR2	Sever Room	Key From Estate	1	0	0	0	0	0	0	1240	24	0	9.60	0.10
	Total		**637**	**38**	**16**	**5**	**11**	**2**	**7**	**3720**				

2nd Floor Data continued

Room number	Purpose	BTU required	Temp(ºC)	Humidity %	Total power(W)	Light Consume(W)	Demand Watt
ETS1	TOILET(OKU)	0	0	0	0	0	0
ETS2	TOILET(MALE)	4059	0	0	5740	5040	574
ETS3	TOILET(FEMALE)	0	0	0	3940	3240	394
E201	Empty Room	1198	22	78	0	0	0
E202A	TELECOMUNICATION LAB	24500	22.2	76	14490	14490	1610
E202B	VLSI LAB	23214	22.5	76	13608	13608	1512
E203	STAFF ROOM	5695	23.5	63	9972	2592	1108
E204A	CISCO NETWORKING LAB	14201	21.2	68	0	0	0
E204C	DATA LAB	4542	21.5	65	0	0	0
E204B	DATA COMMUNICATION LAB	22883	19.8	66	15264	11664	1696
E204D	IE Lab	2045	23.7	69	4896	1296	544
E204E	IE Lab	0	0	0	0	0	0
E205	STAFF ROOM	9158	23.7	77	8190	4860	910
E211A	IB FYP LAB	15550	0	0	0	0	0
E211B	NETWORK/IMAGING LAB	14648	0	78	0	0	0
E212	Empty Room	5239	23.1	77	0	0	0
E213	LECTURE ROOM	35239	23.1	77	0	0	252
E214	LECTURE ROOM	45965	22	69	13914	9954	1546
E215	DEAN DEPARTMENT	600	0	0	0	0	0
E215A	DEAN DEPARTMENT	600	0	0	0	0	0
E215B	DEAN DEPARTMENT	600	0	0	0	0	0
E215C	DEAN DEPARTMENT	3700	0	0	3744	1944	416
E215D	DEAN DEPARTMENT	2393	0	0	1296	1296	144
E210	STAFF ROOM	5845	21	67	0	0	0
EUS1	UNKNOWN	0	0	0	0	0	0
EUS2	UNKNOWN	0	0	0	0	0	0
E209B	COMPUTING LAB	15190	22.2	69	13824	13194	1536
E209A	ENTERPRISE/ DATABASE LAB	14880	23	68	11214	9954	1246
E208	STAFF ROOM	5711	21.5	68	6192	2592	688
E207B	Empty Room	14989	22.7	76	0	0	0
E207A	SOFTWARE ENGINEERING LAB	15345	21.7	76	13194	13194	1466
E207A-1	ELECTRICAL ROOM	1046	19.8	74	0	0	0
E206	Empty Room	2781	24.4	71	0	0	0
E218B	Empty Room	10561	20.2	74	0	0	0
E218A	Empty Room	4917	21	76	0	0	0
E218C	Empty Room	10095	18.8	66	0	0	0
E218D	Empty Room	6630	20	67	0	0	0
ETS6	TOILET(OKU)	0	0	0	0	0	0
ETS5	TOILET(FEMALE)	0	0	0	7540	6840	754
ETS4	TOILET(MALE)	0	0	0	7180	6480	718
E217	STAFF ROOM	2170	0	0	0	0	0

E216	STAFF ROOM	4030	0	0	0	0	0
CCR2	Sever Room	1241	0	0	30240	0	1260
	Total				**184438**	**122238**	**18374**

Appendix G : FEGT room data collection tables example

Room number : E202A

Structure size

Length	12.00	
width	10.00	
height	3.09	

Room area (m^2)	120.00	0.00	120.00

Item	**Quantity**	**Energy /unit**	**Remark**
Fluorescent Tube	44	36	white
Compact Fluorescent (CFL)		18	
Computer (pc)		200	
Emergency light		13	
Projector		240	
Exit light	1	26	
Laptop		70	
Fan		60	
Split Unit			
Server		20	
Exhaust Fan		70	

