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An Energy Audit Results of UP-Technohub Commercial Building in Quezon City, Philippines

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ABSTRACT

Philippine commercial buildings estimates as much as 10% of total electrical usage. This study conducted an energy assessment/audit in a private office building. It mainly discussed the different areas of the office building in this study. It evaluates their existing light and air conditioning consumption about the electrical output. It was observed that the Fan Coil Unit (FCU) operates at lower energy than its standard consumption. While the lighting system in the area does not conform to the desired lux level appropriate to the office facility. Finality, there was a specific time operating schedule for the FCU. Overall, the private facility needs an energy management program in compliance with the country's energy efficiency and energy conservation program.

1. INTRODUCTION

Roughly 10% of the total electric power consumption was being consumed by the Philippines' commercial sectors [1]. Because of this, implementing energy efficiency measures was highly encouraged through technological and behavioral measures. To be considered energy efficient, one must consider minimizing energy consumption while maintaining standard working conditions for worker productivity and health. The conduct of an energy audit of a building or facility is needed to ensure the efficient utilization [2] and recovery of energy [3] by the sustainability efforts as prescribed in the United Nations Sustainable Development Goals (SDG). This includes SDG 11 (Sustainable Cities and Communities) in cities that account for between 60 and 80 percent of energy consumption and generate as much as 70 percent of human-induced greenhouse gas emissions.

The commercial office building to be audited was the UP-Ayala Land Technohub property office as shown in Figure 1. Technohub is envisioned as an integrated community of science-and-technology companies. The office which has a floor area of 85 m^2 is located inside the UP-Ayala Land Technohub complex. It operates every day for 24 hours to support the building management needs of establishments in the complex. Higher operating hours of this commercial office increase its monthly energy consumption.

Within the commercial office facility, three representative areas will be covered namely, the reception area, administration office, and the building engineer's office. For measurements, the office was divided into grids (A1-A14) as shown in Figure 2. Actual measurements of room temperature, number of occupants, illumination, and energy consumption of the air-conditioning and lighting systems were taken at different periods in each grid.

To obtain a wider estimate for overall building energy consumption, this study looked into three areas while monitoring their respective working environments based on lighting and temperature. A survey was managed to collect the standpoints of the occupants of the building [4]. The building is one storey, house-like structure, with only two rooms. Aside from this, the temperature was only monitored based on the entire floor area and was not divided into smaller sections, wherein it some spots can be warmer/cooler.

The main objective of the study is to maximize the efficiency of electricity usage within the property office. Specifically, it aimed to evaluate the performance of existing lighting fixtures to attain the minimum acceptable standard of 300 lux for offices [5]. Another goal of this study was to establish the baseline energy efficiency indices (EEI) for air-conditioning units and the facility's lighting system. The range of values was higher than standard room temperature since the audit period of the project was within the summer season, thus entailing a higher outdoor temperature. As to appropriately check for air conditioning unit efficiency, the range of ambient temperature was set higher to fit the tropical climate of the Philippine environment [6]. Lastly, to come up with the appropriate recommendations to improve the energy conservation program.

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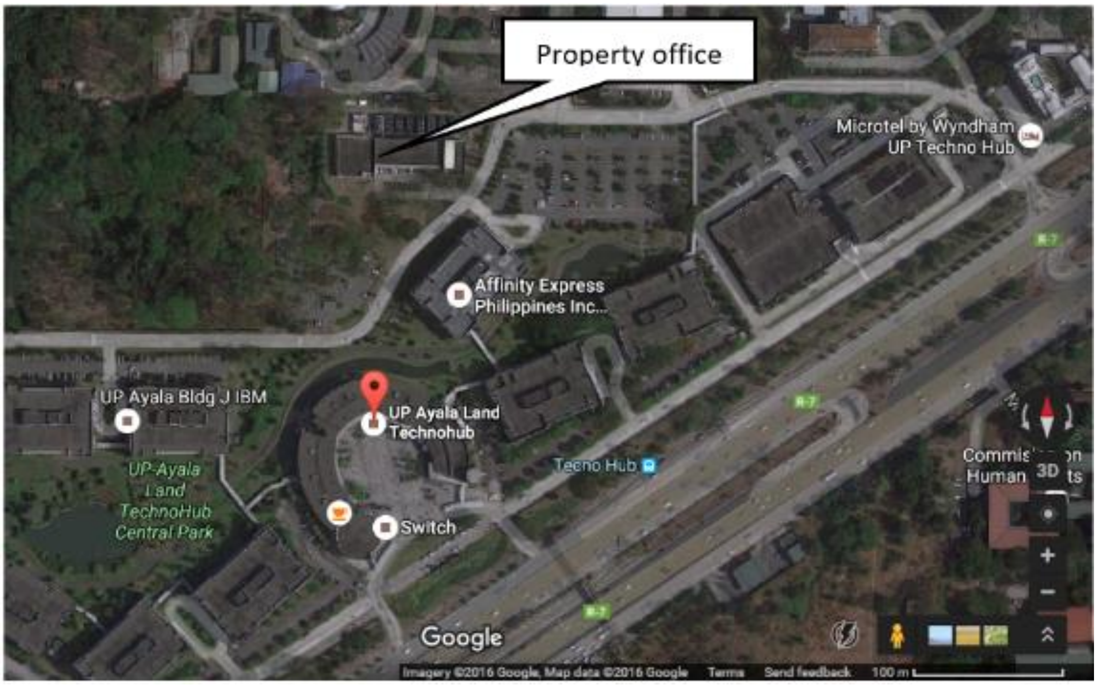

