Developing an Energy Audit for Baseline and Scenario Analysis of a University Library

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Abstract – *In an academic university building, the library is one of the most used facilities as a place for studying and research. To further understand the energy use within the library, a baseline energy consumption profile was created by studying the different equipment in the facility as well as how often people would use them through an energy audit. Lighting and temperature of the area were also measured and compared to current standards for workplace productivity (200-500 lux and 22.5-25.5 °C). Given baseline estimates, recommendations were formulated to optimize electricity consumption within the library while reducing corresponding CO_2 emissions and power costs. Recommendations are expected to result in a significant decrease in total monthly energy consumption of the university library, amounting to Php 54,507/month electricity cost savings and 2.59 ktCO_2 in monthly CO_2 emissions reduction.*

Keywords—Power Consumption, Library, Energy Efficiency, Energy Audit

I. INTRODUCTION

Building energy consumption has been rapidly increasing due to various factors such as population growth and rise in urbanization [1]. In understanding how energy is used within a facility, it is essential to conduct an energy audit since it can further quantify power consumption even through simple tools and methods, which can serve as a baseline for providing energy conservation measures [2]. Academic institutions contribute a significant portion of overall energy consumption due to their high number in the total building stock [3], and given their educational environment, schools can be used as training grounds for implementing the energy auditing process. Within an academic building, the library would be one of the most utilized school facilities since it serves as a study area for students, a place for research due to its vast repository of books, and a venue to hold discussions and meetings [4].

Breaking down energy consumption data lets one understand where the bulk of usage is coming from, which would help formulate more appropriate and cost-efficient energy saving solutions. Developing energy conservation measures would not only reduce power costs but also reduce CO_2 emissions [5]. In most cases, the main contributor to total power usage within a building is from the HVAC system, which makes up 40-60% of energy consumption [6], however for particular facilities such as libraries, most of the energy use would stem from lighting [7].

Apart from energy cost savings, the optimal standard working conditions of the school facilities must be considered in formulating energy scenarios. Factors such as natural light exposure should be considered since it is proven that students exposed to more daylight have a tendency to perform better, however one must take note of measures to counteract the added heat load and glare from sunlight [8]. Lighting design in buildings aims to allow its users to carry out their work as efficiently as possible without sacrificing comfort. In a study by Thangaraj, 61% of students agreed that their seating preference within a facility was affected by lighting and that 65% would want an optimized lighting design [9]. Thermal comfort is also an important factor in creating optimal working conditions, in which climate plays an important role in determining the appropriate temperature standards as tropical countries have a higher threshold for heat tolerance as compared to their temperate counterparts [10].

Energy modelling software is oftentimes used when it comes to analysing building energy efficiency. A research was conducted in a school cafeteria to see which components contribute the largest share on overall power consumption. The study used the Visual DOE 4.1 software which required input parameters such as building shell, operation schedules, and systems such as lighting and air conditioning. From the results, the cooling system made up around 66% of electricity used, followed by lighting and fans [11]. Though the study was able to determine the significant factors, the procedure in obtaining the power densities was not mentioned. In terms of validating the model inputs, the energy audit procedure mentioned the collection of bills but not the actual collection of power measurements, particularly the cooling units which can be prone to a higher actual energy use as the system ages. According to a research paper conducted by the Riga Technical University in Latvia, indoor temperature and relative humidity have an impact when it comes to energy efficiency [12]. The study, however, used the recommended indoor air parameters based on European standards and not an actual building sample. Looking at a study on assessing thermal comfort within the Mediterranean climate, the researchers used a university office building as a case study. The building was equipped with measurement devices to analyse the ambient comfort of the occupants. Aside from this, a survey was administered in order to gather the perspectives of the office occupants [13]. In this case however, the temperature was only monitored based on the entire floor area and was not divided into smaller sections, wherein it is possible for some spots to be warmer/cooler.