Structure Envelope

Window	5		
Wall			
Celling			
Door	3		

OTHER EQUIPMENT	**QUANTITY**	**POWER**	**REMARK**

Continued of room data collection table example

Room temperature

22.2 ℃

Humidity level

76%

Occupied period

9hr

Occupancy

15

Air vent

9

Total Consumption

14490 W

Light Consume

14490 W

Demand Watt

1610

LUX

226	314	200
382	430	490
318	366	450

	N	
W		E
	S	

This indicate which direction the light fixture and Air vent located should view

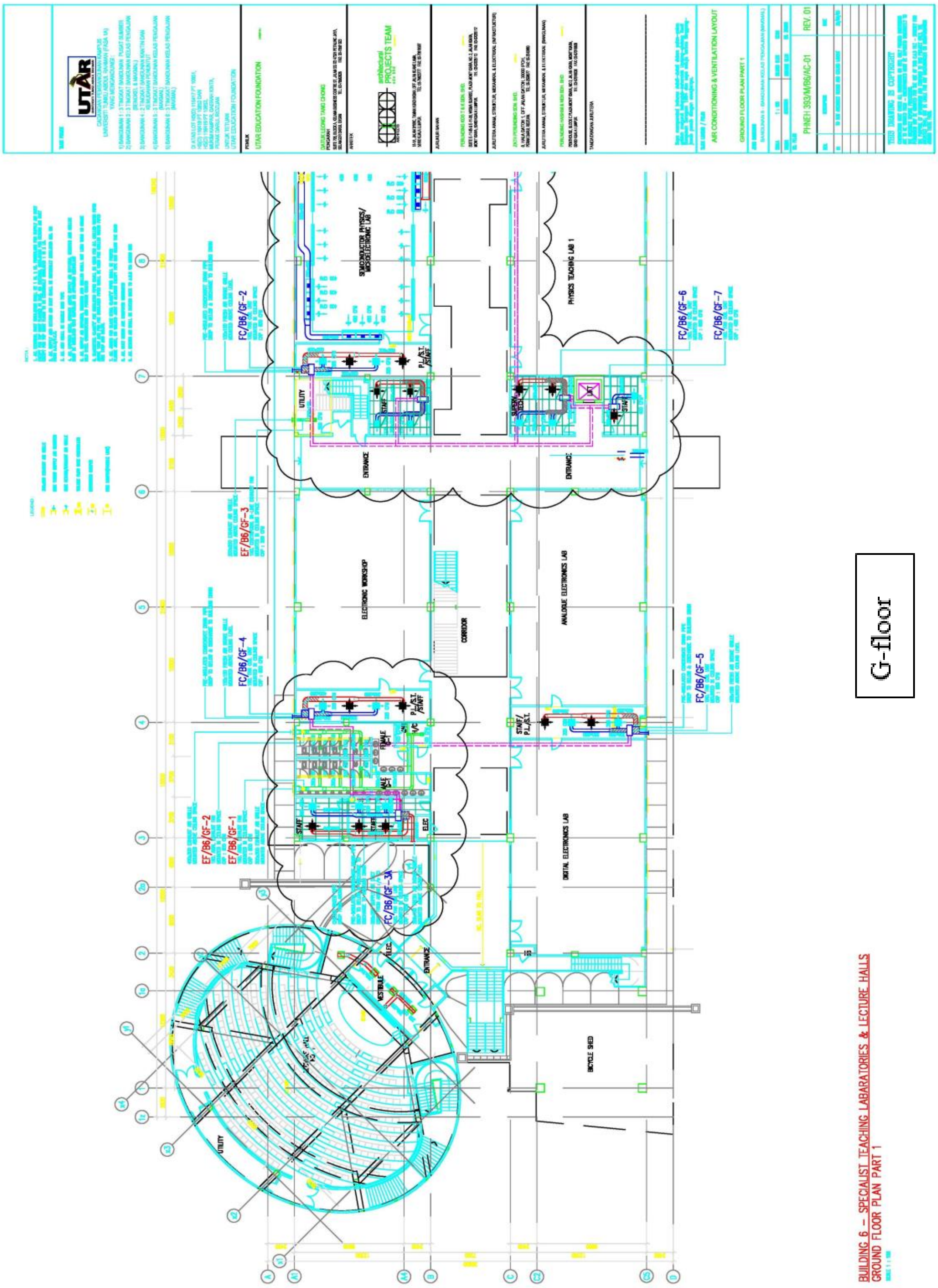
Top row is air flow temperature ℃

Bottom row is air velocity in m/s

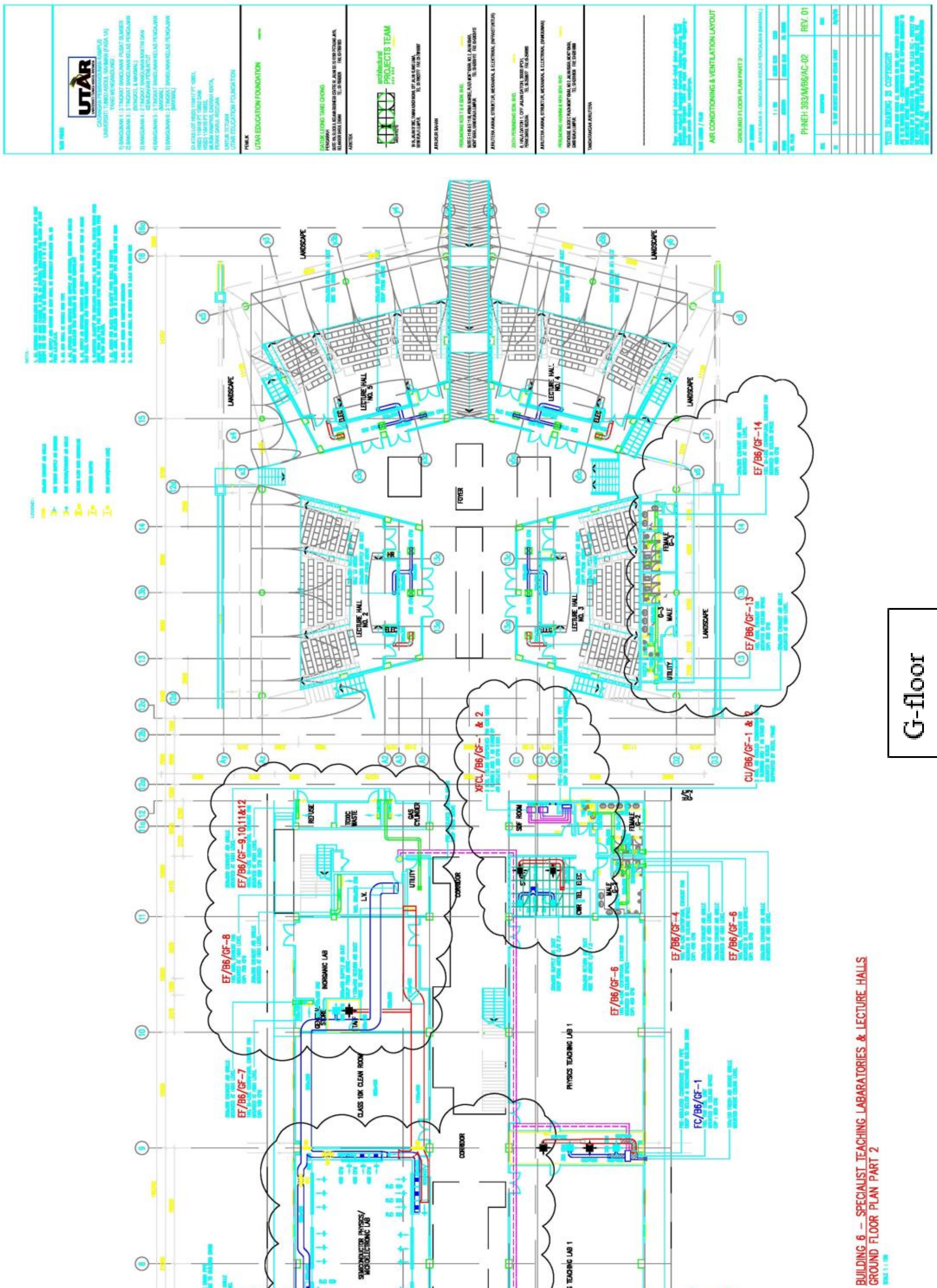
Air Vent Temp/Flow Speed

22.5 0.6	21.7 0.57	20 0.45
19 0.3	off	off
14 3.2	14 2.1	14 2.9

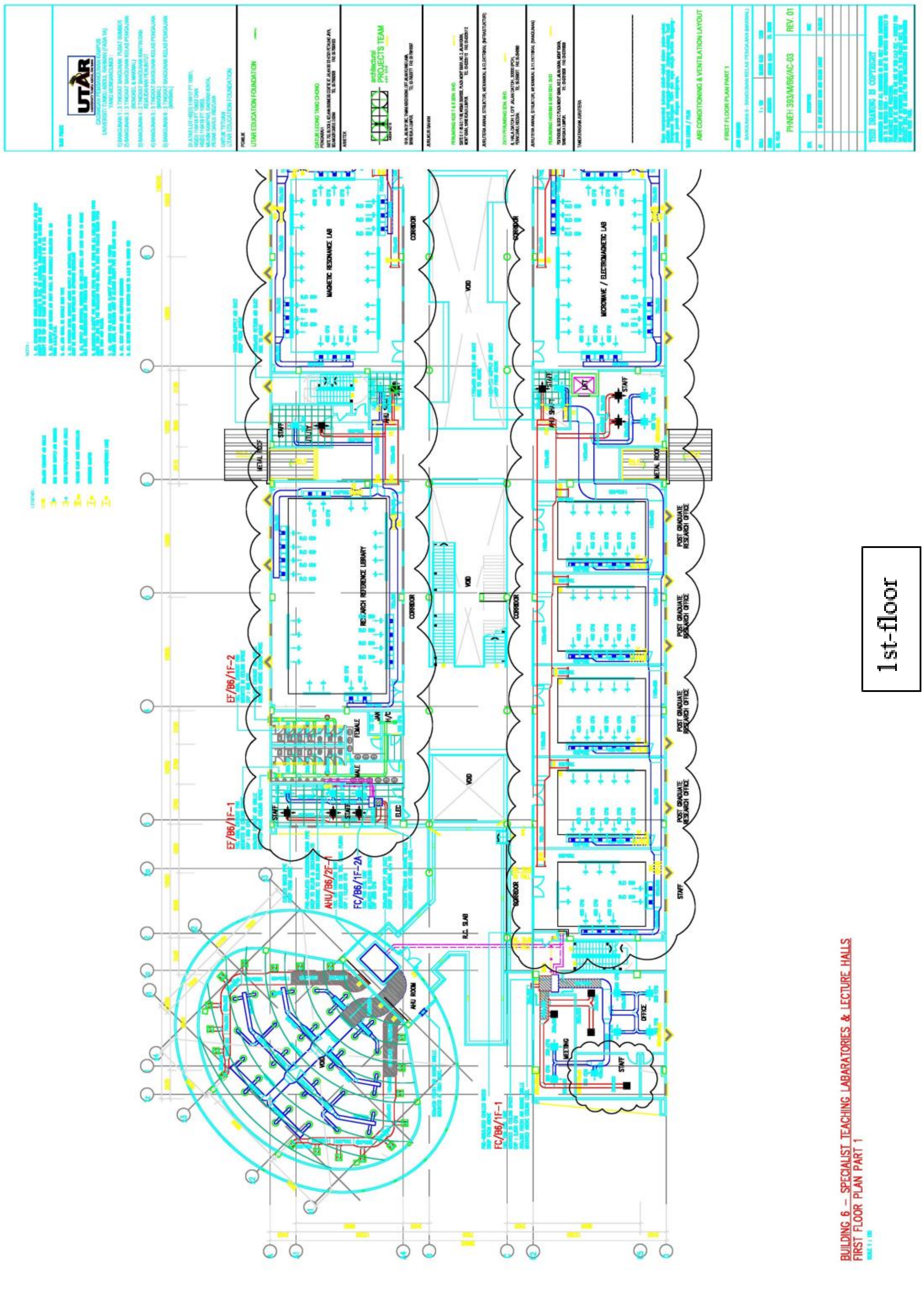
Appendix H : HVAC duct system floor plans



