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Green Building and Environment Sustainability: A Retrofit of Chemical Engineering Pilot Plant Building Universiti Teknologi Malaysia [UTM]

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Abstract

Objectives: To assessing an existing building for retrofitting towards improving its environmental performance and energy efficiency. Methods/Statistical Analysis: A walkthrough assessment and evaluation of a Chemical Engineering Pilot Plant Building facility in University Technology Malaysia, was carried out. In addition, an interview session with the building facility manager was conducted alongside the building evaluation. Findings: The building fall short of the standards required for green and energy efficient building rating. However, retrofitting could be possible towards improving its environmental performance. Applications/Improvement: The result of a possible retrofit of the Chemical Engineering Pilot Plant Building facility using solar PV panels would provide about 41% savings in the building's annual energy consumption.

Keywords: Energy Efficiency, Green Building, Performance, Retrofitting, Sustainability

1. Introduction

Building performance and sustainable environment have been accepted the world over as a means of achieving a reduction in Greenhouse Gas (GHG) emissions and reduce pressure on the world's limited resources. For sustainable performance and energy efficiency to be achieved in a building, the application of an integrated building design process from the planning stage is paramount. However, buildings which are already in existence can be improved towards achieving the same goal with minimal technical alterations. According to BCA Singapore[1], for sustainability and efficiency to be achieved, existing buildings which constitute the highest number in the environment needs to be assess for improvement. These buildings consume over 40% of electricity energy in use.

The need for proactive green buildings awareness among the public could lead to their demand for more environmentally friendly buildings[2]. Malaysia today is among the countries in the world promoting the principles of green buildings and sustainable environment. The national commitment of the Malaysian Government towards sustainability and energy efficiency was categorically stated by[3], the Malaysian Prime Minister at the United Nations climate change conference in Copenhagen 2009[3].

The results of this commitment is seen in the enlistment of several standards and frameworks among which are, the Green Building Index (GBI) and the Low Carbon Cities Framework and assessment systems (LCCF Malaysia) as documents that will assist local authorities, developers and individuals towards reducing environmental impacts and Greenhouse Gas (GHG) emission.

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The Universiti Teknologi Malaysia through Centre for the Study of Built Environment in the Malay World (KALAM), organized an international green environment and building workshop in October 2014, to increase the public awareness about the importance of green building design in tropical climate region of South-East Asia. One of the goals of this workshop is about knowledge sharing on the concept of sustainable environment and green building design to the participants who are professionals in the field. As part of a process of achieving one of the objectives of the above mentioned workshop, a green building concept exercise in some case study buildings on UTM campus were carried out to give experience on its implementation. This present study is an offshoot of one of the case study exercise.

Buildings have been identified to have the most cost effective means of Greenhouse Gas (GHG) mitigation as compared to other sectors[4]. Improvement in building thermal insulation could lead to a reduction in the size of heater and chillers requirements in the building[4] which is marginally cost effective, while a reduction in the energy consumption reduces monthly bills for electricity and gas supply to the building.

A green building is characterized by its efficient use of energy, water and materials as well as providing a comfortable living and working environment for the occupants. In Malaysia, construction works contribute up to about 41% of the amount of total carbon dioxide (CO_2) emissions in the country[5]. If a green initiative is not promoted then in no distant time, the country will be faced with the daunting challenge of environmental degradation and resources depletion. Standards for the assessment and promotion of green building environment such as the Malaysia Green Building Index (GBI) have been established in different countries. For a building to achieve the Malaysia GBI recognition, it must meet the requirements of the six (6) key criteria which are; energy efficiency, Indoor Environmental Quality (IEQ), site and waste management, materials and resources use, water management and innovation[6].

Some basic features of a sustainable and environmentally friendly building are: efficient use of energy and daylighting, rain water harvesting and water recycling, solar energy conversion for use and comfortable living and working environment[7]. An example of an environmentally friendly building in Malaysia is the Energy Commission Building. This building with an installed Photovoltaic (PV) cells of 71.4 kWp yields about 1,400 Kwh/m^2 power generation annually, which has the capacity of reducing carbon dioxide emission of 1,400 tons annually[7].