Fig. 1. Location of the UP AyalaLand Technohub property office.

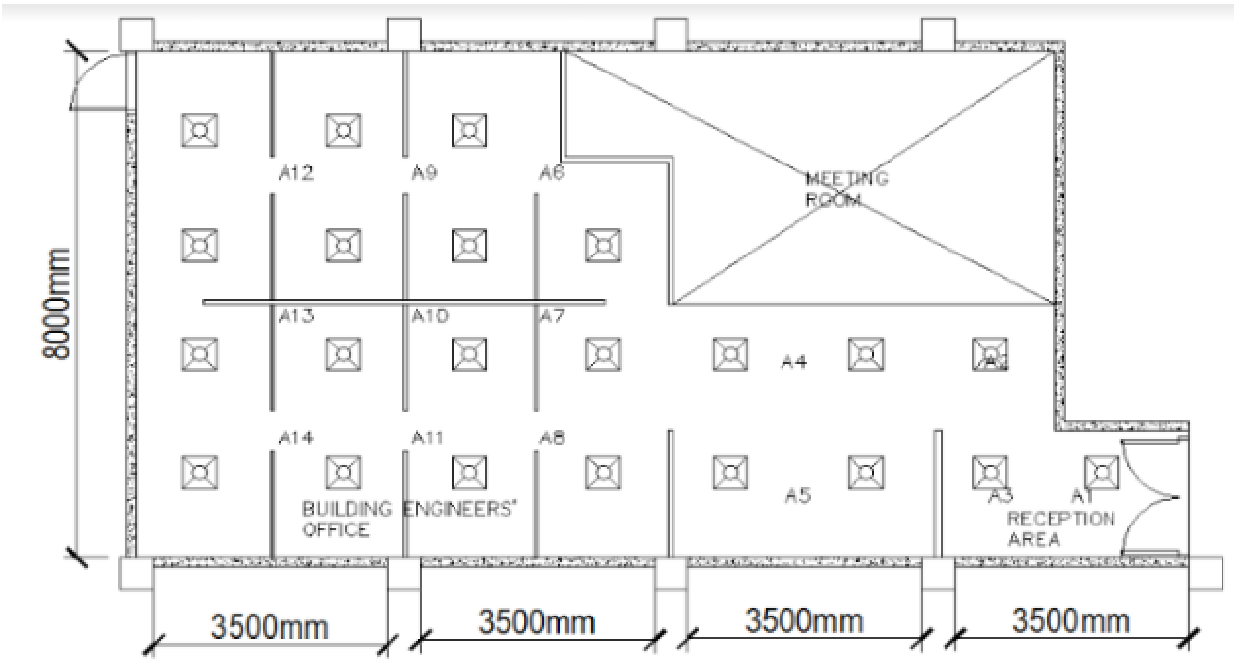

Fig. 2. Grid designation.

2. METHODOLOGY AND RESULTS

Before the conduct of the pre-energy audit inspection, written permission was communicated to the manager of the property office of UP Ayala Technohub to have seamless conduct of the audit. The auditors were oriented about the safety and security procedures of the facility including the areas of the building allowed for inspection namely, (1) evaluate the status of energy management aspects using the Energy Management Matrix, (2) measure light intensity based on the assigned grid of the area of the facility using a downloaded application, (3) measurement of room temperature using Fluke infrared thermometer at a specific regular distance from ceiling FCU diffusers within the office at certain points in the room, (4) voltage and current measurements at the electrical panels were conducted to obtain the power consumption of the fan coil unit, (5) physical Inspection of the furniture within the area and energy-consuming devices to create a detailed floor plan, (6) inventory of the energy-consuming devices and other furniture and fixtures inside the office, and (7) interview with the maintenance personnel to inquire the in-placed energy conservation measures.