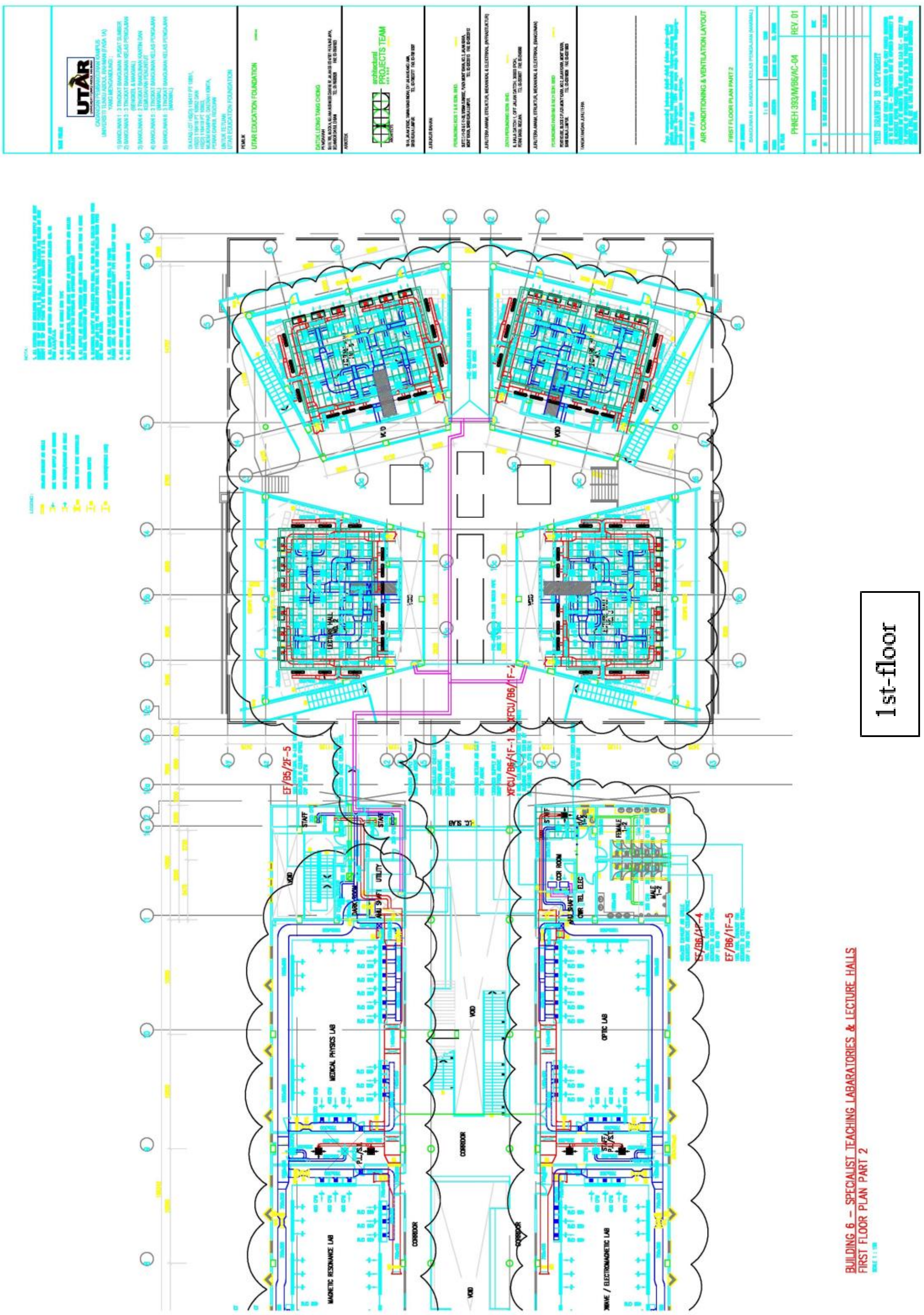
G-floor


AIR CONDITIONING & VENTILATION LAYOUT
BUILDING 6 – SPECIALIST TEACHING LABARATORIES & LECTURE HALLS
GROUND FLOOR PLAN PART 2