In summary, the research gaps found in the literature would be the lack of the bottom-up approach in obtaining energy consumption data as the procedures of collecting actual measurements were not highlighted in the studies. Aside from this, the method of energy monitoring can be further broken down to analyse sections within the building/facility to check for warmer/cooler spots that can be remedied by energy conservation measures. This paper shows how to estimate baseline energy consumption and conduct scenario analysis via a bottom-up approach through the energy audit procedure.

1.1 Objectives of the Study

The main objectives of this study were 1) to estimate the baseline energy consumption of the University of the Philippines Diliman College of Engineering Library 1 and 2) to formulate measures that will reduce electricity consumption, cost, and environmental impact while maintaining standard workplace conditions. Specific objectives include the following:

- To evaluate the performance of existing lighting fixtures in trying to attain the standard of 500 lux for tabletop reading and 200 lux for the shelves' vertical surface [9];
- To evaluate the performance of existing air conditioning units in trying to achieve a room temperature of 22.5 to 25.5 °C during the library's operating hours [14];
- To identify a more efficient lighting type and air conditioning system that will maintain the standard lux and temperature for libraries;
- To determine the computer usage within the library; and
- To evaluate the environmental impact of the library's energy consumption via its CO_2 emissions.

II. METHODOLOGY

2.1 Establishing Baseline Data

2.1.1 Preliminary Data Gathering

Within the academic building, the proponents focused on looking for facilities and offices that function on regular hours to conduct an energy audit, which meant excluding all laboratories, which usually operate depending on the experiments conducted. After assessing the plausible areas for study, the library was chosen due to the high foot traffic and utilization by both students and faculty members.

The library comprises of several sections; Circulation Area, Basement Area, Computer Room, and The Learning Commons Room. The utilization of the computers in the The Learning Commons Room and Computer Room was obtained, as well as the usage of the Online Public Access Catalogue (OPAC) units (Fig.1).

After determining the focus of the study, the proponents interviewed the building administrator and head librarian to gather initial data. The corresponding floor plans for the Ground Floor and Basement were subdivided into 34 and 15 partitions, respectively, which served as guides in measuring the light intensities and temperatures of the assigned divisions (Fig. 2). The basis behind the divisions is to obtain more lux and temperature data points and observe how these are distributed across the facility. The divisions were determined by the table arrangements and shelves placements within the library. The specifications of the air conditioning units and lighting fixtures were also obtained.

