CHAPTER 1: INTRODUCTION

1.1 BACKGROUND OF STUDY

Solar Energy

Solar energy is one of renewable energy that is increasingly attracting consumers nowadays. It is a source of energy that is available to mankind on this planet. Unfortunately, not many of human being is aware with this amazing energy. However as the new technology is becoming more high –tech and more design of solar technology is created, people are more interested in knowing the capabilities of this energy. The constraint of this energy is most probably is the cost of installation of the solar system.

Figure 1: Sun as the Solar Energy Unlimited Sources

Chancellor Complex

The new academic complex was designed by Foster and Partners, and the first phase construction was completed in 2004. The design received an Aga Khan Award for architecture in 2007. The overall layout of the new academic complex is in the shape of a 5-pointed star made up by 5 semi-circles. Board, Y. Bhg. Tan Sri Azizan Zainul Abidin.

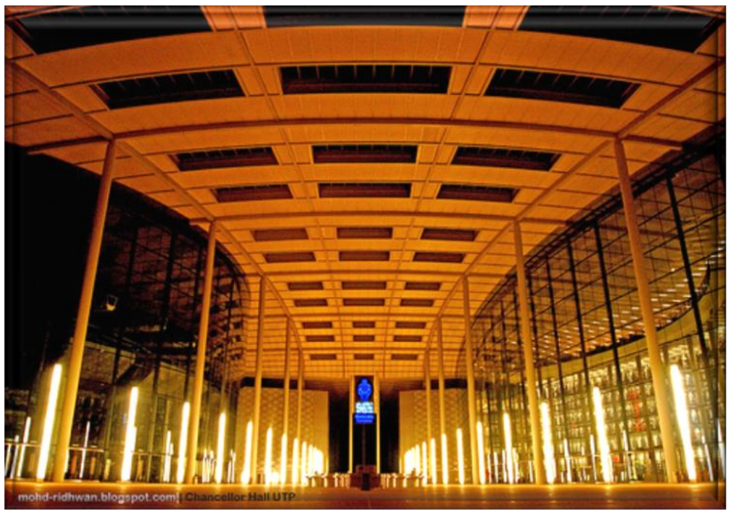

Figure 2: Chancellor Complex

The front-most point of the star where the new academic complex is facing is the elliptical chancellor complex. The chancellor complex houses the chancellor hall, the information resource center, security department, finance department and some of the other important administrative department offices. It is affectionately dubbed the "UFO building" by the students due to its futuristic design.

1.2 PROBLEM STATEMENT

Petroleum is the most widely used energy source, is a fluid and is easily transportable with currently estimated world wide reserves of 12.7 Q [1]. To further complicate matters, the extraction of petroleum will lead to yield considerable carbon dioxide and other pollutants (a 1,000 Mwe power plant burning oil emits over 158 tons of pollutants into the air each year [2]. Gas and coal are also among the most plentiful fossil fuel energy sources that have the same effect to the environment. As our Green House effect has lead us to be more aware with the needs to save our sickening earth.

Other concern is mainly about the availability of this fossil fuel. This type of energy is considered to be finite. It will loose its sources and other energy needs to be created. In other words, to replaced them. This is when renewable energy came in picture. Solar energy as stated is one of the renewable energy that is amazingly shines the earth continuously without failed. It is a source of energy which are more or less continuously refreshed (by nature or by man assisting nature) and which may be considered to be available, at potentially their currents level of supply, for millions of years.

The solution to this problem is to use the available and un-finite resources called renewable energy. In order to produce a clean energy for our world, one of the options is to use the Solar Energy as one of the alternative energy.

1.3 OBJECTIVE AND SCOPE OF STUDY

Objectives:

1. To identify the power consumption and energy needed for Chancellor Complex.
2. To check the solar energy available for the modules.
3. To estimate and suggest the numbers of modules needed to fit the power consumption in Chancellor Complex.
4. To analyze the basic mechanical considerations of installing the modules on the roof top of Chancellor Complex.
5. To analyze the cost analysis of installing the modules on the Chancellor Complex.
6. To recommend some improvement for future study.

Scope of Study:

This project will focus on;

- Location analysis
- Basic calculation on Power/Energy Consumption, Mechanical considerations, the Photovoltaic and the Photovoltaic system
- Cost evaluations

CHAPTER 2: LITERATURE REVIEW

2.1 RENEWABLE ENERGY (SOLAR ENERGY)[3]

Solar energy, a radiant light and heat from the sun that has been harnessed by humans since the ancient times using a range of ever-evolving technologies. Solar radiation along with secondary solar powered resources such as wind and wave power, hydroelectricity and biomass, is account as the available renewable energy on earth. Unfortunately, only a fraction of the available solar energy is used.

2.2 PHOTOVOLTAICS

Photovoltaic convert sunlight directly into electricity. “Photo” refers to light and “voltaic” to electricity. A PV cell is made of a semiconductor material, usually crystalline silicon, which absorbs sunlight. The electricity can be supply into the grid or off grid. There are a few types of Photovoltaic available.

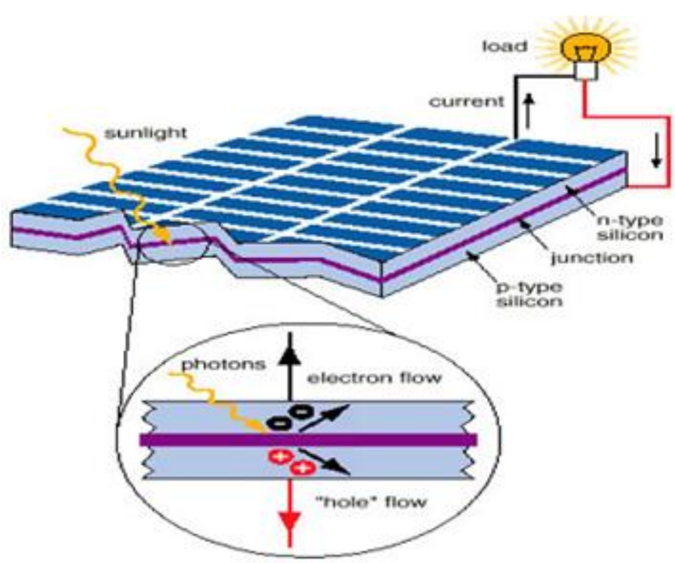

Figure 3: Anatomy of a Photovoltaic

When a photon hits a piece of silicon, one of three things can happen: [3]

1. The photon can pass straight through the silicon — this (generally) happens for lower energy photons,
2. The photon can reflect off the surface,
3. The photon can be absorbed by the silicon, if the photon energy is higher than the silicon band gap value. This generates an electron-hole pair and sometimes heat, depending on the band structure.

When a photon is absorbed, its energy is given to an electron in the crystal lattice. Usually this electron is in the valence band, and is tightly bound in covalent bonds between neighboring atoms, and hence unable to move far. The energy given to it by the photon "excites" it into the conduction band, where it is free to move around within the semiconductor. The covalent bond that the electron was previously a part of now has one fewer electron — this is known as a hole. The presence of a missing covalent bond allows the bonded electrons of neighboring atoms to move into the "hole," leaving another hole behind, and in this way a hole can move through the lattice. Thus, it can be said that photons absorbed in the semiconductor create mobile electron-hole pairs.

A photon need only have greater energy than that of the band gap in order to excite an electron from the valence band into the conduction band. However, the solar frequency spectrum approximates a black body spectrum at ~6000 K, and as such, much of the solar radiation reaching the Earth is composed of photons with energies greater than the band gap of silicon. These higher energy photons will be absorbed by the solar cell, but the difference in energy between these photons and the silicon band gap is converted into heat (via lattice vibrations — called phonons) rather than into usable electrical energy.

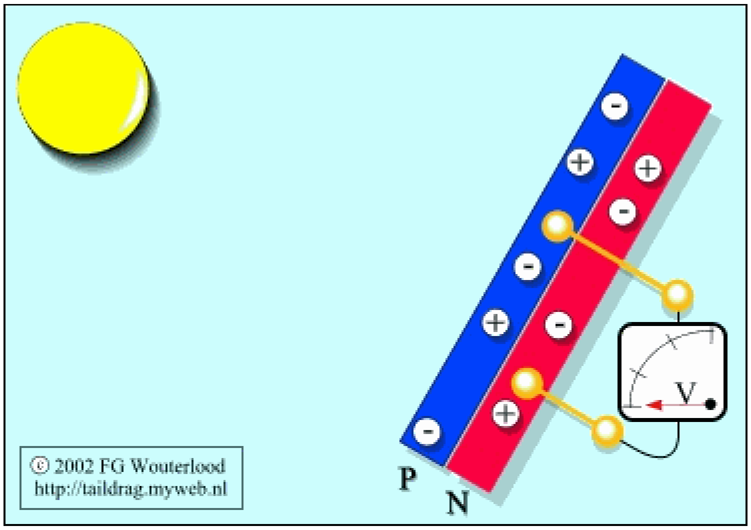

Figure 4: P-N Junction

The most commonly known solar cell is configured as a large-area p-n junction made from silicon. As a simplification, one can imagine bringing a layer of n-type silicon into direct contact with a layer of p-type silicon. In practice, p-n junctions of silicon solar cells are not made in this way, but rather by diffusing an n-type doping into one side of a p-type wafer (or vice versa).