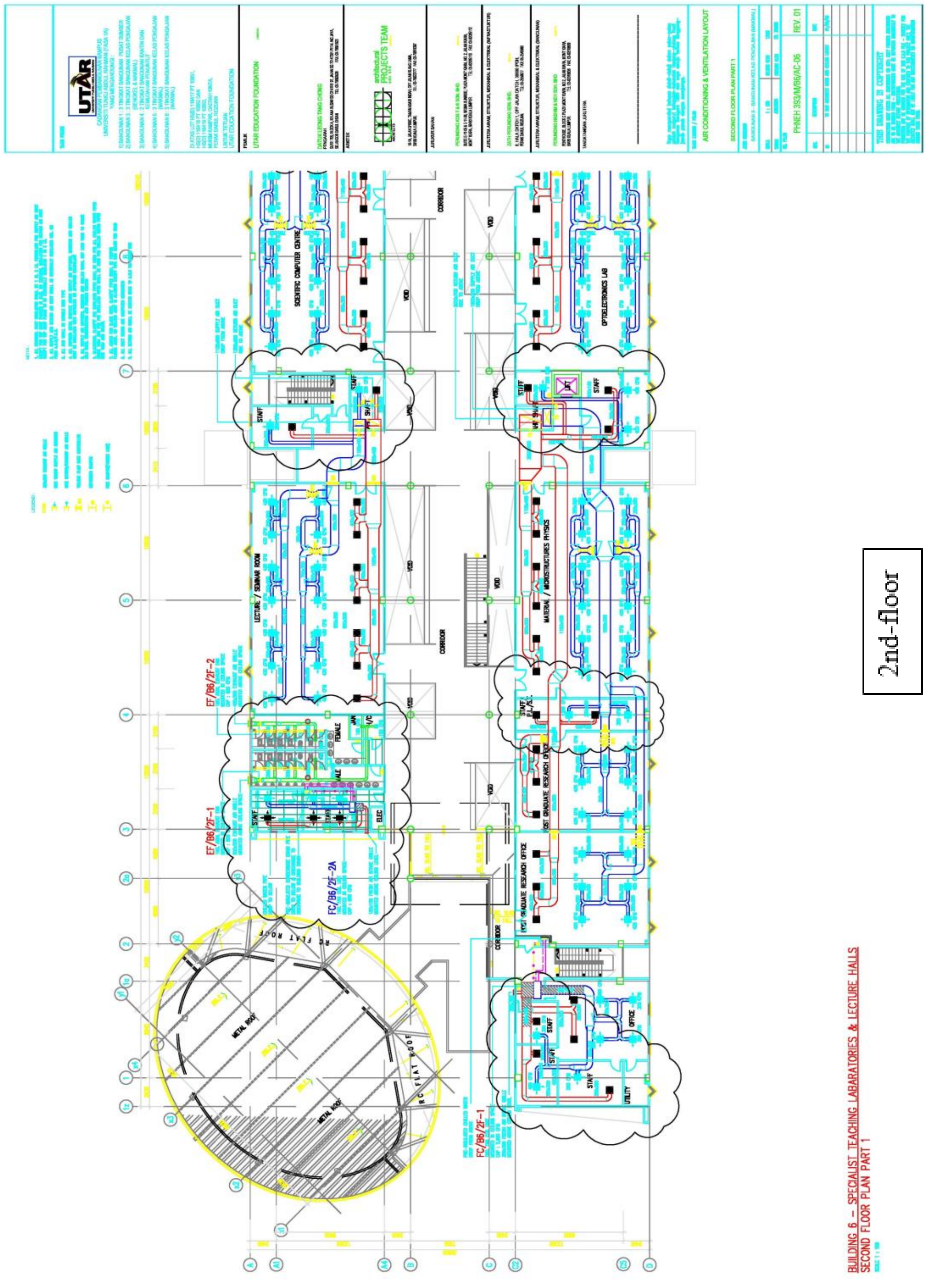
G-floor

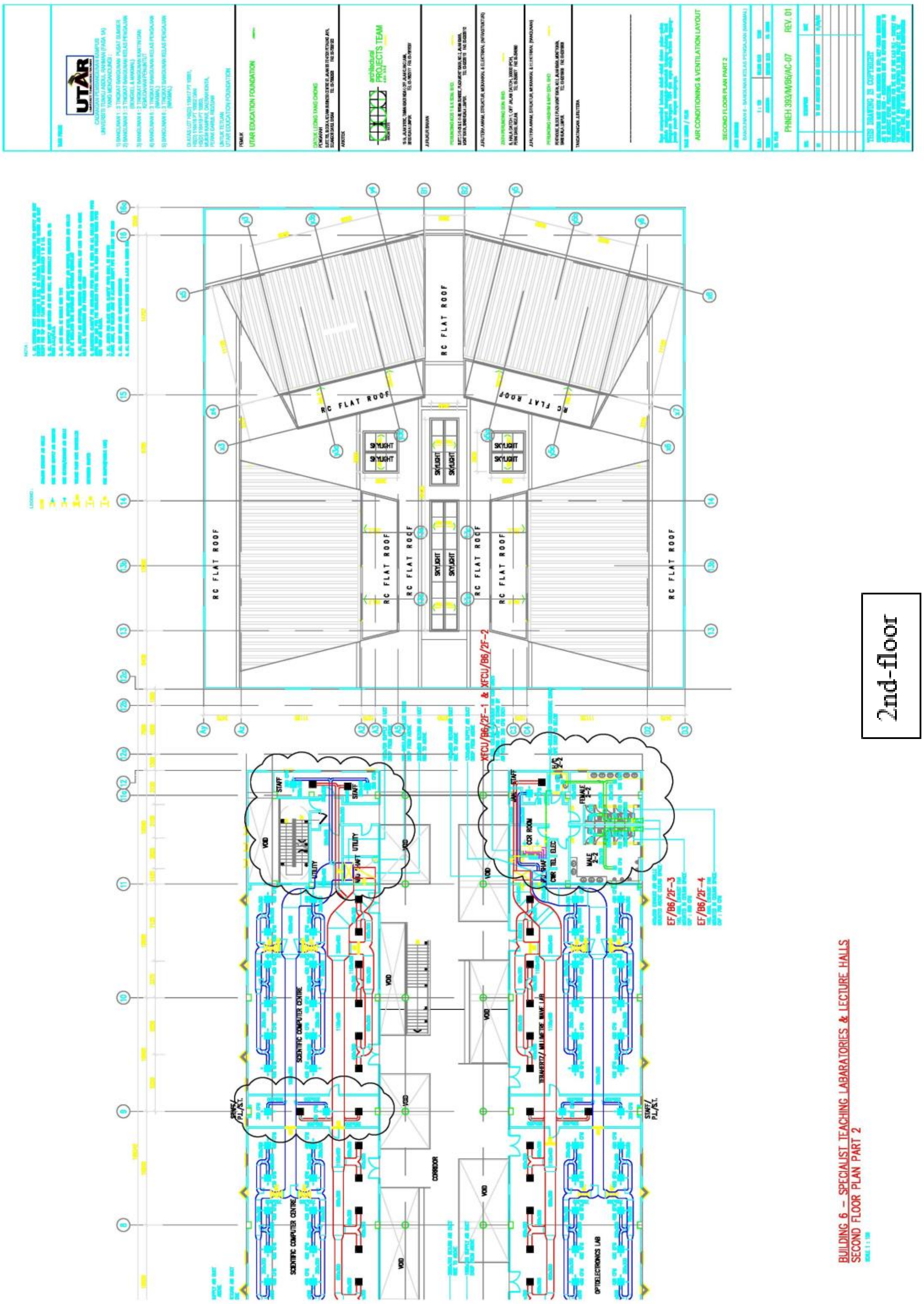

BUILDING 6 – SPECIALIST TEACHING LABARATORIES & LECTURE HALLS
FIRST FLOOR PLAN PART 1
AIR CONDITIONING & VENTILATION LAYOUT
UTAR EDUCATION FOUNDATION
MAGNETIC RESONANCE LAB
MICROWAVE / ELECTROMAGNETIC LAB
RESEARCH REFERENCE LIBRARY
POST GRADUATE RESEARCH OFFICE
CORRIDOR
VOID
AHU ROOM
R.C. SLAB
METAL ROOF
STAFF
OFFICE
EF/B6/1F-1
EF/B6/1F-2
AHU/B6/2F-1
FC/B6/1F-2A
FC/B6/1F-1