Energy has played a substantial part as a factor for sustainability and building performance. Improving shading devices properties and control measures especially in large glass window facade buildings have potentials for energy savings[8]. In[4] suggested two ways in which cost effective energy demand can be achieved in buildings, these are: User-based and Infrastructure-based approach. The user-based approach involves creating awareness in the building occupants of the efficient use of energy while infrastructure-based involves measures taken at the design planning stage or retrofitting stage.

Solar heat gain into a building is affected by the building shading and window size, which in turn influences the amount of cooling required in the building[9]. There is a relationship between building shading, heat gain and daylighting and energy consumption in buildings. Heat gain into a building through solar radiation can be reduced by the use of shading device on the building. However, the used of shading devices on a building can also affect the amount of daylighting into the building. The effectiveness of a building shading device should be such that it enhances both heat gain and daylighting requirement of the building. Where there is more heat gain into a building through sunlight harvesting for daylighting, there will be increased energy consumption for cooling and less for lighting. On the other hand, in reducing the amount of heat gain through the introduction of solar shading device on the building, there will be an increase in energy consumption for lighting. So also, an introduction of shade reflectance on building fenestration can improve cooling thereby reducing the overall energy requirement of a space[8]. Furthermore, building orientation that maximized the use of daylighting would reduce the energy requirement for lighting in a building. A building form which allows for the free flow of air into and out of a building allows for natural ventilation which in turn reduces energy required for cooling in order to achieve occupants' comfort. The application of intelligent building facade such as, the use of Photovoltaic (PV) shading device can considerably enhanced energy performance and improves daylighting in buildings [10].

Buildings which have been ascertained to consume the highest energy requirement in the world, also has the highest opportunity towards protecting the environment and conservation of energy[10]. A comparison between buildings, transportation systems and the industry shows that the amount of carbon emission is more from buildings[11]. With the important role building retrofitting plays in the reduction of environmental loads, just a handful of research have been carried out with respect to existing buildings retrofitting[12]. The retrofitting of a building requires an understanding of the existing building performance before considering the improvement to be made on it[13]. Consequently, providing a better energy performance and new comfort requirement for an existing building must therefore be in consonant with an alteration that should be well-suited for the building[13]. Therefore, this study is basically concerned with the assessment of the existing Chemical Engineering Pilot Plant building towards improving it environmental performance and energy efficiency towards promoting sustainable architecture.

2. Methods/Case Study

For any retrofitting to take place on an existing building, the building's current state needs to be established. Therefore, an on-spot assessment of a Chemical Engineering Pilot Plant Building was carried out as a case study. This includes general observation and an interview session with the facility manager of the pilot plant building.

2.1 Chemical Engineering Pilot Plant Building Facility Assessment

The Chemical Engineering Pilot Plant building (Figure 1) is a multi-purpose building facility designed and constructed for research and business development. The facility is located at UTM Campus, Johor DarulTakzim. The design and conceptualization of the building started in 1992 through 1994 and the construction work was completed in 1998. The building is equipped with both laboratory and processing equipment which are of semi-industrial scale.