If a piece of p-type silicon is placed in intimate contact with a piece of n-type silicon, then a diffusion of electrons occurs from the region of high electron concentration (the n-type side of the junction) into the region of low electron concentration (p-type side of the junction). When the electrons diffuse across the p-n junction, they recombine with holes on the p-type side. The diffusion of carriers does not happen indefinitely however, because of an electric field which is created by the imbalance of charge immediately on either side of the junction which this diffusion creates. The electric field established across the p-n junction creates a diode that promotes charge flow, known as drift current, that opposes and eventually balances out the diffusion of electron and holes. This region where electrons and holes have diffused across the junction is called the depletion region because it no longer contains any mobile charge carriers. It is also known as the space charge region.

Figure 5: Different types of Photovoltaic

Benefits of Photovoltaics:

- No emissions in use
- Technically reliable (most of the guaranteed last between 20-25 years warranty)
- Avoidance of climate change levy for non-domestic buildings
- Helping to meet our national, regional or local renewable energy and carbon dioxide emission targets
- PV produce electricity at point of need so energy is not lost moving it from one place to another
- One of the few renewable technologies that can be used very successfully in urban areas
- Architectural integration – PVs can be added almost invisible to buildings, can be used as design element or can lead the architectural concept of a building

2.3 SOLAR RADIATION [4]

To a good approximation, the Sun acts as a perfect emitter of radiation; black body, at a temperature close to 5800K. The resulting or can be count as the average energy flux incident on a unit area perpendicular to the beam outside the Earth's atmosphere is known as the solar constant; S=1367 W/m^2. As the Sun radiates at the amount, it enters the solar rays will get absorbed by the Ozone, carbon monoxide and dioxide and water particles. This absorption will depends on the thickness of the atmosphere,; AM (Air Mass) through which the rays travel. Air Mass depends on upon time of the day, time of the year, altitude and latitude of the place.

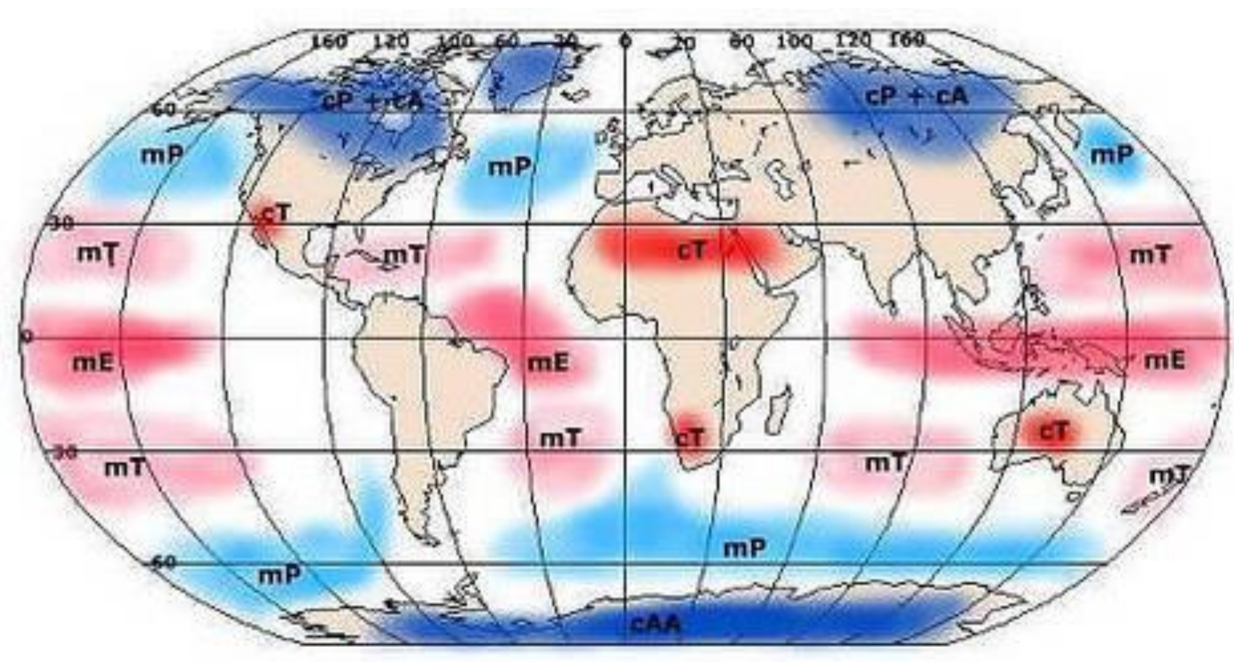

Figure 6: Air Mass differs at every part of Earth (Malaysia in the mE region; m: monsoon; E: Equatorial)

Thus in general, the total power from a radiant source falling on a unit area is called as irradiance. As mention above, the total average energy flux incident on the Earth is obtained by multiplying the S by πR^2, where R is the Earth radius (area of disk presented to the Sun's radiation by the

Earth). The total area of the Earth; $4\pi R^2$ being divided by $S\pi R^2$ will give 342 W/m^2 as the average flux incident on a unit surface area:

$$\frac{S}{4} = 342W/m^2$$

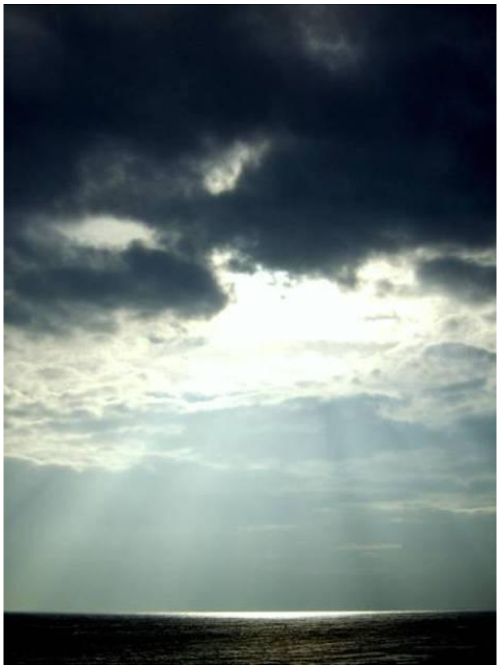

Figure 7: Sunlight shining through clouds Dunstanburg, England

To calculate the amount of sunlight reaching the ground, both the elliptical orbit of the Earth and the attenuation by the Earth's atmosphere have to be taken into account. The extraterrestrial solar illuminance (E_{ext}), corrected for the elliptical orbit by using the day number of the year (dn), is:

$$E_{\mathrm{ext}} = E_{\mathrm{sc}}\left[1 + 0.034 \cdot \cos\left(2\pi\frac{\mathrm{dn}-3}{365}\right)\right],$$

Where dn=1 on January 1; dn=2 on January 2; dn=32 on February 1, etc. In this formula dn-3 is used, because in modern times Earth's perihelion, the closest approach to the Sun and therefore the maximum E_{ext}, occurs around January 3 each year.

The solar illuminance constant (E_{sc}), is equal to 128×10^3lx. The direct normal illuminance (E_{dn}), corrected for the attenuating effects of the atmosphere is given by:

$$E_{\mathrm{dn}} = E_{\mathrm{ext}}\, e^{-cm},$$

“c” is the atmospheric extinction coefficient and “*m*” is the relative optical air mass.

On Earth, solar radiation is obvious as daylight when the sun is above the horizon. When the direct radiation is not blocked by clouds, it is experienced as sunshine, combining the perception of bright white light (sunlight in the strict sense) and warming. The warming on the body, the ground and other objects depends on the absorption (electromagnetic radiation) of the electromagnetic radiation in the form of heat.

But the seasonal and latitudinal distribution and intensity of solar radiation received at the Earth's surface also varies. The earth receives energy from the sun at the rate of 10^{16} KJ per day. As the sun shines for an average of twelve hours everyday, the Earth will receives about 7.2×10^{18} KJ.