1st-floor

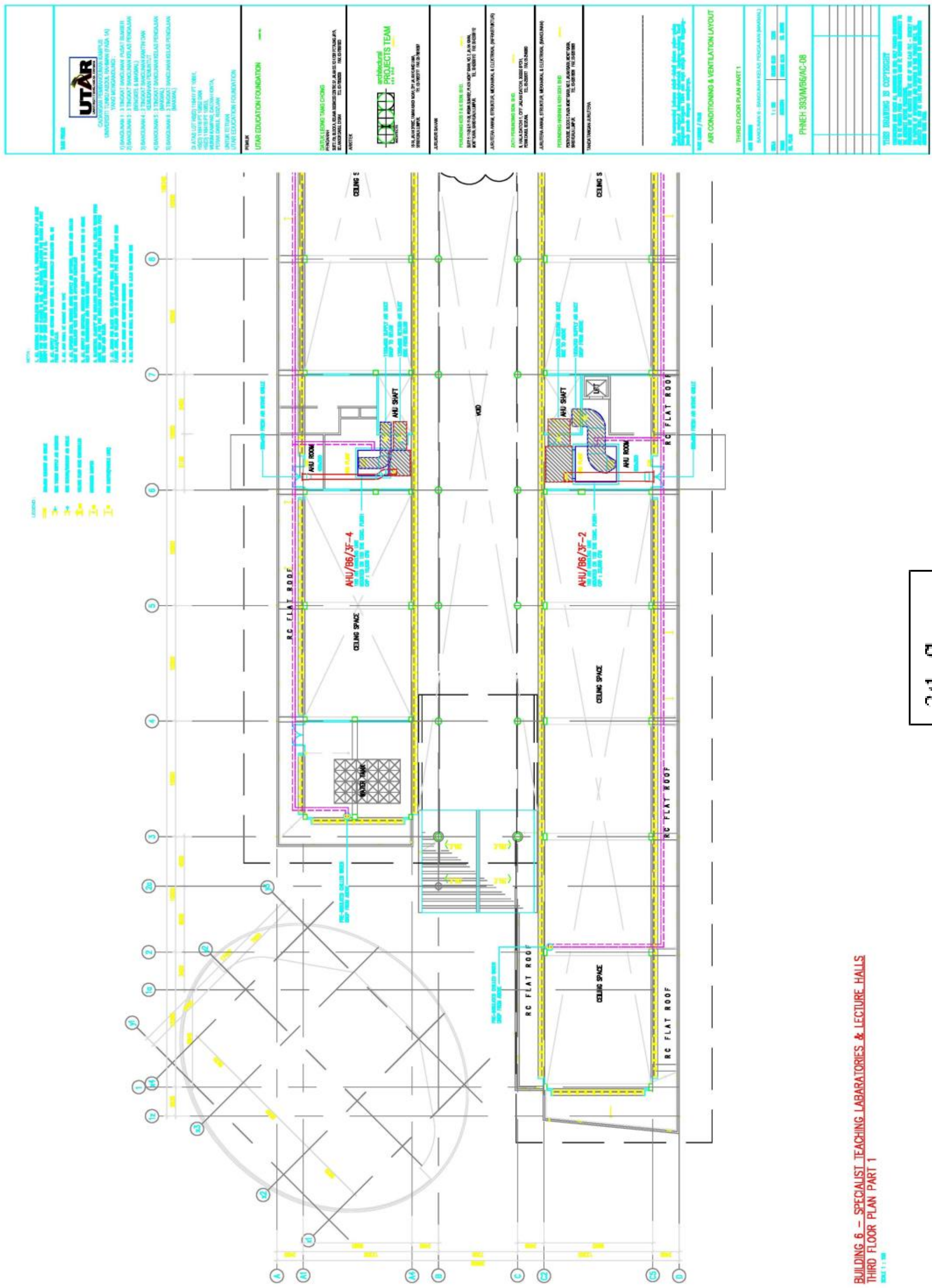


UTAR EDUCATION FOUNDATION
AIR CONDITIONING & VENTILATION LAYOUT
FIRST FLOOR PLAN PART 2
REV. 01
BUILDING 6 – SPECIALIST TEACHING LABARATORIES & LECTURE HALLS
FIRST FLOOR PLAN PART 2
MEDICAL PHYSICS LAB
OPTIC LAB
CORRIDOR
VOID
1st-floor