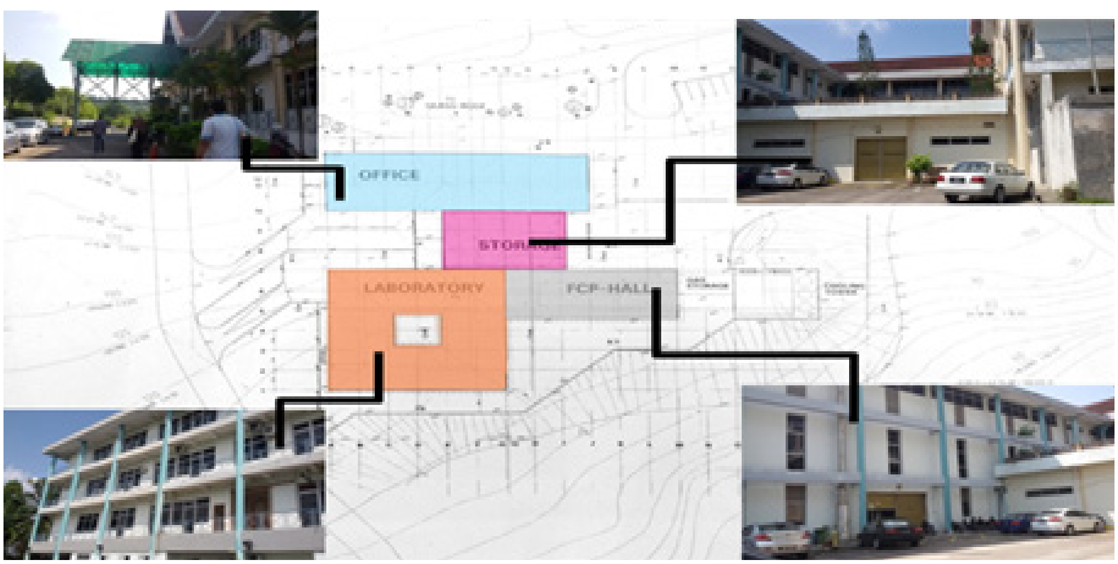

Figure 1. Site plan of chemical engineering pilot plant building, UTM (field photos).

The building form is a combination of four geometrical shapes which house four different units - staff offices, storage area, laboratory and a chemical processing hall. The building is constructed of reinforced concrete structure with in-filled brick walls and curtain internal walls. The roofing material on the office area and the laboratory area is made of slates while the storage area and the chemical processing hall have reinforced concrete roof slab. The windows on the building are single glazed with aluminium frames having floor slab overhang as shading.

A review of the electrical energy consumption bill for this facility shows that the average monthly energy consumption is 80,001.35 KWh which cost RM 35,280.58. This rate of energy consumption emits about 640.01 tonnes of carbon dioxide (CO_2).

2.2 Building Appraisal

The appraisal of the building is based on the Malaysia Green Building Index (GBI) guidelines for Non-Residential Existing Buildings (NREB) as shown in Figure 2, but with much emphasis laid on energy efficiency. For a building to be considered as environmentally friendly in Malaysia, it must meet the minimum requirements of the six (6) GBI criteria.

Figure 2. GBI guidelines rating tool[14].

Figure 3. Lighting and ventilation in the building.

Table 1. 2013 Electricity energy consumption and carbon footprint (electricity bills)

Month, 2013	Electricity Used (kWh)	Electricity Cost (RM)	CO_2 Emitted (Tonnes)	Trees to Offset per Month
Jan.	90,427.47	39,878.51	67.03	32
Feb.	61,865.91	27,282.87	45.86	22
Mar.	83,792.74	36,952.60	62.12	30
Apr.	74,417.51	32,818.12	55.17	26
May	87,432.26	38,557.63	64.81	31
Jun.	96,007.91	42,339.49	71.17	34
Jul.	80,535.60	35,516.20	59.70	28
Aug.	73,863.88	32,573.97	54.76	26
Sep.	98,844.93	43,590.61	73.27	35
Oct.	63,460.51	27,986.08	47.04	22
Nov.	67,368.35	29,709.44	49.94	24
Dec.	81,999.12	36,161.61	60.79	29
Note: Cost is calculated based on 1 kWh = 44.1 Sen (RM 0.441)				