2.4 THE EARTH AND THE SUN

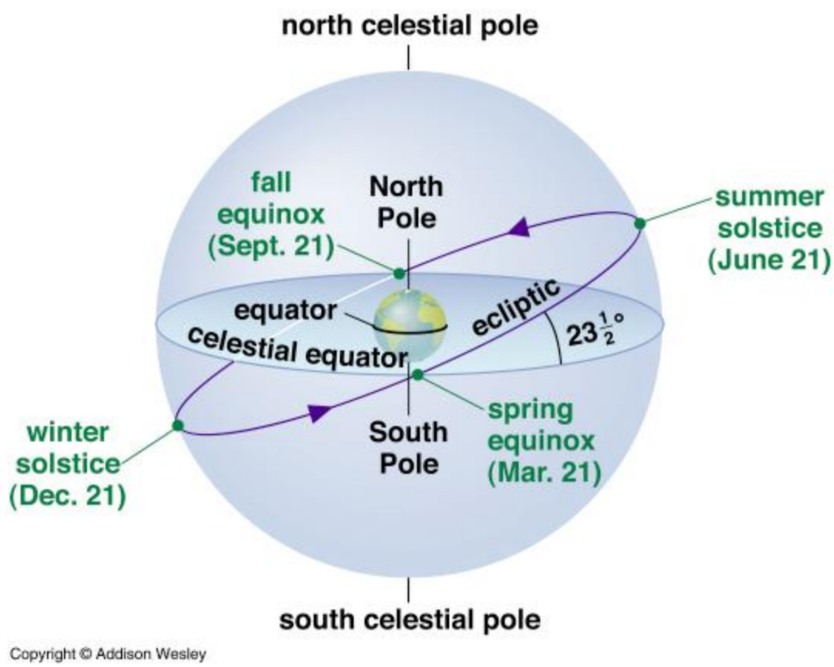

Figure 8: the Celestial Sphere with the apparent yearly motion of the Sun

The Earth revolves around the Sun in an elliptical orbit with the Sun in one of the foci. The plane of this orbit is called the elliptic. The time taken for the Earth to complete rotating this orbit is defines as one year. The relative position of the Sun and Earth is conveniently represented as the celestial sphere around the Earth (Figure 8). The equatorial plane intersects the celestial sphere in the celestial equator, and the polar axis in the celestial poles. The motion of the earth round the Sun is depicted as in the apparent motion of the Sun in the elliptic which is tilted at 23.45^o to the celestial equator. The angle between the line joining the centers of the Sun and the Earth and the Equatorial plane is called solar declination and denoted by δ.[5]

$$Solar\ declination, \delta = \pi \frac{23.45}{180} sin\left(2\pi \frac{284 + dn}{365}\right) \qquad (in\ radians)$$

Malaysia lies entirely in the equatorial region. The climate is governed by the regime of the north-east and south-west monsoons which blows alternatively during the year. The period of change between the two monsoons is being marked by heavy rainfall. The country experiences more than 170 rainy days per year. Ambient temperature remains uniformly high throughout the year, ranging form 26.0 to 32.0 centigrade. Most locations have relative humidity of 80-88%, rising to nearly 90% in the highland area, and never fall below 60%. The monthly average daily solar irradiation in Malaysia is 4.21kWh/m^2 – 5.56kWh/m^2, with the average monthly sunshine duration ranging from 4 to 8 hours. The highest irradiation is 6.81kWh/m^2 in August and November. Meanwhile, the lowest can be achieved is 0.61 kWh/m^2 that is in December. Northern region and in East Malaysia have the highest potential for solar potential for solar energy application due to its high solar radiation throughout the year. [6]

Solar radiation and the position of the panel in regard to the incoming radiation play an important role in improving the efficiency as well as increasing the energy which can be harnessed from the Sun.

2.5 CASE STUDIES

PV system is not vey new in Malaysia. There are a few examples of this solar roof being installed in our country. Some of them are still under research and some of them has been used thoroughly to supply power to the whole building. Below are some of the case studies that the author takes as references.

2.5.1 Case Study I: Pusat Tenaga Malaysia Zero Energy Office (ZEO) Building [7]

Figure 9: Aerial view of ZEO building

PTM is showcasing sustainable and green building design in Malaysia and in the South East Asia Region. The first of its kind in Malaysia, PTM ZEO sets a new standard of energy efficiency by generating sufficient electricity from its BIPV system for the entire office use. A ceiling energy index target of less than 50kWh/m^2 year has been set for this building. Four different PV systems with different technologies will be installed. First, using the biggest comprises 47.28 kWp of polycrystalline module on the main roof and amorphous silicon units with a capacity of 6.08 kWp at the second roof. At the car park roof will be having integrated monocrystalline PV modules with a capacity of 27 kWp and at the atrium using the glass-glass semi transparent PV modules. All of these systems will be connected to high quality and highly efficient grid-connected inverters complete with PV monitoring system.

2.5.2 Case Study II: Enterprise 4, Technology Park Malaysia: The Largest Rooftop Photovoltaic – Grid Connected Power Project in Asia Pacific [8]

Figure 10: Aerial view of Technology Park Malaysia

TPM or Technology Park Malaysia is one of the pioneer usages of solar energy to power to its entire network system at Enterprise 4. TPM is a solar powered, grid-connected system with the UPS battery bank, a generator back-up that ensures uninterrupted and secure power. This current development is the largest solar array project not only in Malaysia, but also in Asia Pacific. The solar project is dedicated to the building's network systems. This is a novel application of photovoltaic energy, and one of the first of its kind. The project at Enterprise 4 not only ensures renewable and reliable energy for TPM IT's server rooms and equipment but also serves to fulfil the tenants' network needs. It highlights the possibilities of utilising photovoltaic energy in applications that go beyond the ordinary.

TPM is involved in R&D in solar energy as this area opens up potential for an extremely lucrative burgeoning local industry. Current market trends are dictated by overseas monopolies that sell silicon semiconductor materials at exorbitantly marked-up prices.

Statistics suggest that what begins as sand that is priced at barely a few cents per kilogram, undergoes processing and progressively increases due to inflated manufacturing costs. The final product is sold as wafer or photovoltaic material that costs anywhere between US$ 400-800/Kg (Ciszek, "Silicon Growth Technology from Photovoltaics", 1994). The ability to produce silicon within Malaysia not only opens up the doors to new technologies, but also allows us to produce silicon for our own usage at a competitive and reasonable market value prices. Overall, this enables the full utilisation of natural resources that are readily available domestically, in addition to the natural sunlight energy that is abundant in Malaysia. It also stimulates the local energy generating market to move towards diverse, and recyclable energy.

The system at Enterprise 4 comprises 4,824 fixed mounted roof modules, facing 15 degrees in the southern direction, having a maximum capacity of 362 KW.

CHAPTER 3: METHODOLOGY

1.1 RESEARCH METHODOLOGY

Figure 11: Research Methodology

Initiation of Project

During this stage, the author did a topic selection. In order to a have a brief understanding, the author also did a minor research on it.

Project Understanding

Further understanding was made in order to have a better stand on the selected project topic. At this stage, the author identified the objective of the project.

Scope Selection

At this stage, the author reviewed the objectives, the author managed to narrow down the objective and scope of study.

Data Gathering

All data and other findings was gathered and initial analysis is initiated. The results was made based on the findings.

3.2 MILESTONE

Table 1: Milestone for FYP II

No	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Understanding the Feasibility Concept														
2	Preliminary Research Work														
3	Cont'd on the Sun and Earth Orientation														
4	Cont'd on the PV panels														
5	Collecting on the calculations detail and theory to be used														
6	Location Assessment														
7	Submission Progress Report														
8	Project Work														
9	Report Preparation														
10	Submission of Final Report														
11	Oral Presentation														

CHAPTER 4: DATA GATHERING, DISCUSSIONS AND RESULTS

4.1 TRONOH

University Teknologi PETRONAS is situated in Tronoh Perak. By having ; Latitude: 4° 25' 0 N, Longitude: 100° 58' 60 E .

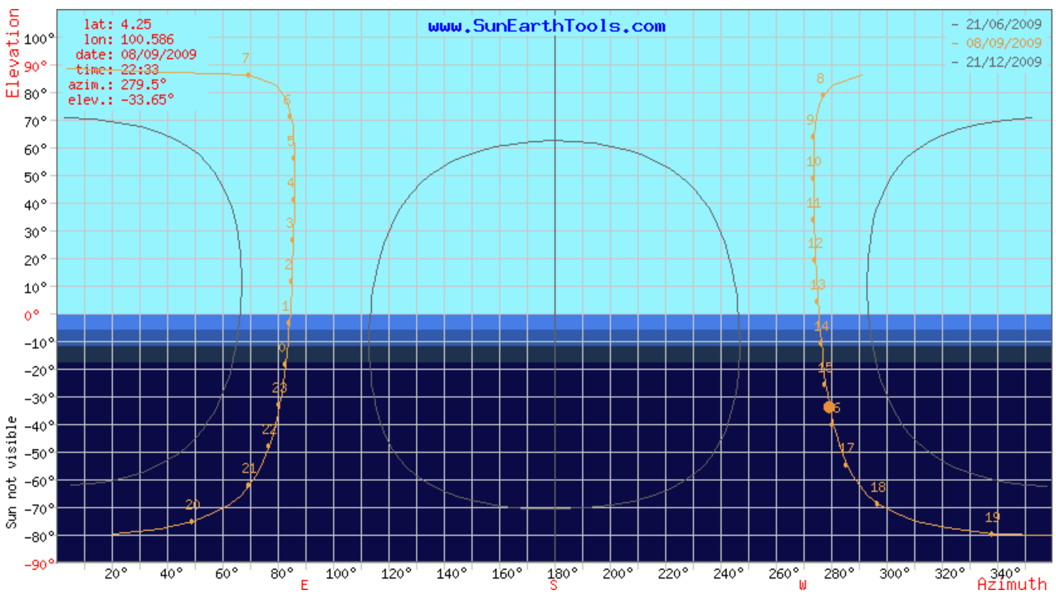

Figure 12: Sun Positioning Chart

Universiti Teknologi PETRONAS enjoys a moderate amount of sunlight where the annual average daily solar radiation is ranging between 4.21 kWh/m^2 to 5.56 kWh/m^2. The highest solar radiation was estimated at 6.38 kWh/m^2 in August and November while the lowest was 0.61 kWh/m^2 in December. Most radiation data are measured for horizontal surfaces. Truthfully, in only Penang and Kuala Lumpur have the measured data on the direct and diffuse solar radiation.