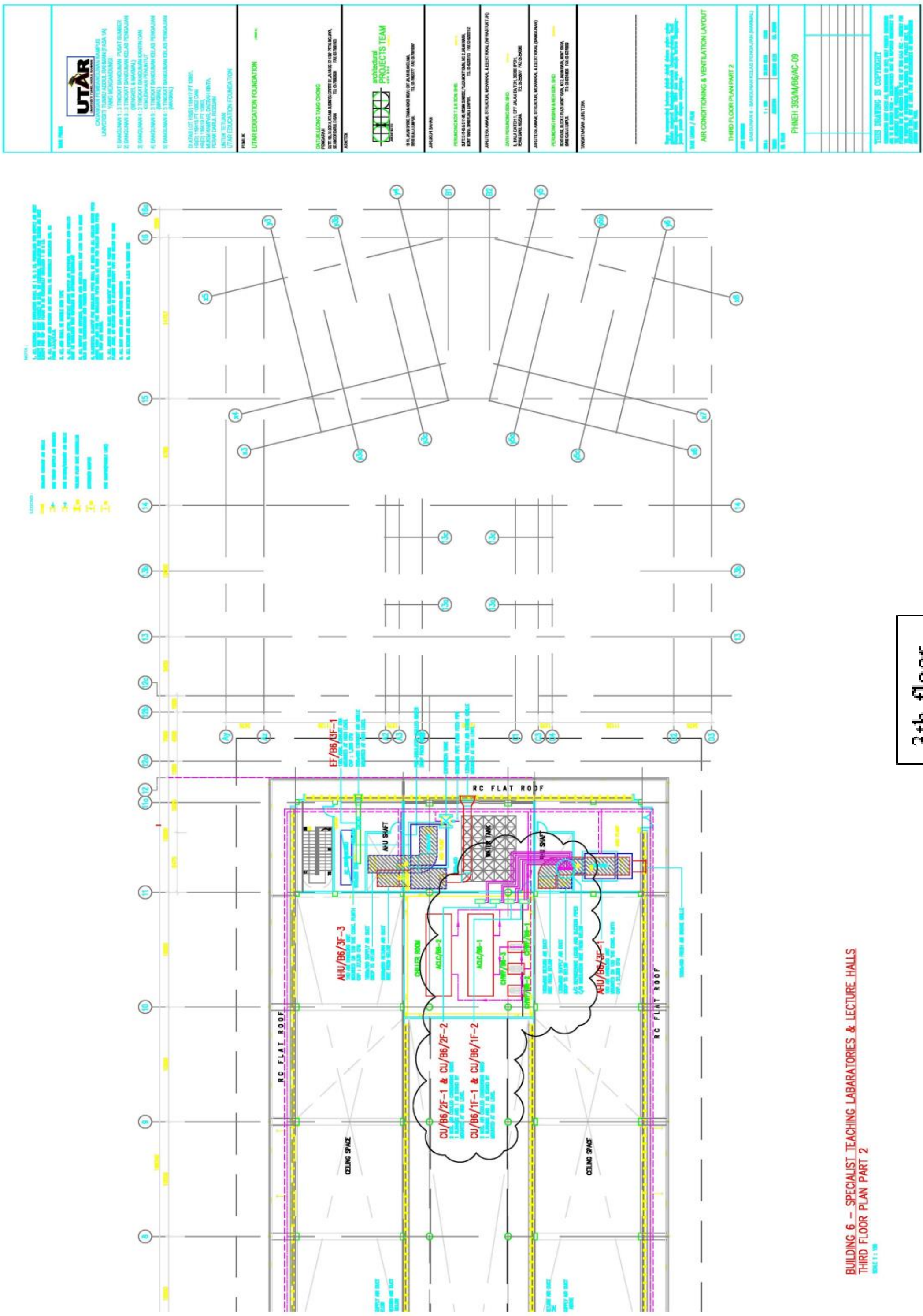

2nd-floor
BUILDING 6 – SPECIALIST TEACHING LABARATORIES & LECTURE HALLS
SECOND FLOOR PLAN PART 1
AIR CONDITIONING & VENTILATION LAYOUT
SCIENTIFIC COMPUTER CENTRE
LECTURE / SEMINAR ROOM
OPTOELECTRONICS LAB
MATERIAL / MICROSTRUCTURES PHYSICS
POST GRADUATE RESEARCH OFFICE
CORRIDOR
VOID
STAFF
OFFICE
UTILITY
EF/B6/2F-1
EF/B6/2F-2
FC/B6/2F-2A
FC/B6/2F-1
METAL ROOF
FLAT ROOF



AIR CONDITIONING & VENTILATION LAYOUT
SECOND FLOOR PLAN PART 2
UTAR EDUCATION FOUNDATION
PROJECTS TEAM
REV. 01
RC FLAT ROOF
SKYLIGHT
XFCU/B6/2F-1 & XFCU/B6/2F-2
ET/B6/2F-3
ET/B6/2F-4
SCIENTIFIC COMPUTER CENTRE
OPTOELECTRONICS LAB
CORRIDOR
VOID
2nd-floor
BUILDING 6 – SPECIALIST TEACHING LABARATORIES & LECTURE HALLS
SECOND FLOOR PLAN PART 2

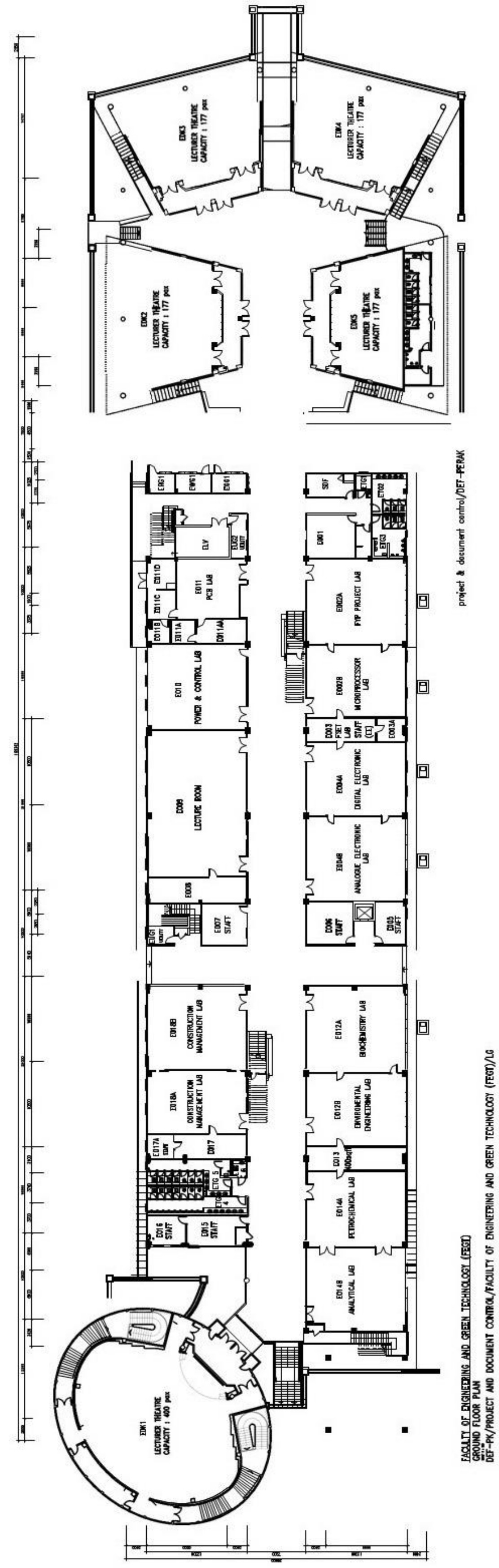

UTAR
UTAR EDUCATION FOUNDATION
AIR CONDITIONING & VENTILATION LAYOUT
AHU/B6/3F-4
AHU/B6/3F-2
AHU ROOM
AHU SHAFT
VOID
CEILING SPACE
RC FLAT ROOF
BUILDING 6 – SPECIALIST TEACHING LABARATORIES & LECTURE HALLS
THIRD FLOOR PLAN PART 1