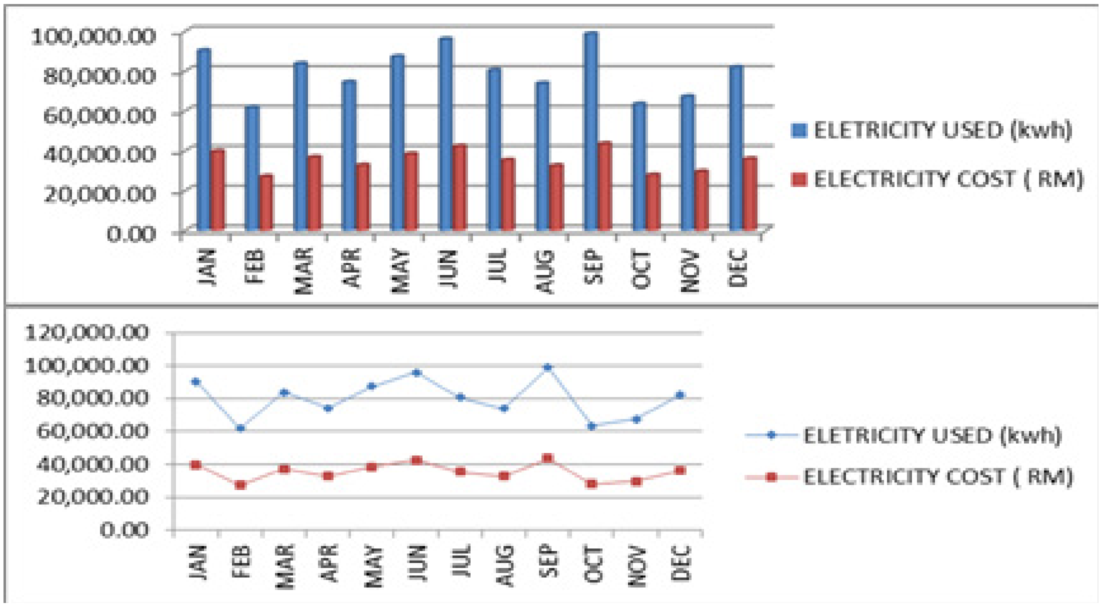

Figure 4. Electricity consumption and cost in chemical engineering power plant building.

The entrance lobby into the office area of the building has a triple volume glazed atrium which allows for daylight harvesting (Figure 1). The introduction of a courtyard within the laboratory area provided for good daylighting and natural ventilation. However, the building corridor around the courtyard has completely fixed window glazing. This goes against the ethics of providing courtyards within a building configuration in order to maximized natural cross ventilation. The windows are installed with big operable glass panels for daylighting but it's designed and construction could not allow occupants to be opening it for natural ventilation. The utilization of daylighting based on the building orientation and fenestration contribute significantly to energy savings for lighting. Most lights are off in the day time when the building is mostly in use. The building circulation areas depend on natural ventilation while the occupied spaces are mainly ventilated using centralized air conditioning system with cooling towers.

The annual consumption of electricity of this building facility in 2013 (Table 1) is 1,042,015.31 kWh which is estimated at a cost of RM 459, 528.75 for each 1 kwh = 44.1 Sen (RM 0.441). Based on an online carbon footprint calculator, the electrical energy consumption of this building emits about 772.45 metric tonnes of carbon dioxide (CO_2) into the environment[14]. CO_2 emitted to the environment are absorbed by plants during photosynthesis and only about 2.4 tonnes of carbon.

A footprint is absorbed during this process. Therefore, about 321 trees are required to offset the CO_2 emitted from the consumption of electricity by this building. In Malaysia, offsetting 772.45 metric tonnes of CO_2 will cost about $ 11226.65 ($ 14.52 per tonne)[14]. Figure 3 shows the relationship between energy consumption and cost, while Figure 4 shows the relationship between the carbon dioxide emission and number of trees required for offset. The occupants of the building have control over temperature within their occupied spaces. The temperature of the air-conditioned spaces is maintained at between 24ºC and 26ºC. The Indoor Air Quality (IAQ) is not always pure as smells and odour from the chemicals used in the laboratory and processing hall are not contained away from