2.1 Data and Analysis

The UP Technohub (Property Office) uses FCU (fan coil unit). A fan coil unit (FCU) was a simple device consisting of a heating and/or cooling heat exchanger or 'coil' and fan. It was part of an HVAC (heating, ventilation, and air-conditioning) system found in residential, commercial, and industrial buildings. A fan coil unit was a diverse device sometimes using ductwork and was used to control the temperature in the space where it was installed or serve multiple spaces. It was controlled either by a manual on/off switch or by a thermostat, which controls the throughput of water to the heat exchanger using a control valve and/or the fan speed. Fan coil units circulate cold water through a coil to condition the ADMIN office. The office gets its cold water from a central plant, or mechanical room containing equipment for removing heat from the central building's closed loop.

To analyze the EEI of the FCU, we should note the changes in temperature of chilled water, and its mass rate using Equation 1 and Equation 2.

Actual EEI formula:

$$\text{EEI (FCU)} = \frac{\dfrac{\text{actual energy}}{\text{electrical consumption}}}{\text{standard temperature of the office}} \tag{1}$$

Standard EEI Formula

$$\text{EEI (FCU)} = \frac{\dfrac{\text{standard energy}}{\text{electrical consumption}}}{\text{standard human comfort of temperature}} \tag{2}$$

The light levels were measured using an android application, with the uncertainty of 1 lux. The EEI and sample calculation were shown in Equation 3. And each luminaire has a theoretical power rating of 40 Watts (2 x 20 Watts). The EEI uncertainty (*Δ*EEI) is shown in Equation 4.

$$\text{EEI} = \frac{\text{Power}}{\text{Light Level}} \tag{3}$$

$$\Delta\text{EEI} = \text{EEI} * \sqrt{\left(\frac{\Delta \text{LL}}{\text{LL}}\right)^2} \tag{4}$$

2.2 Temperature Analysis

Audit data were gathered a different time intervals. After the data gathering, EEI was computed. Comparison will be made for the actual and standard temperatures for human comfort cooling.

Based on the standard set by ASHRAE [5], human comfort cooling through initiatives that aimed to strike a balance between the energy-saving, hence less CO_2 emission, and thermal comfort, even though 25.5°C may not be the most preferred room temperature for every person.

Fan usage amperage was monitored from 11 am to 7 pm, and produced an actual energy consumption of 1.33 kW, this was compared to the office standard power of 6.3 kW to be consumed from an ADMIN office of 85 m^2. The actual EEI for the air conditioning unit was 8 kW-hrs per 25.5°C as compared to the ideal EEI of 37.8 kW-hrs / 25.5°C.

2.3 Lighting System

The light level of illuminance (lux) was the amount of light measured in the plane surface (or the total luminous flux incident on a unit area of a surface) [7]. According to the National Optical Astronomy Observatory, the national observatory in the United States, the outdoor level can be as high as 10,000 lux while the light level indoors, near windows, could be reduced to approximately 1,000 lux. In the middle area of a building, it could be as low as 25-50 lux. For low light levels, additional equipment is necessary to compensate for this [8].

Today, light levels were common in the range of 500-1000 lux. For precision and depending on the need of the activity, the light level may even be 1500-2000 lux. In general, several factors affect the light level on a specified surface such as the quantity and quality of light, amount of flicker, amount of glare, contrast, and shadows. Each factor must be adjusted for optimization for applications in an emergency, safety, operations, and security situations. Standards serve to address concerns related to design, placement, installation, minimum energy requirements, and efficient allocation of illumination in different locations with different purposes, as well as efficiency, durability, cost, and maintainability [9].

Light levels have been one of the main focuses of visual comfort. As observed, the more intense the task is, the brighter the room should be [7], [8]. The lighting throughout the facility identified for the pre-energy audit inspection at the UP AyalaLand Technohub Property Office was provided by fluorescent luminaires with T8 technology lamps and electronic ballasts. Lighting systems were powered by 220 volts. Areas were reviewed for current conditions as shown in Figure 3. Any differences in the inventory and equipment on-site were taken into account when preparing estimates and calculations [9].