3th-floor

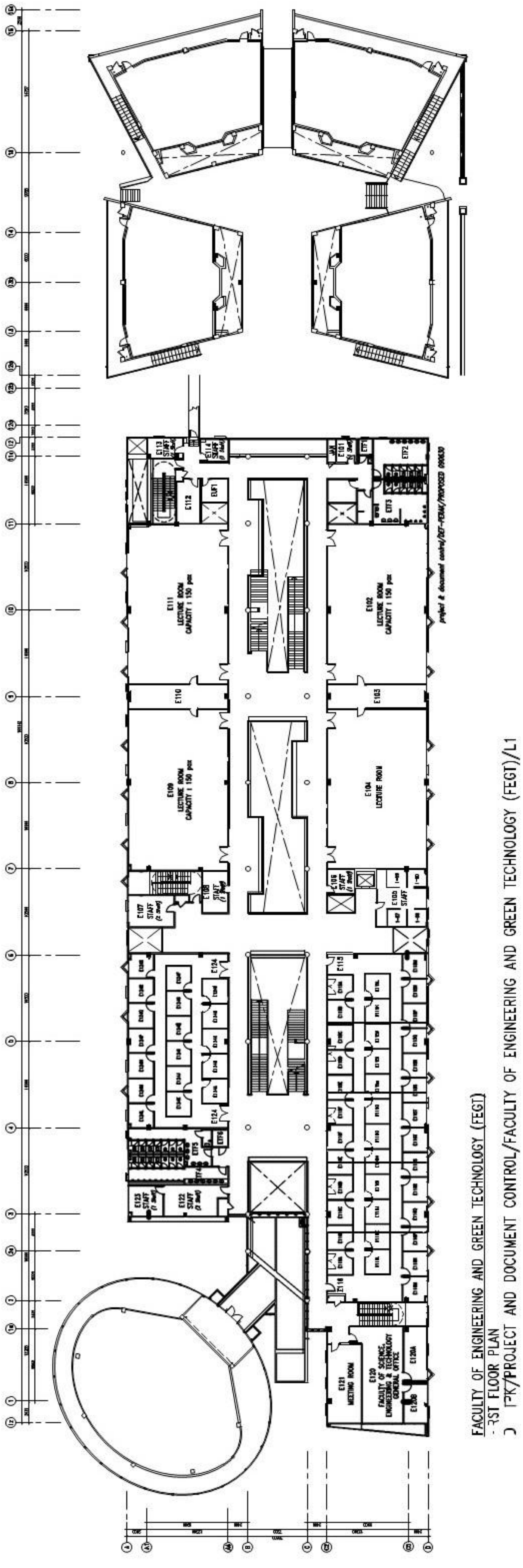

BUILDING 6 – SPECIALIST TEACHING LABARATORIES & LECTURE HALLS
THIRD FLOOR PLAN PART 2
RC FLAT ROOF
AIR CONDITIONING & VENTILATION LAYOUT
THIRD FLOOR PLAN PART 2
UTAR EDUCATION FOUNDATION

3th-floor

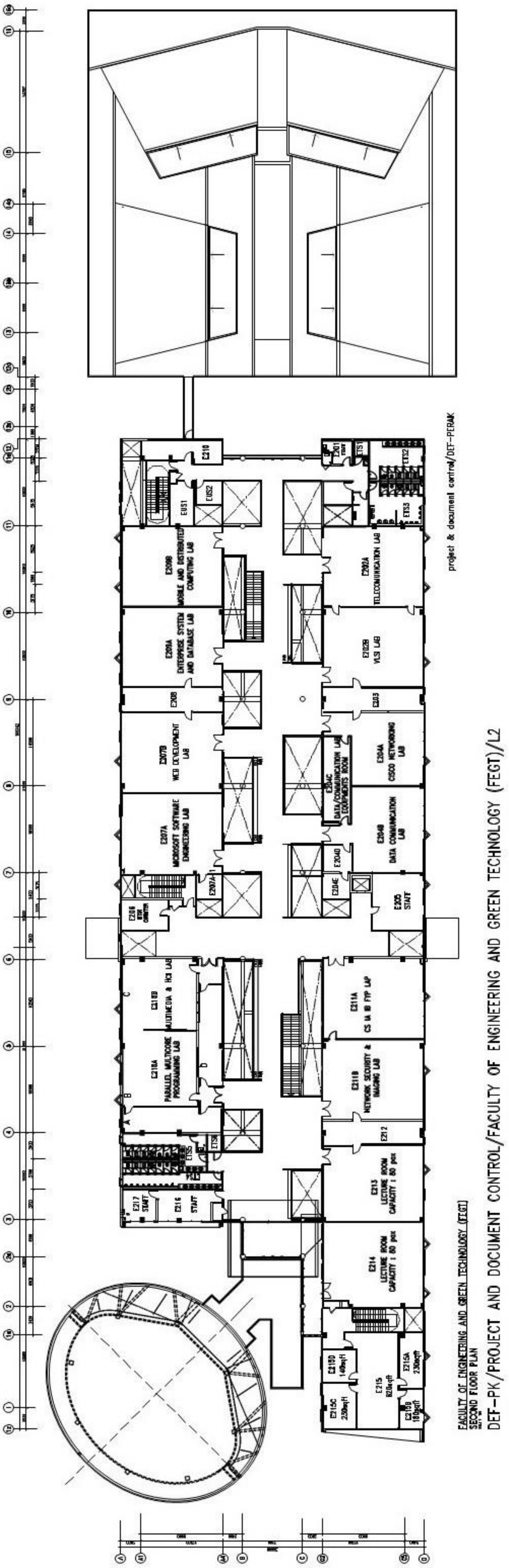
Appendix I : FEGT floor plans



G-floor


FACULTY OF ENGINEERING AND GREEN TECHNOLOGY (FEGT)
FIRST FLOOR PLAN
PROJECT AND DOCUMENT CONTROL/FACULTY OF ENGINEERING AND GREEN TECHNOLOGY (FEGT)/L1

1st-floor


project & document control/DEF-PERAK
FACULTY OF ENGINEERING AND GREEN TECHNOLOGY (FEGT)
SECOND FLOOR PLAN
DEF-PK/PROJECT AND DOCUMENT CONTROL/FACULTY OF ENGINEERING AND GREEN TECHNOLOGY (FEGT)/L2

2nd-floor

Appendix J : UTAR FEGT map location