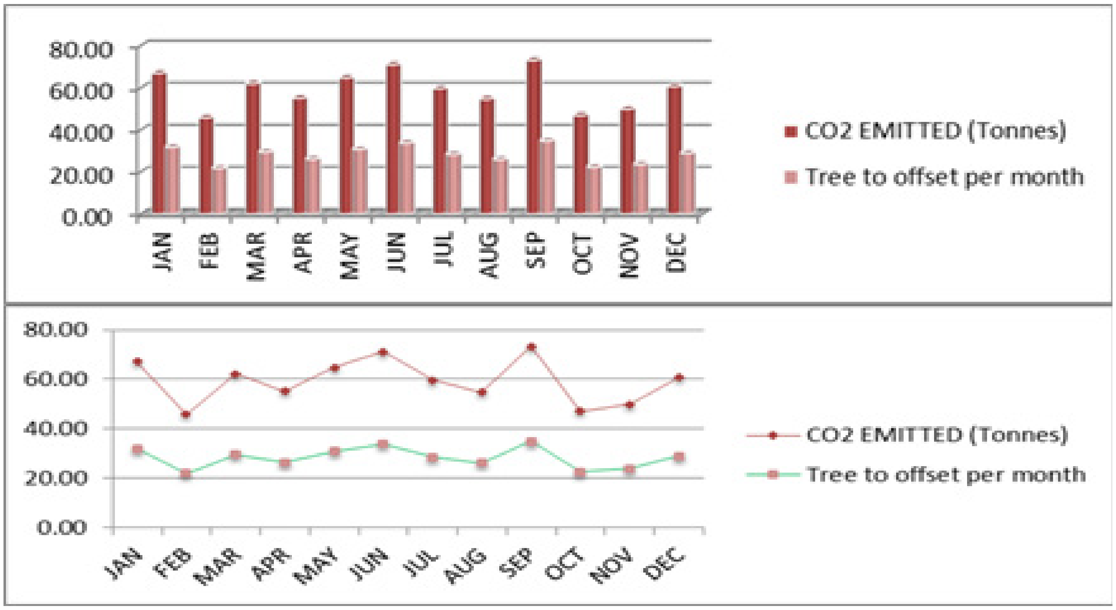

Figure 5. Carbon footprint in chemical engineering power plant building.

Figure 6. Light reflection and glare in occupied spaces (field photos).

the occupied zones. Sound quality is good as background noise is only evident when some of the equipment is being used. For lighting, there is no proper window shading which resulted into the effect of glare that affects the building occupants as they perform their daily activities (Figure 5). There is no cross ventilation in the building and also heat gain is a problem. Figure 6 shows the plan configuration of lighting and ventilation in the building facility.

There are waste bins at strategic location for separate waste material collection to allow for ease of collection for recycling. The building waste water in channelled directly into the building's central sewerage without recycling for re-use. Rain water harvesting is never considered in this building. The need for rain water to be collected and use appropriately will reduce the demand for clean water and wastages.

The site is properly planned and positioned with landscape elements which serve as buffer for traffic and noise from parking and access roads. These landscape elements also help in CO_2 reduction and also in ventilation. There is green environmental concept awareness for the occupants of these building. The building has some green awareness features for the efficient use of energy and other services as evident in the reminder stickers besides electrical appliances, occupancy detection control and waste separations.

3. Retrofit Proposal

The proposal for the retrofitting of this building under study to achieved energy efficiency and environmental