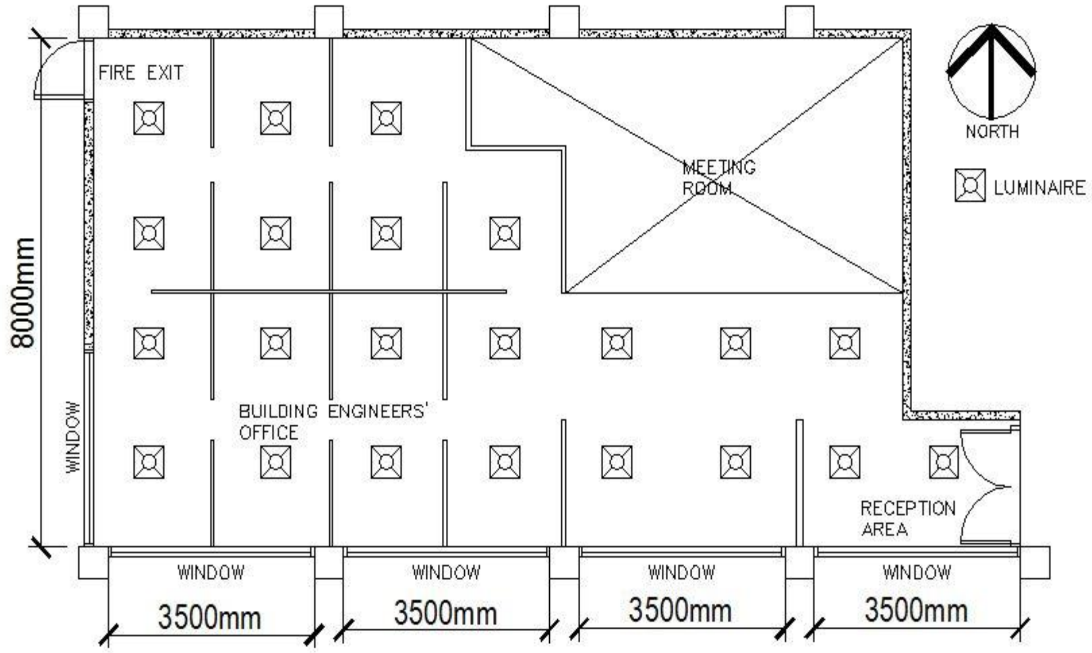

Fig. 3. Lighting layout.

Light levels were taken at nine time slots (on weekdays and weekends) on different lux points. The probability distribution gives an average of 289.9 ± 220.9 lux. The standard deviation is quite large, comprising 76 % of the mean. This average was expected because there is no lighting schedule in the facility. Since the spread from the mean value of the light levels on the facility is too large, the minimum and maximum light levels were considered for this assessment. Taking the light level measurement on the walk-through schedule, the generalizations could be taken as assessment points for this activity. Since the walk-through was done on weekdays and a weekend, the light level measurements were compared on those schedules, as well as those taken on each of the lux points.

Out of the weekday light level measurements shown in Figure 4, the 1100 data was significantly higher by 64 % than the night-time data (2200 and 2300).

Based on Figure 5, the weekend morning (1100, 1200) measurements were highest averaging 457 ± 33 lux, followed by the evening (1800, 1900) measurements at 205.2 ± 0.4 lux, and lastly the afternoon (1300, 1400) measurements with 159 ± 20 lux.