Figure 13: Tronoh, Perak

Figure 14: Aerial View of Universiti Teknologi PETRONAS

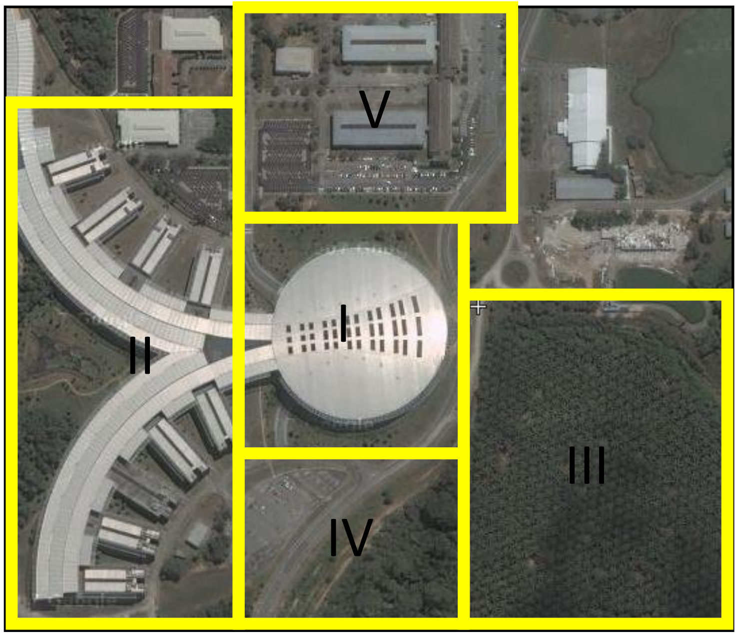

Figure15: Aerial View of Chancellor Complex

Location I: Chancellor Complex

Location II: New Academic Building

Location III: Oil Palm Plantation

Location IV: Idle Land / Site Vegetation

Location V: Car Park and Old USM Building

4.2 SITE LOCATION: CHANCELLOR COMPLEX

Description about the site:

- Gross floor area: c. 40,000 square metres
- Height: 21 metres high
- Roof Diameter: 150 metres round
- Building separated into two crescent shape halves.
    - Half accommodates the resource centre
    - Half accommodates the Chancellor Hall
    - These two halves are connected by a covered public Plaza

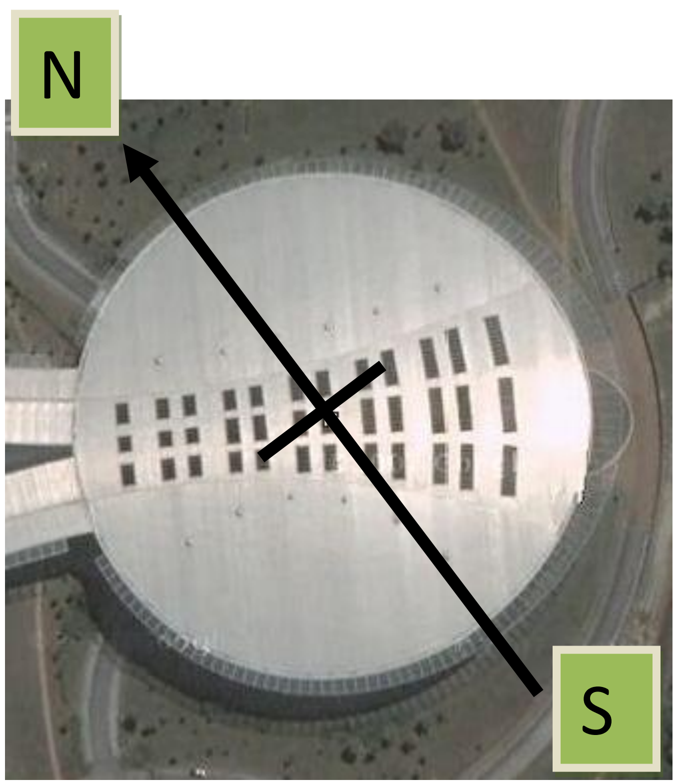

Figure16: North - South Direction

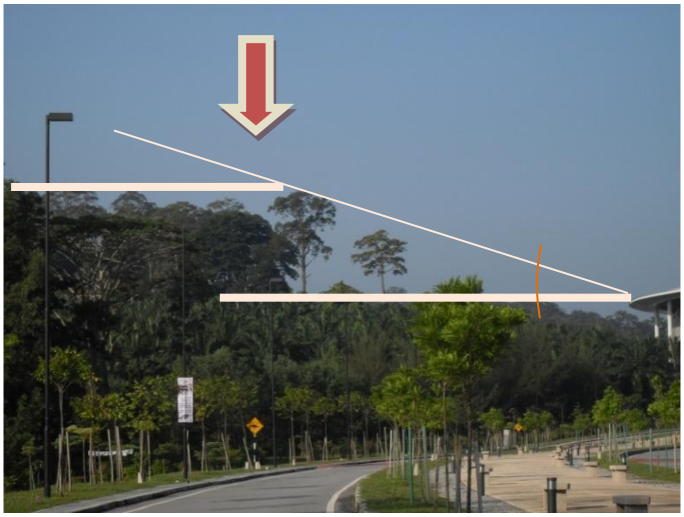

Figure 17: The Elevation View of the Site Vegetation - Chancellor Complex

The Chancellor Complex is located at 4°22’55” N; 100°58’10” E, where the building has a diameter of 150 metres round shape. As in Figure 17, there are 5 locations that needed to be screening its potential of minimizing the performance of installing Photovoltaic on the Chancellor Complex Roof. By looking at Figure 4, South-facing is in the Idle Land / Site Vegetation.

Figure18: The East View of Chancellor

The height vegetation on the hill has the possibilities on giving a shading impact on the roof. Advantageously the distance between the site vegetation and the Chancellor Complex are not very near as the trees grown are already at its peak height. The Oil Palm Plantation is not a problem, because, its height is known not to be tall as 21 metres taller than the Complex as mature trees are single-stemmed, and grow to 20 m tall.[9] The South –facing (the orientation) is exposed liberally to the incoming sunlight from the South. There is no requirement to remove the site vegetation/idle land as UTP wants to maintain the nature environment on the hill side.

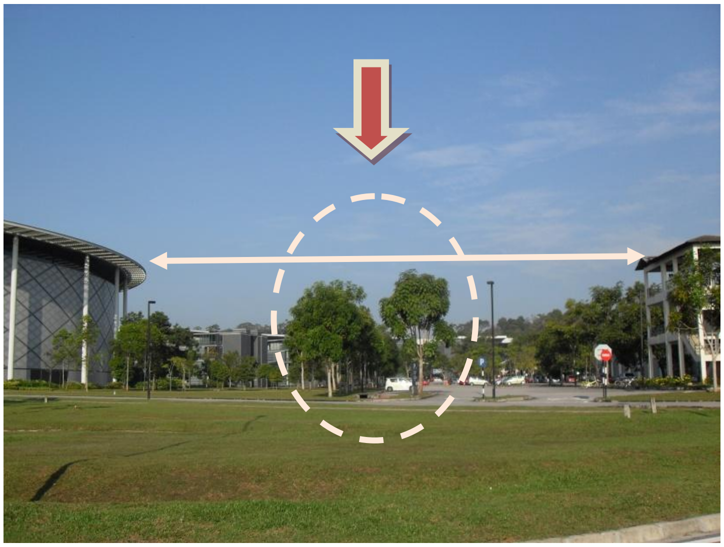

Figure 19: The view of Chancellor Complex - USM old buildings

The East Side of the Chancellor Complex, as in the Figure 19, is the USM old buildings and parking lot. There is no potential of shading area that is concerns. A few of trees are still the phase of growing. On the other side, the old building is a distance away, where it did not really caused an impact after a few years to come. This applies to the other side of chancellor complex.

Thus, the site is free of obstruction and therefore judge to be suitable. There are some potential losses at some diffuse radiation due to the site vegetation / idle land but it is not very significant. Plus, the USM old building and car park can be marked as dead zone. Chancellor Complex can be considered to have a good solar access.

Proposed installation of PV: Roof-Mounted. (Building Integrated)

Table 3: Advantages vs. Disadvantages

Advantage	Disadvantage
No extra land needed	**Non-easy access for installation and maintenance**
Require shorter wire runs	**Limitation to future PV expansions**
Less vulnerable to vandalism	**--**
Aesthetically appealing	**--**

Table 4: Roof/Site presentation for consideration

Roof square footage(estimation)	**17671.46 m^2**
Year built	**Completed in 2004**
Last year re-roofed	**Nil**
Height of the building	**21 m**
Ventilation in Electrical Room	**Yes**
Available space for inverter, Transformer and AC disconnects	**Yes**

4.3 PHOTOVOLTAIC SYSTEM

Photovoltaic System consists of different components that should be selected accordingly to the Stand-Alone Photovoltaic System. The some major components for the system are battery bank, solar charge controller, inverter and cabling.