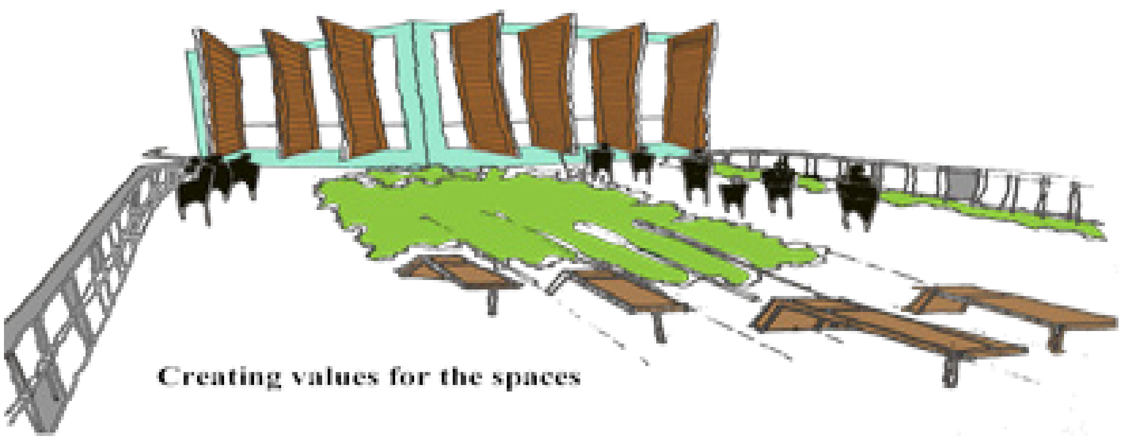

Figure 2. EEG signals before and after the pre-processing steps

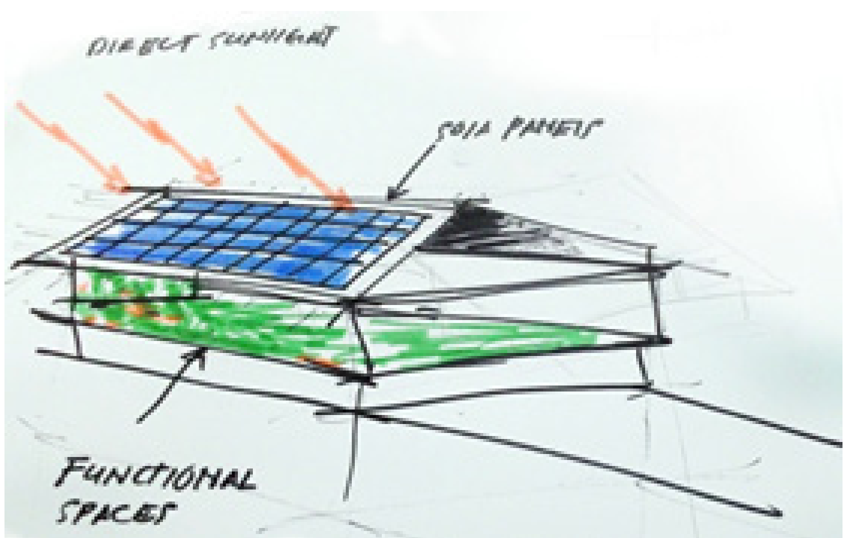

Figure 8. Solar PV installation on roof top.

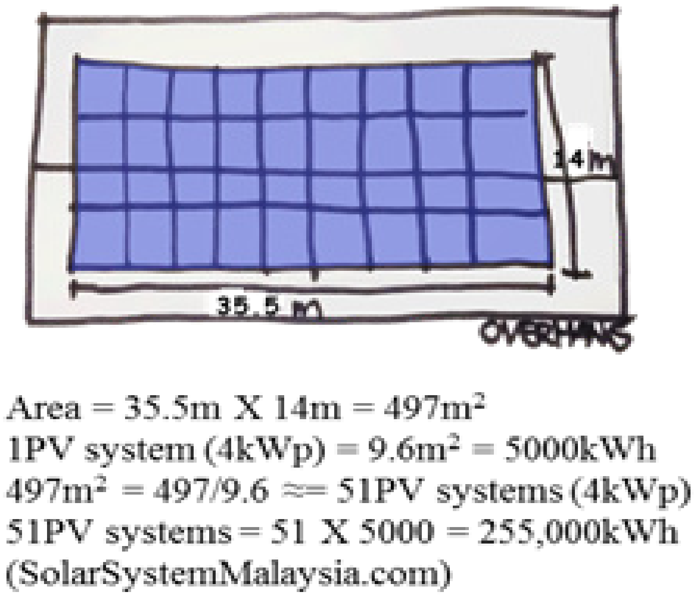

Figure 9. Photovoltaic system installation on chemical processing hall roof top.