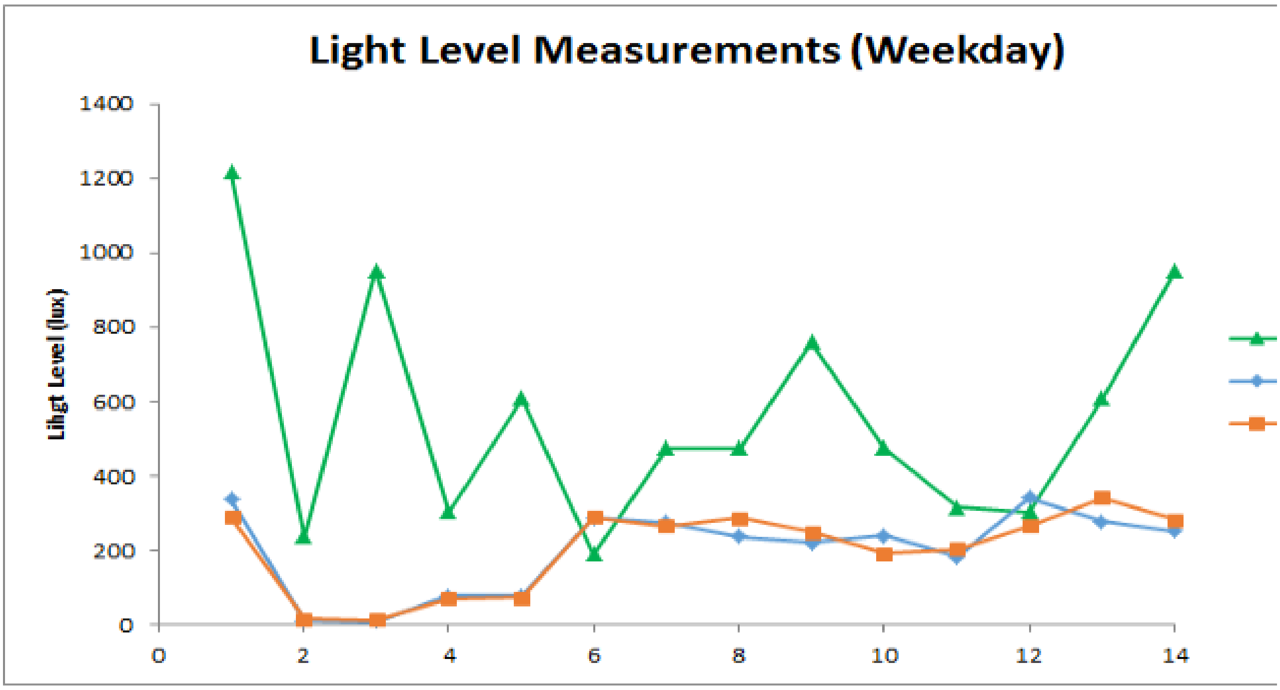

Fig. 4. Light level measurements taken at the facility on a weekday.

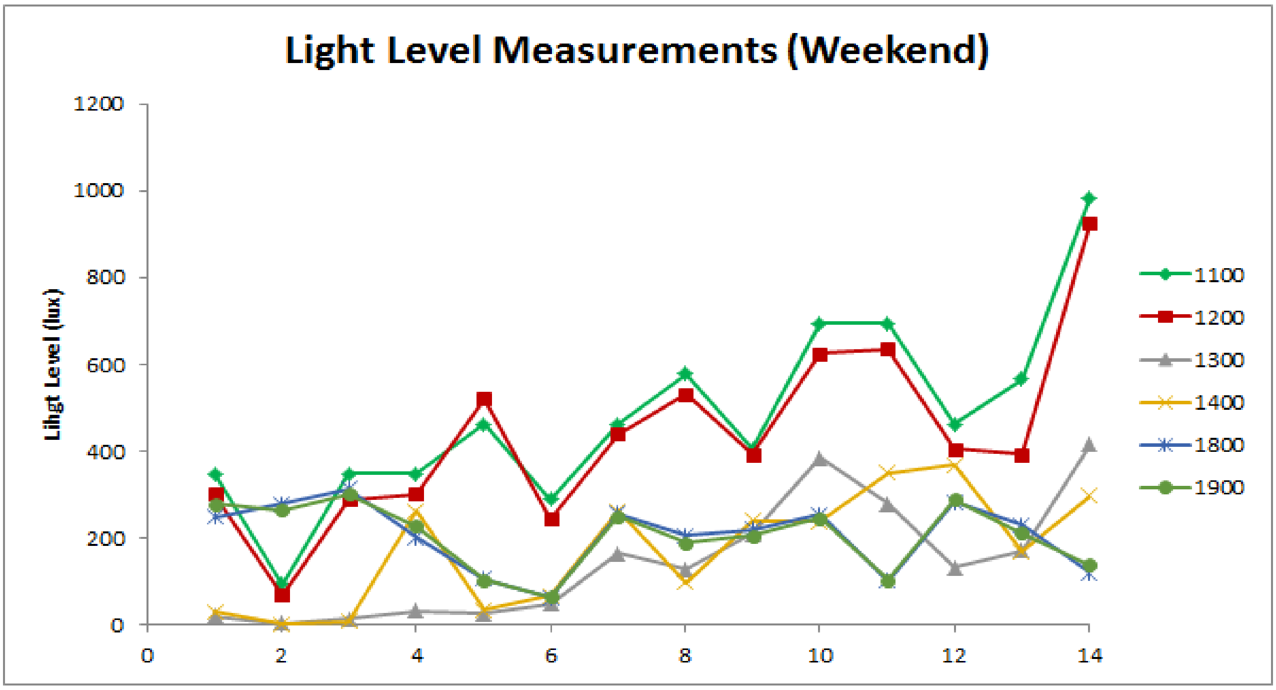

Fig. 5. Light level measurements taken at the facility on a weekend.

Table 1. Luminaire locations.

Location	Area	Luminaire
A1	Reception	central to 1 functional luminaire
A3	End of facility	central to 2 functional luminaires
A6	Corner of facility	central to 3 functional luminaires
A12, A13	Reception	central to 4 functional luminaires

Considering the lux points, the maximum light level measurements were identified at the following: A1 (weekday), A12-A13 (weekend), and the minimum light level measurements were identified at the following lux points: A6 (weekday), A3 (weekend). These were distinguished in Table 1.

The maximum light level at A1 on the weekday was due to its inherent location - found directly beneath a functional luminaire. Since the facility was generally operational during weekdays business hours, it was expected to have a more intense light level at the reception area. On weekends, the light levels at A12 and A13 were maximized at the end part of the room (away from the windows where light tended to be diffused to the dark environment outside the office). Moreover, these lux points were central to 4 functional luminaires.