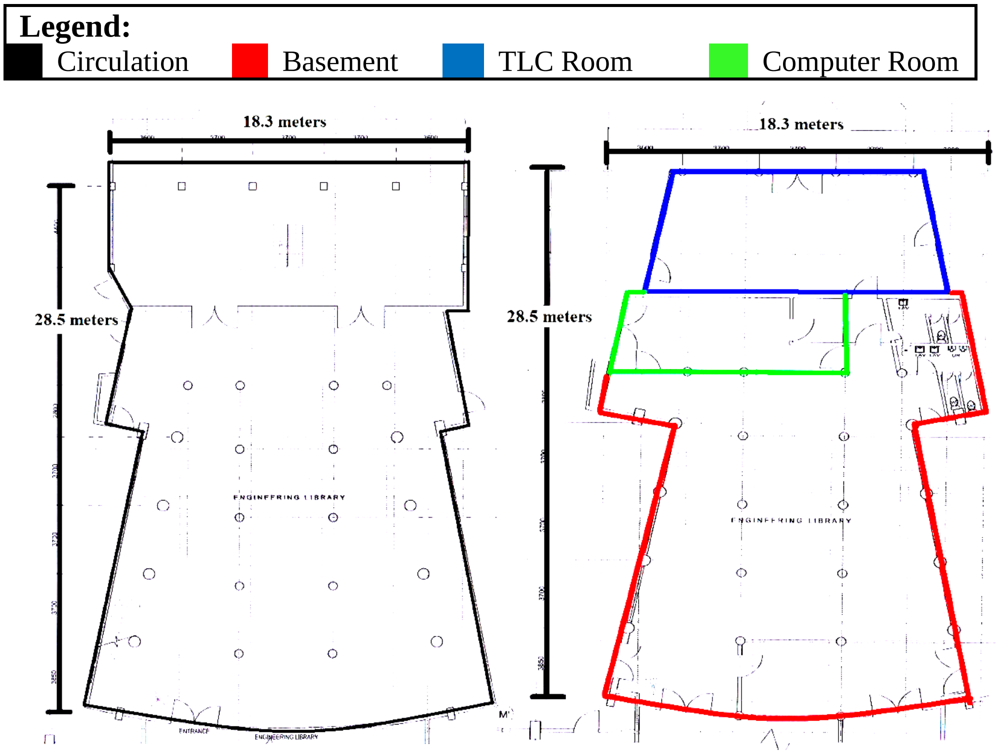

Figure 1. Respective sections of Library Ground Floor (left) and Basement (right)

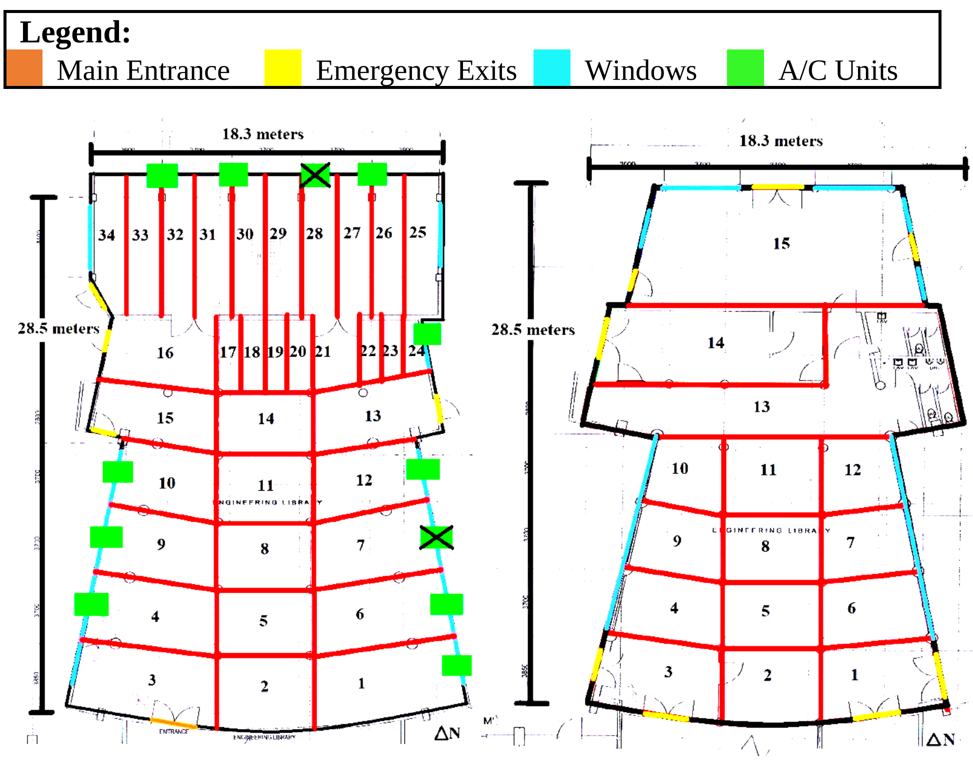

Figure 2. Respective divisions of Library Ground Floor (left) and Basement (right)

2.1.2 Energy Audit

An energy audit is defined as the study of a building or facility to determine how and where energy is being used, from which energy saving measures can be identified [15]. There are three levels of energy audits according to the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE); Site Assessment or Walkthrough Audits (Level I), Energy Survey and Engineering Analysis (Level II), and Detailed Analysis of Capital-Intensive Measures (Level III) [16]. This study has applied the Level II energy audit wherein a more detailed surveying of the area would yield various energy conservation measures along with its corresponding savings.