sustainability should be easy, possible and economical. The problem of glare in this building can be tackled through the introduction of adjustable louvered shading devices. This will reduce the effect of direct sun rays into the building. Changing the existing glazed panels into standardized operable window panels will enhanced easy usage by occupants for natural ventilation both in the office and laboratory areas. The fixed lighted corridor in the courtyard within the laboratory area if changed to louver glass will enhance both natural ventilation and daylighting while reducing glare. Also, green vertical plants can be introduced on the external walls as shading to the building to reduce heat gain and also as filter for odours and smell from chemicals which are most often use in the building.

The concrete roof slab if converted into a green roof will improve its environmental performance. The application of green roof retrofits on the concrete slab roof can serve as a barrier to the reoccurring leakages normally reported in the building facility as shown in Figure 7. The green roof should be an extensive one with a thin soil depth as maintaining it does not required huge resources[15]. The introduction of the green roof decreases rain water runoff, increase more oxygen in the environment and improve on energy efficiency in the building[16]. The introduction of green roofing elements on the roof slab will enhanced reduction in emitted carbon dioxide (CO_2), increase oxygen (O_2) intake and helps in cooling the environment to reduce cost of air-conditioning. The green roof prevents water leakage into the building as it also creates a new garden space for recreation and resting. Rain water harvesting system can be installed alongside the green roof for water collection to be used in toilet flushing and landscape irrigation.

Improvement to the building energy consumption could involve the right-sizing of air-conditioning system after undertaking measures that will allow the building to use both natural ventilation and air-conditioning. High efficient lighting and occupancy and Lux sensor could be installed to reduced energy consumption from lighting. The maximized use of daylighting that would allow for optimum cooling in the building is also required. The

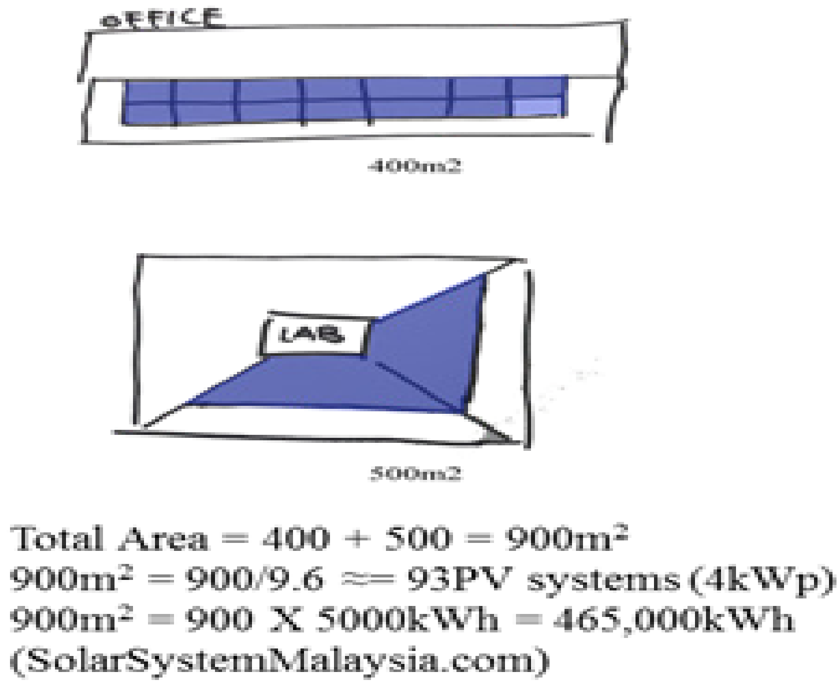

Figure 10. PV systems installation on existing pitch roof.

maximization of the daylighting should not be at the detriment of heat gain reduction in the building and vice versa.