The minimum light level at A6 could be explained by its location in the facility. Since it was located at the corner of the room, with only 3 functional luminaires in its vicinity, as compared to other lux points central to 4 functional luminaires, or found directly beneath a functional luminaire, it would have a less intense light level. During the weekend, the light level at A3 was minimal because the luminaires at the reception area were intentionally turned off (1 out of 3) as the office was not expecting an influx of clients on the day.

Comparing the light levels with literature, we come up with this summary where the actual usage of the facility site was compared to standard level usage [7].

At A1, the light level taken in the morning corresponds to standard level use in drawing work, mechanical workshop, and operational theatre, which were for fine work and precise inspection. The light level taken in the morning could be decreased by turning off (1 out of 3) one luminaire, as the reception desk does not necessitate such usage. At A12 and A13, the light levels taken in the evening were just enough for office work where visual tasks are moderately easy with high contrast or larger size [8], [9].

At A6, the light level taken in the morning corresponds to standard level use in warehouse, home, theater, and library archives which were for visual tasks in occupied interiors. Since A6 was in the workstation already, the light level could be improved by adding another artificial source of light like a desk lamp, or any kind of movable lamp to meet the light level required for office use. As previously mentioned, A6 was found in a corner of the room, within the vicinity of only three luminaires. At A3, the light level taken in the evening was similar to light levels in tunnels and walkways which were rarely used interiors for movement and fine detail. The light level could be increased by turning on another luminaire to meet the light level required for office use [8], [9].

On the weekend, not all luminaires were

intentionally turned on as there were few personnel presents on the day. Following the working principle that the operational luminaires were dependent on the use of the occupants, it was just intuitive to find that the most intense light levels were in the morning, as the natural light coming from outside gets through the transparent windows, dispersing through the facility. In the afternoon, the light levels get less intense because the natural light was less bright during the time. The light levels in the evening were relatively higher than the light levels in the afternoon because more luminaires are turned on at the time.

The maximum light levels at A14 and A12 in the morning and afternoon time slots, respectively, correspond to the inherent location of the lux points. These lux points were found at the end of the room, with all luminaires turned on. These lux points were central to 4 functional luminaires. Moreover, A14 was found near the transparent window, which at daytime receives the greatest influx of natural light from the outside. In the evening, the maximum light level was found at A3, which was in the reception area. This was just as expected as in the evening, more luminaires were intentionally turned on for use by the occupants in the facility. The lux point at A3 was central to two functional luminaires.

The minimum light levels during daytime were found at A2, a lux point at the reception area. This was predicted as, during the daytime, some of the luminaires (1 out of 3) at the reception area were intentionally turned off to conserve energy. In the evening, the minimum light level was found at A6, the same lux point with minimum light level measurement on a weekday. The main factor affecting the light level was that this lux point is found in a corner of the room.

Comparing the light levels with literature, the researcher came up with this summary where the actual usage of the facility site was compared to standard level usage.

The light level at A14 taken in the morning corresponds to usage for very difficult visual tasks such as in general inspection, electronic assembly, gauge and tool room, and supermarkets. It could be reduced to a level that was suitable for office work. Reduction of the light level could be done by turning off one or two luminaires within the vicinity. In the afternoon, and evening, the light levels at A14 and A12, and A3, respectively are sufficient for office work [8], [9].

In the morning and afternoon, and evening, the light levels at A2, and A6, respectively, correspond to relative lighting for occasional interiors for movement and casual seeing with good usage in corridors and changing rooms. The recommendation for relatively dim lighting in the reception was to increase the light level to meet the standards for office use. This could be achieved by turning on one luminaire at the reception to aid the light level at A2 and sourcing out another light at A6 [8], [9].