Table 5: PV system Components

Components	Description
Battery bank 	The battery type recommended for using in solar PV system is deep cycle battery. Deep cycle battery is specifically designed for to be discharged to low energy level and rapid recharged or cycle charged and discharged day after day for years. The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days.
Inverter  	An inverter is used in the system where AC power output is needed. The input rating of the inverter should never be lower than the total watt of appliances. The inverter must have the same nominal voltage as your battery.

Solar Charge Controller 	The solar charge controller is typically rated against Amperage and Voltage capacities. Select the solar charge controller to match the voltage of PV array and batteries and then identify which type of solar charge controller is right for your application. Make sure that solar charge controller has enough capacity to handle the current from PV array.

4.4 POWER/ENERGY CONSUMPTION

Table 6: Chancellor Complex –Section Capacity

Chancellor Complex Section	I (Amp) (Full capacity)	I(Amp) (50% capacity)
SSBRC	3000	1500
SSBMH	2500	1250
SSBERC	1500	750
Chill Water Pump	1000	500
Undercroft	2500	1250

The data in Table 4 are the full capacity of a Chancellor Complex can handle. Thus, as this full capacity is only been used at the optimum value during the Convocation that always been held once a year. As informed by a UTP Maintenance site Technician, Mr Fatimi. No data log for everyday consumption has been made for Chancellor Complex or any parts of the new academic building. As, the power consumption is made for a bulk consumption from the GDC.

By looking at the given data, all parts of chancellor complex have been separate to a five sections. They are, SSBRC, SSBMH, SSBERC, Chill Water Pump and Undercroft.

- SSBRC : Information Resource Centre
- SSBMH : Chancellor Hall
- SSBERC : Exterior in Chancellor Complex
- Chilled Water Pump : To cool and dehumidify air
- Undercroft : Below compartment of Chancellor Complex

In order to yield the Power by using the information given, 415 V is used as the single phase – load before evenly distributed to 3 phase load. The equation used is;

$$\boxed{P_{kW} = \sqrt{3}\ V\,I\cos\theta}$$

- $I =$ given in the table
- $\text{phase angle}, \cos\theta = 0.85$
- $\text{line to line voltage, use } V = 415\ V$

Estimated Calculation for Power Consumption,

i) SSBRC ,

$$P_{kW} = \sqrt{3}(415\ V)(1500Amp)(0.85)$$

$$\mathbf{P_{kW} = 916.47kW}$$

ii) SSBMH,

$$P_{kW} = \sqrt{3}(415\ V)(1250Amp)(0.85)$$

$$\mathbf{P_{kW} = 763.7kW}$$

iii) SSBERC,

$$P_{kW} = \sqrt{3}(415\ V)(750Amp)(0.85)$$

$$\mathbf{P_{kW} = 458.2kW}$$

iv) Chilled Water Pump,

$$P_{kW} = \sqrt{3}(415\ V)(500Amp)(0.85)$$

$$\mathbf{P_{kW} = 305.5kW}$$

v) Undercroft,

$$P_{kW} = \sqrt{3}(415\ V)(1250Amp)(0.85)$$

$$\mathbf{P_{kW} = 763.7kW}$$

Hence the total Energy Consumption per day will be,

$$P_{kWh} = (916.47kW + 763.7kW + 458.2kW + 305.5kW + 763.7kW) x\ 8 = \mathbf{25660\ kWh}$$

- Time the energy lost in the system, 1.3

$$25660\ kWh/day\ x\ 1.3 = \mathbf{33359\ kWh/day}$$

- Energy Consumption per month will be,

$$33359\ kWh\ x\ 30\ days/month = \mathbf{1000.8\ MWh/year}$$

- Energy Consumption per year will be,

$$1000.8 \text{ MWh x } 12 \text{ month/year} = \mathbf{12009.1\ MWh/year}$$

Thus, the targeted 50% of an electricity bill per month need to be reduced, thus, the required PV system is,

$$50\% \text{ x } 1786.98 \,{}^{\text{MWh}}/_{\text{month}} = 893.49 \text{ MWh/month}$$

4.5 PHOTOVOLTAIC SYSTEM SIZING

The calculation on the size of solar panel is based on energy consumption. The total consumption for Chancellor Complex is about 59.56MWh per day. The sizing of Photovoltaic arrays must abide to this total consumption. The energy loss in the system is needed to be taken account. Hence, the calculated value is multiplied with 1.3.

$$\text{The energy consumption} = \ 33359\ \text{kWh/day}$$

To yield the PV surface area (m^2)

$$= \frac{\text{energy consumption per day}}{\text{solar radiation x cell efficiency}}$$

This value is indicated as the available 100 % solar beam. Thus, approximately A = 17671.46 m^2 . That is the maximum area that can be used to maximize the output of harnessing energy. Thoroughly, the roof can be estimated to produce. By using average irradiation in Malaysia that is between the range of $2000\text{Wh/m}^2 - 5000\text{Wh/m}^2$.

Assume that for the whole day, there is 8 hours of peak hours and taken account the shading considerations, the estimated available energy are;

Assume that based on the average irradiation in Malaysia,,

- For bright sunshine, $\mathrm{E} = 5000 \frac{\mathrm{W}}{\mathrm{m^2}}$ x 4 hours $= 20000 \, {}^{\mathrm{Wh}}/_{\mathrm{m^2}}$
- For shady condition, $\mathrm{E} = 2500 \frac{\mathrm{W}}{\mathrm{m^2}}$ x 3 hours $= 7500 \, {}^{\mathrm{Wh}}/_{\mathrm{m^2}}$
- For modest sunshine condition, $\mathrm{E} = 1500 \frac{\mathrm{W}}{\mathrm{m^2}}$ x 1 hour = $1500 \, {}^{\mathrm{Wh}}/_{\mathrm{m^2}}$

The total estimated energy available is the $29000 \, {}^{Wh}/_{m^2}$

$$\mathrm{E} = 17671 \, \mathrm{m^2} \times 29000 \, {}^{\mathrm{Wh}}/_{\mathrm{m^2}} = \mathbf{512.5 \, MWh}$$

Expected amount of energy that available for Chancellor Complex roof is **512.5 MWh**.

Figure 20: Solar Module

Suggestion of Photovoltaic to be used: (the data will be taken account for calculations)

- Dimensions(WxHxD) : 1.046m x 1.559m x 0.262m
- Weight : 44.1 lbs = 18.6 kg
- Maximum Power : 315 W
- Maximum Load : 50 psf
- Efficiency: 19.3%

The PV area will be,

$$\text{PV surface area}(\text{m}^2) = \frac{33359\ \text{kWh/day}}{29000\ \text{Wh/m}^2\ \text{x}\ 19.3\%}$$

$$= 59.60\ \text{m}^2$$

No of panel required,

$$\text{No of panel} = \frac{59.60\ \text{m}^2}{1.63\text{m}^2} = 36.56\ \text{modules} \cong 37\text{modules}$$

The suggestion layout is as below,

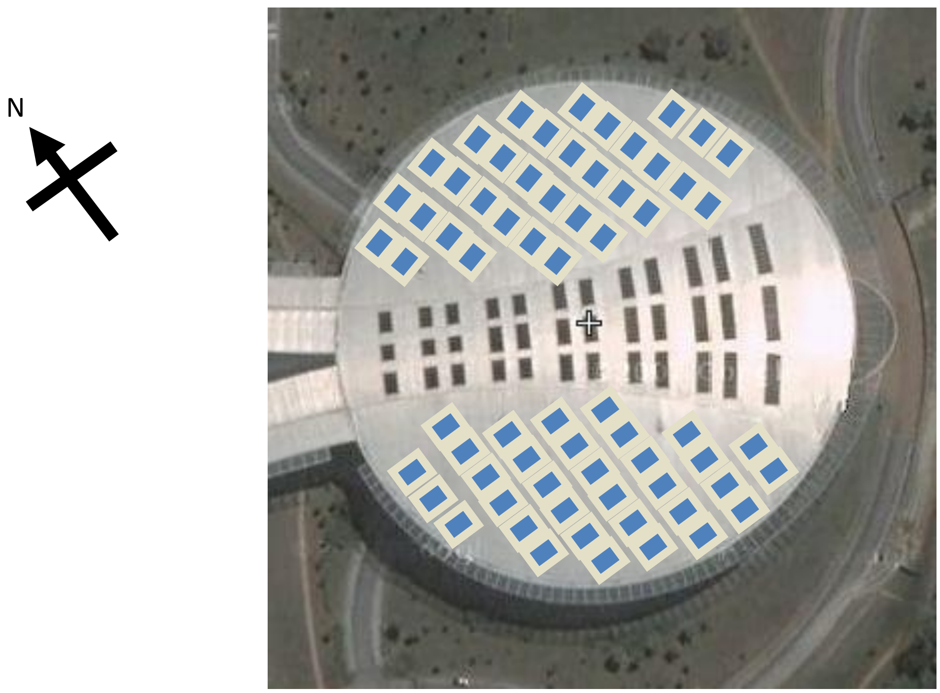

Figure 21: Suggestion layout of modules

All the PVs will be installed horizontally-flat on the roof.