An alternative to power generation to the building can be through solar Photovoltaic (PV) panels (Figure 8). Solar energy is a clean alternative to fossil fuels. Electricity produced by solar PV is clean and silent and does not release any harmful substances into the environment.

In Malaysia, a 4 kWp solar PV system yields about 5000 kWh of power annually[17]. The dimension of a PV module is 1200 mm X 507 mm. A 4 kWp PV system consists of an array of 16 modules. A 4 kWp system with 16 modules each of size of 0.6m^2 (1200 mm X 507 mm) will require an approximate area of 9.6 m^2 (Figure 9).

The installation of a 4 kWp polycrystalline PV system on the 497 m^2 mono-pitch roof (Figure 9) will yield a power generation of 255,000 kWh per year to the building.

The total area available for the installation on the existing pitch roof is the roof area exposed to un-shaded building orientation, which is 900 m^2 for both the office area and laboratory area roof (Figure 10) and can be installed with 4 kWp PV systems that will generate power of 465,500 kWh per year. The total generation that is possible with the installation of a 4 kWp PV system on this facility roof top is 720,500 kWh annually. The total annual electricity power consumption of this building in 2013 as shown in Table 1 is 1,042,015.31 kWh. The installation of the PV solar panels which generates about 720,000 kWh of power annually will result into 41% reduction in the energy cost of the building. The relationship between the facility annual consumption and building energy saving is shown in the chart in Figure 11. Carbon dioxide emission from the building will also be cut down by about 41% every year. This building will be saving about RM 142,008.75 every year as a result of the installation of

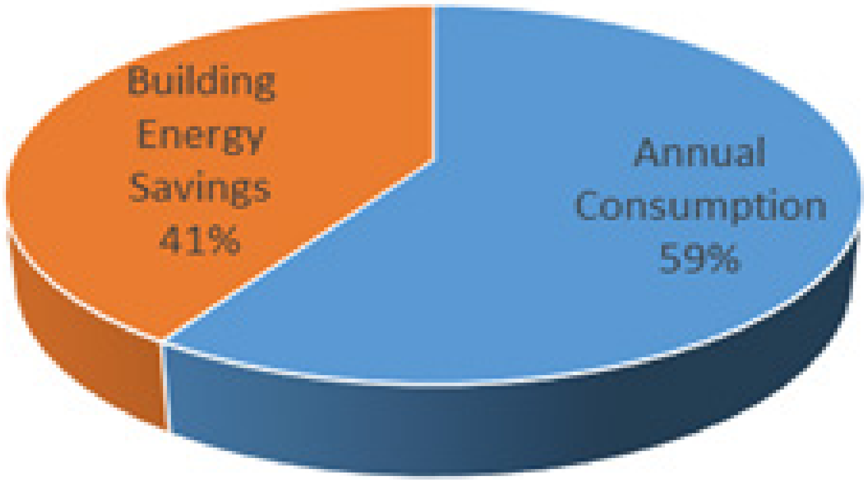

Figure 11. Annual consumption and building energy savings.

retrofitted solar panels in addition to saving the environment.

4. Conclusion

The Chemical Engineering Pilot Plant building cannot be seen as a green and energy efficient building. However, a case study assessment reveals that the building can be improved towards sustainability and green building performance. Therefore, the need is to carry out the necessary retrofitting as suggested by this study. Achieving maximum daylighting and natural ventilation in the Chemical Engineering Pilot Plant building is possible without any structural changes to the building configuration. The utilization of the concrete roof slab on top of the chemical processing hall for the harvest of sun rays by Photovoltaic cells would reduce electricity consumption and save cost and above all, reduce the depletion of the environment for future generations yet unborn.

The transformation of this building into a sustainable and environmentally friendly facility will be an important milestone in building retrofitting in Universiti Teknologi Malaysia (UTM).

5. Acknowledgement

This study was carried out while participating as a facilitator during the International Green Environment and Building Workshop organised by KALAM. The Chemical Engineering Pilot Plant building was one of the selected buildings used as case study to exercise the green building concept during the workshop to give an experience on its implementation.

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