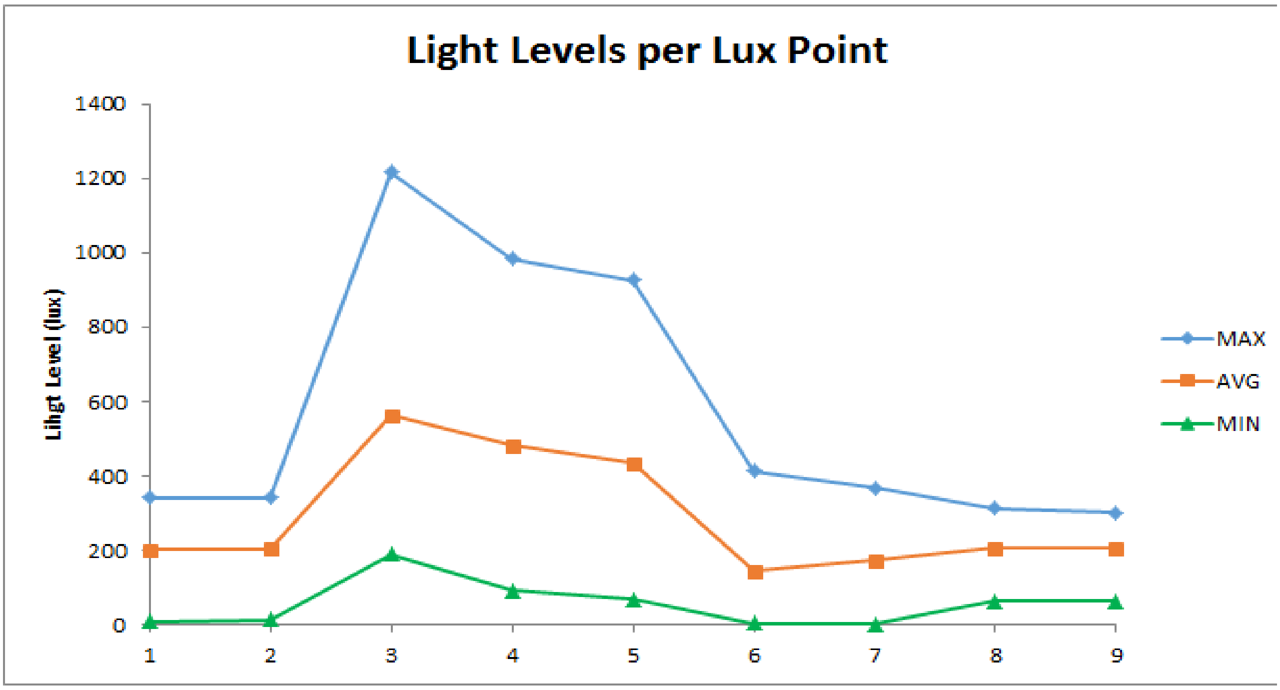

Fig. 6. Light level measurements taken per point.

Figure 6 shows the maximum, average, and minimum values at each time slot. The maximum light levels were recorded on time slot 3, taken at 1100. The measurements were taken on a weekday morning when the luminaires were fully operational due to the needs of the occupants, on weekdays when the population size was optimal, and most especially when the natural light was highly transmitting through the office space.

The minimum light levels were recorded on time slot 7, taken at 1400. The measurements were taken on a weekend afternoon, especially when some of the luminaires (three out of 22) were intentionally turned off to conserve energy when the occupants are minimal, and when the office space uses the natural light as a light source.

Comparing the light levels with literature, the actual usage of the facility was compared to standard level usage from literature.

The maximum light level taken on a weekday morning corresponds to usage for very difficult visual tasks such as in general inspection, electronic assembly, gauge and tool room, and supermarkets. It could be reduced to a level that was suitable for office work [8], [9].

The minimum light level taken on a weekend afternoon corresponds to relative lighting for occasional interiors for movement and casual seeing with good usage in corridors and changing rooms. The recommendation for relatively dim lighting was to increase the light level to meet the standards for office use [8], [9].

The computed EEI on each lux point was a function of the light level as shown in Figure 7, since the power rating standardized for each luminaire was constant. Therefore, the higher the EEI, the lower the light level at a constant power rating, and the lower the EEI, the higher the light level at a constant power rating. The lowest EEI with the highest light level was taken on time slot 3, weekday morning. This accounts for the light level taken on a weekday morning with relative usage for very difficult visual tasks such as in general inspection, electronic assembly, gauge and tool room, and supermarkets. It could be reduced to a level that is suitable for office work [8], [9].