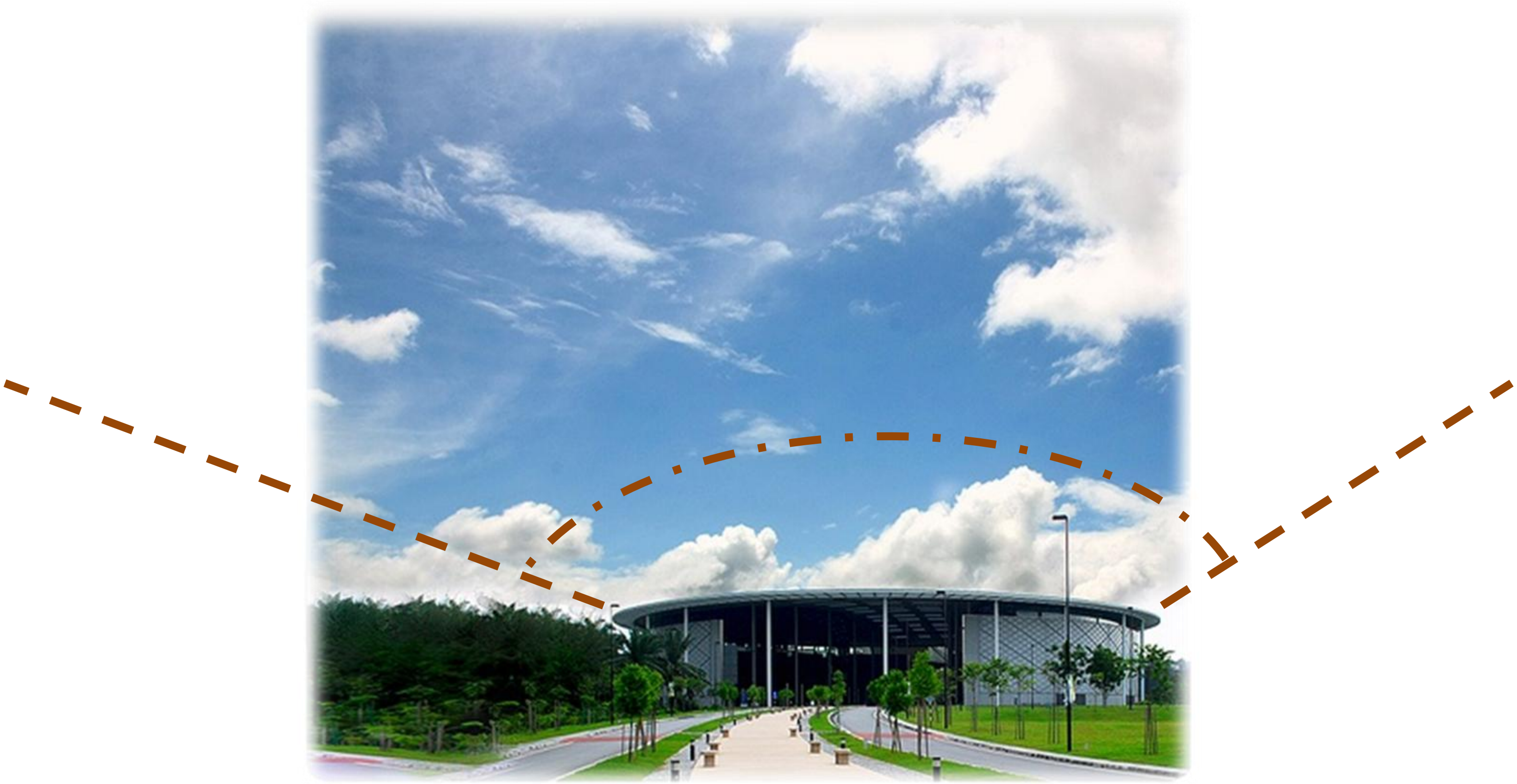

Figure 22: Overall view of Chancellor Complex

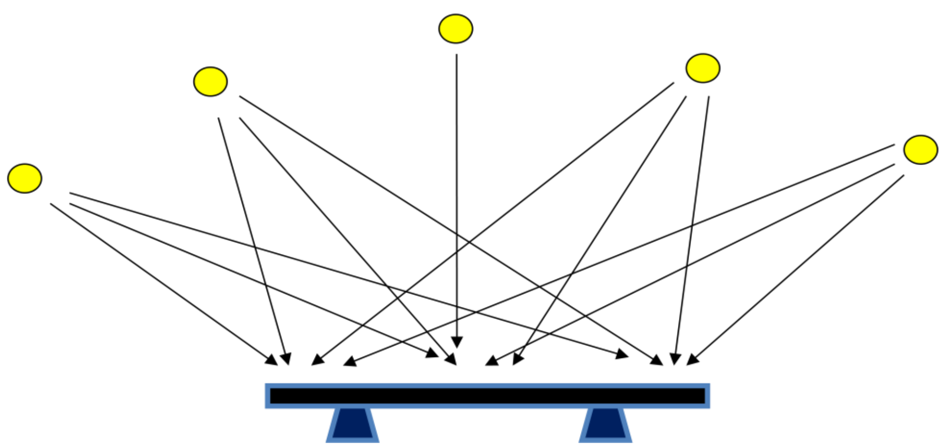

Figure 23: Predicted Sunlight hitting onto a Horizontal-Flat Solar Panel

In ideal situation, with perfectly clear sunny weather all the year round and a flat load profile, maximum annual output is obtained with the modules incline to the horizontal at the angle of latitude.

The orientation accordingly has an important bearing reducing the amount of total solar radiation. According to a journal "Impact of Solar Radiation on High-Rise Built Form In Tropical Climate" stated that the amount of indirect solar radiation falling on a surface is almost independent of surface orientation whereas direct radiation is highly dependent on orientation. In this study 66 units of modules are chosen in order to supply the power needed by the chancellor complex. Moreover the Solar modules are going to be installed on the horizontal roof instead of the vertical wall unlike the journal.

$$\text{The PV area} \quad = 1.046 \text{ m x } 1.559 \text{ m} = 1.63\text{m}^2$$

For inverter sizing, the input rating of the inverters should never be lower than the total watt of appliances. The inverter must have the nominal voltage as your battery. The battery size should be 25%-30% bigger than total watts of appliances.

For the battery sizing, it is recommended to use deep cycle battery. A deep cycle battery is specifically designed for to be discharged to low energy level and rapid recharged or cycle charge and discharged day after day for years. The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days.

$$\text{Battery capacity(Ah)} = \frac{\text{Total watt} - \text{hours per day used by appliances x Days of autonomy}}{(0.85 \text{ x } 0.6 \text{ x nominal battery voltage}}$$

$$\text{Battery capacity (Ah)} = \frac{59.56\text{MWh x 3 days}}{(0.85 \text{ x } .6 \text{ x } 12\text{V}} = 29.2 \text{ MAh}$$

Hence, the battery is rated 12V 29.2MAh for 3 days autonomy.

4.6 LOADS [10]

- Live Load
- Dead Load
- Structural Load
- Wind Load
- Rain Load
- Etc.

Diagrams that shows the loads acting on the Photovoltaic Array

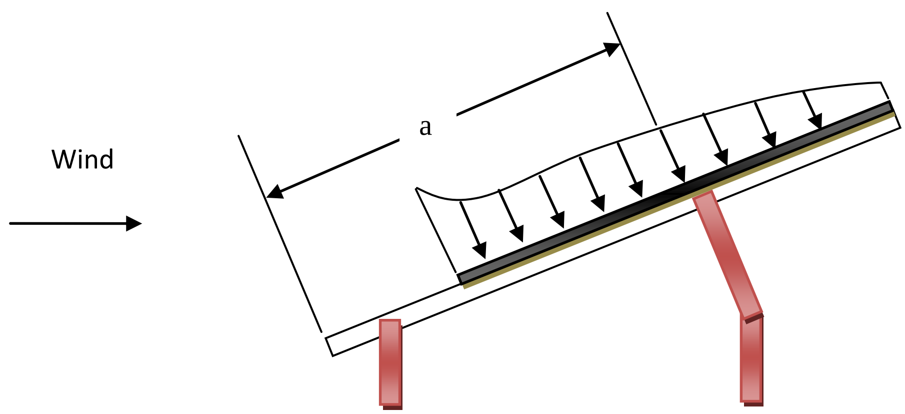

***Figure 23: Wind loading towards the front of the array*.**

Rear structural is in compression. Hence, the structure will be analyzed to be in buckling state. Figure 24 shows that the wing loading is acted from the rear of the array structure. It believed to lift the array from its supports and the rear support will be under tension. Boeing showed that for single array, the wind forces at were at minimum array tilt angles of about 20^o above the horizontal.

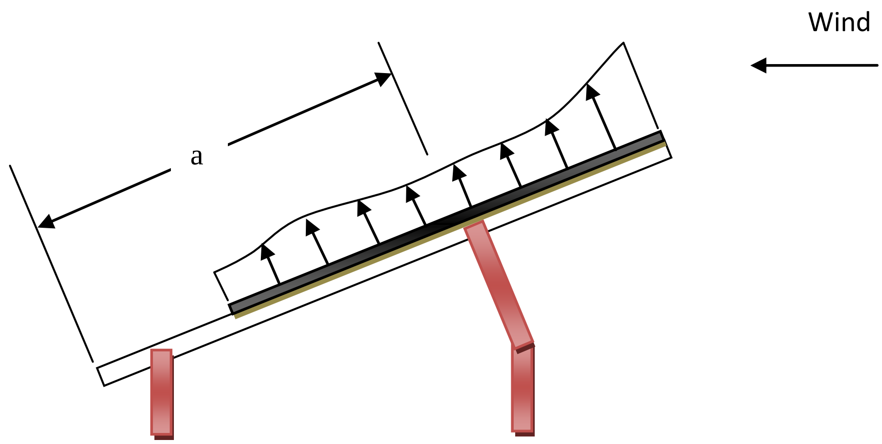

Figure 24: Wind loading towards the rear structure of the array.

Wind Load

Wind calculation (the highest basic wind speed. Let say, in Tronoh the expected wind loading is about 100 mph. Thus, velocity pressure yield an equation computed using the equation:

$$\boxed{q = 0.00256 K_Z K_{ZT} K_d V^2 I}$$

From chart and graph, the standard yield,

- Velocity Pressure exposure to coefficient at height Z, $K_z = 0.85$
- Topographical factor, $K_{ZT} = 1.00$
- Wind directionality factor, $K_d = 0.85$
- Basic wind speed in mph, $V = 100$ mph
- Importance factor, $I = 1.00$

Calculation to yield $velocity\ pressure, q$:

$$q = 0.00256 K_Z K_{ZT} K_d V^2 I$$

$$q = 0.00256 \text{ x } 0.85 \text{ x } 1.00 \text{ x } 0.85 \text{ x } 100^2 \text{ x } 1.00$$

$$q = 18.496 \text{ psf}$$

- Wind pressure,

$$\boxed{p = q\ GC_f}$$

Where:

- $G =$ gust effect factor factor $= 0.85$

Assume,

- $C_f =$ force coefficient $= 0.70$

Calculation,

$$p = q\ GC_f$$

$$p = 18.496 \text{ x } 0.85 \text{ x } 0.70$$

$$p = 11 \text{ psf}$$

Hence, the chosen PV area = $1.63\text{m}^2 = 17.55\text{ft}^2$, the total **uplifting (resultant) force** acting on the array would be;

$$11 \text{ psf x } 17.55 \text{ ft}^2 = 193.05 \text{ lb.}$$

A number of attachment points, and the size of mounting necessary to safely carry this load can be determine by knowing the resultant force. Rather computing this pressure distribution, it is more prudent to assume a worst case scenario for wind loading and the design of mounting system that is capable to survive the associated loading. An approach towards this by applying the methodology in the standards in the ASCE standards yields a reasonable upper limit on the design wind pressure of **55 psf.**

Dead Load

Dead Load (static) calculation consists of the weight of all the materials that are supported by the structural members and themselves together. All materials in this context means that Photovoltaics array mounted on the roof of a building that is the modules are structurally tied together in panels using steel or aluminum structural members. The weight is later transmitted onto the roof structure of the building.

- Total Dead Loads $(psf)$the roof must carry is the combination of;

$$= \text{weight of the modules} + \text{structural members used to form the panel} \\ + \text{ attachment hardware} + \text{mounting brackets}$$

- Assume to act uniformly onto the roof covered by the array area. Dead loads for photovoltaic system fall in the range of **2 to 5 psf**.

Thus,

In the suggested PV model showed that the

$$44.1 \text{ lbs x } 37 \text{ units} = 1631.7 \text{ lbs}$$

- Total area of the Photovoltaic arrays area;

$$1631.7 \text{ lbs} \div (17.55 \text{ ft}^2 \text{ x } 37) = 2.51 \text{ psf}$$

- 2.51 psf is in the range of the allowable **Dead Load** (psf) set.

Live Load

A photovoltaic system that is produced by individuals and their equipment and materials during installations, maintenance and inspection are called as Live Loads. Live load can be large in magnitude, but intermittent and attribute to wind, snow etc and maintenance personnel. In designing structures to carry load, it can be treat as uniformly distributed loads (psf).

Assumptions:

- A man weigh $= 120$ kg $= 264.55$ lbs

  For one installation, estimated that number of man $= 10$ people

Estimated weigh= 265.55 lbs x 10 people $= 2645.5$ lbs

- Equipment + material load/weigh= 50 kg $= 110.23$ lbs

For one installation,

Estimated that each person will bring along 1 pack of equipment + material

$$= 110.23\ lbs\ x\ 10\ pack = 1102.3\ lbs$$

- The area of the roof is $= 190214\ \text{ft}^2$

- Thus the Live Load is;
  $= (2645.5 + 1102.3) \div 190214\ \text{ft}^2$
  $= 3747.8\ \text{lbs}\ \div 190214.3\ \text{ft}^2$
  $= 0.01970\ \text{psf}\ \leq 3\ \text{psf}$

Hence, the estimated Live Load is less than3 psf. For photovoltaic arrays, live loads are usually assumed to be distributed uniformly and are small, on the order of $\boldsymbol{3\ psf}$ or less.

4.7 Array Mounting

To meet a structural, code and safety requirements, a good array mounting design should have the following requirements:

- Minimizing installation costs
- Enhancing array performance
- Providing reasonable accessibility for installation and maintenance
- Making the system aesthetically appropriate for the site and application

As in the available roof on the chancellor complex is indicated in the GOOD condition. The construction finish in late 2004 and the year this project is conducted are 2010. The margin is just only 6 years. The Photovoltaics design life time is almost more than 20 years. Thus, for the Chancellor Complex, the author had to look into Building integration considerations.

The designer will need to look upon:

- Developing package kits
- Minimizing the total number of parts
- Minimizing part variations
- Designing parts to be multifunctional
- Designing for ease of assembly
- Minimizing assembly direction
- Maximizing compliance in assembly
- Minimizing handling in assembly and installation

The whole idea is to accelerate the installation process, reduce costs and improve quality. Once the building has been set up, installation of the prewired photovoltaic arrays, inverter and other balance-of-system components is achieved at a fraction of the time and cost of a custom installation.

There are many types of mounting available in market. They are:

- **Standoff Mounting**

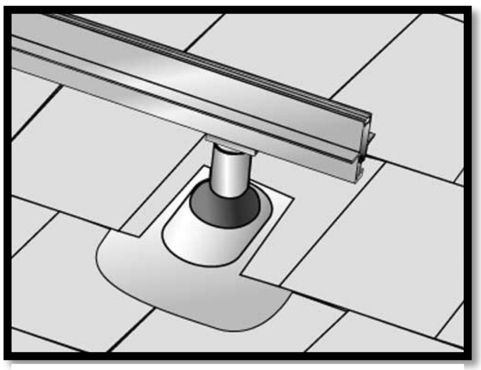

Figure 25: Standoff Mounting

Standoff arrays are mounted above and parallel to the roof surface. The designs allow both lateral and vertical airflow along the back surface of the modules. Moreover, it designs to induce pressure differences between air inlet and exit regions.

- **Rack Mounting**

Figure 26: Rack Mounting

Rack-mounted arrays are above and tilted with respect to the roof. They may be mechanically attached to the building structure or may employ ballast to resist wind and other mechanical loads. Subjected to higher structural load, incur higher costs mounting hardware but the total energy is often higher because of better orientations and lower average operating temperatures.

- **Integrated Mounting**

Figure 27: Example of Integrated Array mounting

It is understandable that integrated mounting are referred to as building integrated photovoltaics (BIPV) or integral mounting. The array will replace the conventional roofing or glazing materials as illustrated in the Figure 27.

- **Direct Mounting**

Figure 28: Dow powerhouse solar panel looks like ordinary roof shingles

In direct mounting, the array is affixed direct to the roofing material or underlayment, with little or no airspace between the modules and the roof. Thin film products become highly popular as it is not sensitive to operating temperature.

Array operating temperatures for direct mounts are usually higher than for other technique.