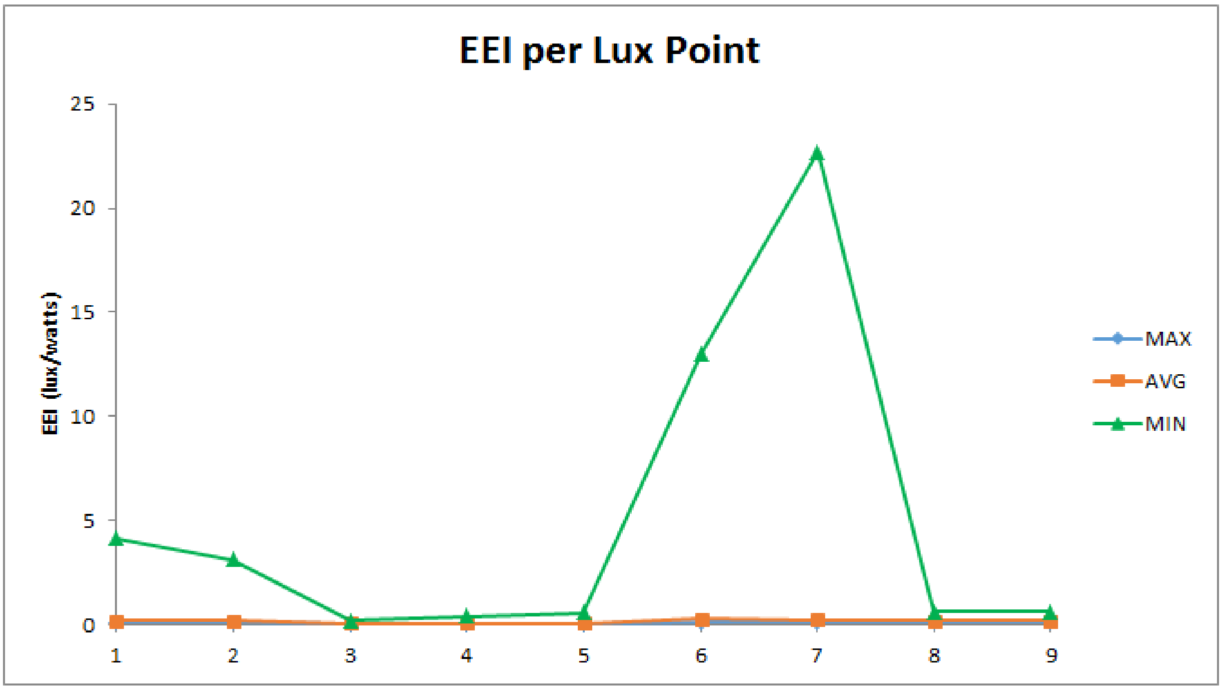

Fig. 7. EEI computed per time slot.

The highest EEI with the lowest light level was taken on time slot 7, accounting for the weekend afternoon light levels which correspond to relative lighting for occasional interiors for movement and casual seeing with good usage in corridors and changing rooms. The recommendation for relatively dim lighting was to increase the light level to meet the standards for office use [8], [9].

Lighting levels vary widely throughout the facility. As a result, areas of similar usage can have different light levels. This results in light levels being adequate in some areas but below the recommended levels in other areas.

The interior lighting within the facility was manually controlled. They were switched on by the occupants according to need. There appears to be no timed or automated control for the main lighting in the facility. As a result, the lighting systems in the facility operate many hours per day and per week longer than facility occupancy or use. For the audited facility, peak occupancy use was from 8:00 AM to 5:00 PM but generally, the facility was operational all days, with a few personnel on duty as officers-in-charge during off-peak occupancy usage.

Critical seeing areas were reviewed for the comfort of the visual environment and the adequacy of illumination to meet the needs of the occupants by the light levels. General recommendations of reducing and increasing the light level can be addressed by switching off and on the necessary luminaires to meet the standard light level for office use.

3. CONCLUSIONS AND RECOMMENDATIONS

The result of the pre-energy audit activity in the Property Office of UP Ayala Land Technohub proved that there were aspects in the energy utilization practice of the office that needs re-alignment based on standards and best practices of energy efficiency towards the attainment of the sustainable energy management system. Based on noticable physical observations and the results of computations of energy efficiency indices (EEIs), the author derived the following conclusions and recommendations.

1. Actual energy consumption for FCU was lower than the standard energy consumption for comfort

cooling due to the unavailability of other data required for the FCU. Only FAN unit power was calculated. Also, the set temperature for the admin was lower than the human comfort temperature of 25.5 ºC.

2. The measured lux values comprising the fourteen (14) identified grid points were not in conformance with the desired lux level of appropriate luminance for this kind of facility. The distribution of the luminaires inside the property office should cover the areas where the bulk of activities of personnel happened every day during office hours. Consider revising the layout of desks and consoles for optimum lux distribution in the area and providing effective controls that prevent lights from being left on unnecessarily.
3. There was no total awareness of personnel on the Energy Efficiency and Energy Conservation Program. The office manager was encouraged to attend specific training for energy efficiency from reputable sources and entities to conduct awareness seminars for all personnel.
4. There was no in-placed sustainable energy management (SEM) program in the office. This study recommends tapping experts and considering the implementation of SEM for the effective utilization of energy in the Property Office and across the UP-Technohub facility.

The results of this study can be used as a baseline for any enclosed offices in conducting an energy audit procedure in the Philippines. For future research, the performance of the commercial building with regards to energy audit can be studied further.

Simulation software can also be used to further examine the factors affecting every design system of the commercial building in power consumption.

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