4.8 COMPUTING MECHANICAL LOADS AND STRESSES

As in figure 1 show that a structure experiencing downward forces toward the plane of the array. Thus, in this project rack mounting is the preferable method as

$$P = \frac{EI\pi^2}{L^2} = \frac{EAr^2\pi^2}{L^2} = \frac{EA\pi^2}{(L/r)^2}$$

Where,

$I = \text{moment of inertia of the cross} - \text{sectional area} = Ar^2$

$A = \text{cross sectional area of the column}$

$r = \text{radius of gyration of the cross sectional area}$

$\frac{L}{r} = \text{slenderness ration of the column}$

Assumption:

The rack mounted is to be chosen as the mounting type for the photovoltaic arrays is $1\text{ in x }1\text{ in x}\frac{1}{8}\text{in}$. supported by square 6105 T-5 aluminum tubing cross sectional dimensions of The radius of gyration of the cross section is $0.361\ \text{in}^2$. The modulus elasticity for the aluminum is $10\ x\ 10^6\ psi$ and the cross sectional area is $0.50\ \text{in}^2$. The computed maximum force the member can withstand without buckling by having a rear support structural member; $5\ \text{ft}(60\ \text{in})$.

By using the above equation,

$$P = \frac{10^7(0.50)\pi}{(60/0.361)^2} = 697.8 \text{ lbs}$$

Hence, for each rear support member should not be subjected to compressive forces that approach 697.8 lbs.

Due to the uplifting force, it will produce tensile stresses in hardware used to secure the array to a roof and support structure.

Assumption:

17.55ft^2 Photovoltaic array is secured to a roof using four $\frac{1}{4}$ in x $\frac{3}{4}$ in hex bolt made of 304 stainless steel. The rack mounted array is subjected to a uniform uplifting pressure distribution 55 psf(the maximum). The allowable tensile strength for 304 stainless steel is 24,750 psi. The tensile strength computed can be shown as,

$$S = \frac{P}{A}$$

The resultant force acting on the array is 55 psf x $17.55 \text{ ft}^2 = 965.3$ lbs.

Thus, for each hex Bolt: ${}^{965.3}/_{4} = 241.3$ lbs .By using the above calculation,

$$S = \frac{P}{A} = \frac{241.3}{0.0767} = 3{,}146 \text{ psi}$$

The computed stress is below the allowable stress for 304 Stainless Steel. It appears that there is no risk of failure in tension.

4.5. COST ANALYSIS

Economic Analysis

Calculation on payback period is considering the major components. They are Photovoltaic modules and rack mounting (For this economic analysis, all prices are based on large scale purchasing)

Table 7: Main Components Cost

Material	Price (USD)
Array	685.00 x 37
Rack Mounting Structure	198 x 37
Labor	20K
TOTAL	**52,671**

The total amount is USD 52,671 K x RM 3.21= RM 169,073.90

ASSUMPTION MADE

Labor : $ 20K = RM 64200

Capital Investment : RM 169,073.90

Useful life : 10

Annual expenses : Electrical Bill

Depreciation Method : Straight Line

Table 8: For 50%Energy Consumption

Per monthly consumption More than 400 kWh/month	**Rates(RM)**
500 kWh per month(28.6 sen/kWh)	**500 x 0.286 = 14300**
100kWh per month (37.8 sen/kWh)(501-600kWh)	**100 x 0.378 = 3780**
100kWh per month (38.7 sen/kWh)(601-700kWh)	**100 x 0.387 = 3870**
100kWh per month (39.7 sen/kWh)(701-800kWh)	**100 x 0.397 = 3970**
100kWh per month (41.7 sen/kWh)(801-900kWh)	**100 x 0.417 = 4170**
For 901kWh and onwards (44.6 sen/kWh)	**499,500 x 0.466 = 232,767**
TOTAL	**262,857**

In table 4, the electrical bill is based on the 50% solar panel consumption.

The 50% energy consumption = 500.4 MWh/month

Energy consumption per month = 1783990 kWh

Table 9: For energy consumption per month

Per monthly consumption More than 400 kWh/month	**Rates(RM)**
500 kWh per month(28.6 sen/kWh)	**500 x 0.286 = 14300**
100kWh per month (37.8 sen/kWh)(501-600kWh)	**100 x 0.378 = 3780**
100kWh per month (38.7 sen/kWh)(601-700kWh)	**100 x 0.387 = 3870**
100kWh per month (39.7 sen/kWh)(701-800kWh)	**100 x 0.397 = 3970**
100kWh per month (41.7 sen/kWh)(801-900kWh)	**100 x 0.417 = 4170**
For 901kWh and onwards (44.6 sen/kWh)	**999900 x 0.466 = 465,953.40**
TOTAL	**496,043.40**

Percentage of electricity savings,

$$\frac{\mathbf{RM\ 262,857}}{\mathbf{RM\ 496,043.40}}\ x\ 100\% = 52.99\% > 50\%$$

Table 10: The cash outflow of the solar PV system for 10 years

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cash Inflow	262857	262857	262857	262857	262857	262857	262857	262857	262857	262857
Cash Outflow	169074	0	0	0	0	0	0	0	0	0
Net Cash flow	93783	262857	262857	262857	262857	262857	262857	262857	262857	262857
Cum. Cash flow	93783	356640	619497	882354	1145211	1408068	1670925	1933782	2196639	2459496

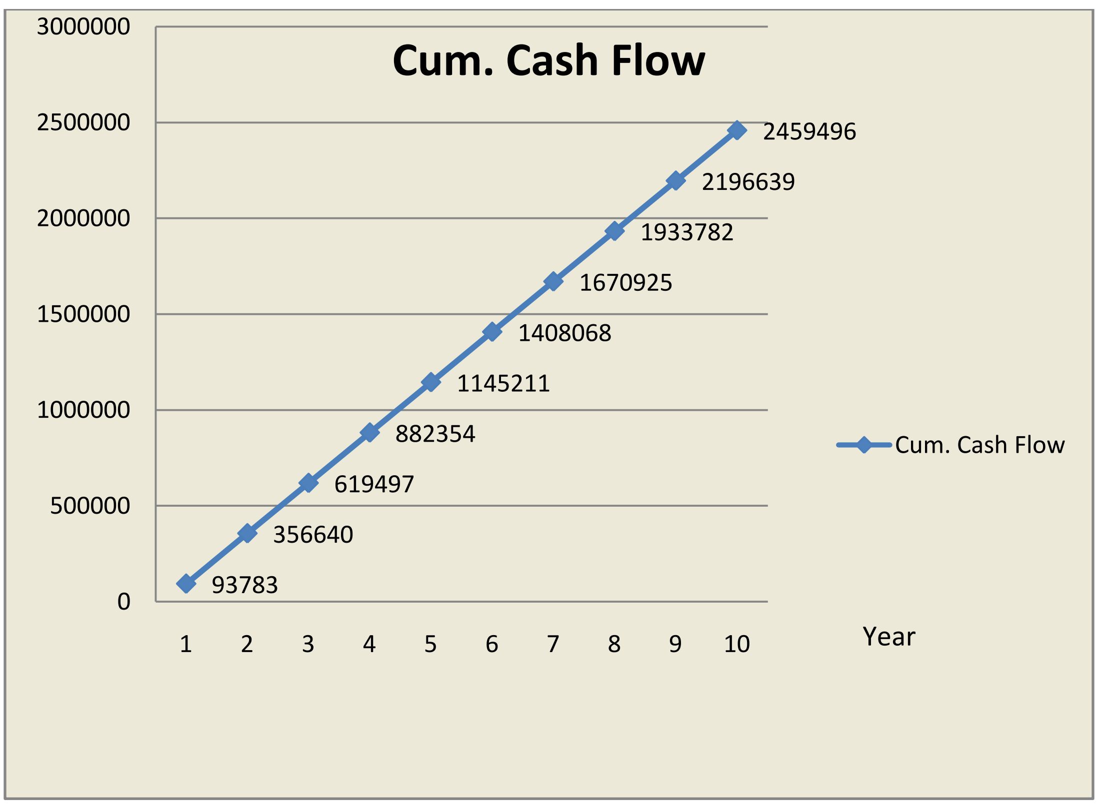

Figure 4: Cum Cash Flow vs Year

As shown in the table, in the year 1, the cumulative cash flow shows in the positive value.. At this point, this system has paid back its cost that would have otherwise been used to pay for energy. The values in this point will represent a net saving.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSION

The rough data gathering and results of discussions shows that the Chancellor Complex has the potential to collect a huge amount of energy. The idea of installing the Photovoltaic Solar panel on the Chancellor Roof top is feasible based on a few considerations. The data gathering and a few considerations have been made as the foundation for further studies in this solar energy in within campus (Universiti Teknologi PETRONAS-UTP). It can save more than 50% of electricity bill per month. The payback period of the design PV system shows that it takes less than 10 years to recover the main components cost. If the cost extended to cover with the maintenance and installation cost, there is no doubt that it is still within the range of 10 years to recover the cost. Overall studies in this report could help the UTP communities to be more aware the possibilities of installing Photovoltaics in UTP. It is a good way of showing the country that UTP is with them in realizing the United Nations Development Program on Malaysia Building Integrated Photovoltaic (BIPV) Technology Application Project (MBIPV) in the 10th Malaysian Plan.

5.2 RECOMMENDATION

The project is feasible based on the a few main aspects. A modest investigation and studies will lead to more structured results. Lack of documents in this project leads to non-structured results. No inventory of drawings available in UTP and no Data Log of energy used for a certain sections in UTP new building blocks. Further actions need to be done in order to smooth the further feasibility study for this project.