The energy audit measurements were obtained thrice a day; 10am, 1pm, and 4pm, for a duration of five days during March, the beginning of the summer season wherein peak energy consumption is expected. These measurements include the actual power consumption of the air conditioning units, the light intensity, and temperature per division and these were obtained using a clamp meter, lux sensor, and ambient temperature sensor, respectively. The list of equipment used and their corresponding specifications are shown in Table 1.

Table 1. Equipment and Corresponding Specifications

Equipment	**Specifications**	**Precision**
Light Meter	Range: 2000/20000/200000 Lux Spectral response: CIE Photopic.	4% 10dgts (10,000Lux) to 5% 10dgts (10,000Lux)
Temperature Probe	Range: –40 to 135°C Temperature sensor: 20 kΩ	±0.2°C at 0°C ±0.5°C at 100°C
Clamp Meter	Range: 1000AAC, 750VAC, 1000VDC	±3%

2.1.3 Work Sampling

Along with the technical attributes of the library, it was essential to look into the factors relating to the behavioral aspects of its occupants. Computer usage was measured through the work sampling method where duration of three activities (e.g. in use, idle, and off) were observed. This approach deals with obtaining the proportion of a certain device in operation during a given time interval [17]. A pilot study on the computer usage was initially conducted to determine the appropriate sample size for the actual work sampling. An initial sample size of 25 was utilized over a period of five days, considering a 95% confidence interval and 5% margin of error. The sample size for the work sampling proper was calculated using Equation 1.

$$n = \frac{z^2 p(1-p)}{h^2}$$

Where n = required sample size
z = standard normal deviate for desired confidence level
p = estimated value of sample proportion
h = acceptable error level in percent

(Eq.1)

From this, the utilization of Mac and Windows computers were calculated, and a sample size of 33 and 31 for Mac and Windows were obtained, respectively. For the purpose of convenience, the computed sample sizes of both computers were rounded up to 35 each for a period of six days. For the OPAC units, the computed sample size was 46 which was extended to 25 per day for a period of three days. In designing the work sampling forms, the generated times ranged between 8:00 am to 6:00 pm as to account for the operating hours within the library.

2.2 Developing Alternatives

After the data were gathered and analyzed, alternatives were developed to optimize energy consumption within the library. These alternatives were compared with the current setup using several criteria such as ability to meet operating standards, CO_2 emissions, net present value (NPV), and savings in kWh & Philippine pesos in comparison to the current system. A rate of 9.36 PhP per kWh was used in the computation of cost savings [18]. An emission factor of 0.5038 tCO_2/MWh was used in obtaining the CO_2 emissions of the current system and the proposed alternatives as provided by the Philippine Department of Energy [19].

III. RESULTS AND DISCUSSION

3.1 Baseline Data

3.1.1 Light Intensity

The light intensities within the university library were obtained by measuring the lux from the center of each division. The average lux values for each division were plotted in the heat maps placed next to the original floor plans for both the Ground Floor and Basement (Fig. 3).

From the graphs, there were some areas with varying lux which can be explained by the position of the sun during the different times of the day. At 10:00 am, the sun was by the east side of the library which is represented by Divisions 1, 6, 7, 12, 13, 24, and 25 at the Ground Floor and Divisions 1, 6, 7, and 12 at the Basement area. With this, the corresponding sections obtained a higher lux value at this time. At 4:00 pm, the sun was by the west side of the library which is represented by Divisions 3, 4, 9, 10, 15, 16, and 34 at the Ground Floor and Divisions 3, 4, 9, and 10 at the Basement area. With this, the corresponding divisions had a higher lux value at this time. The lux values at the Basement area exhibited larger deviations from one another since most of the windows do not have blinds; thus the sunlight affected the lux values within the floor more as opposed to the Ground Floor.

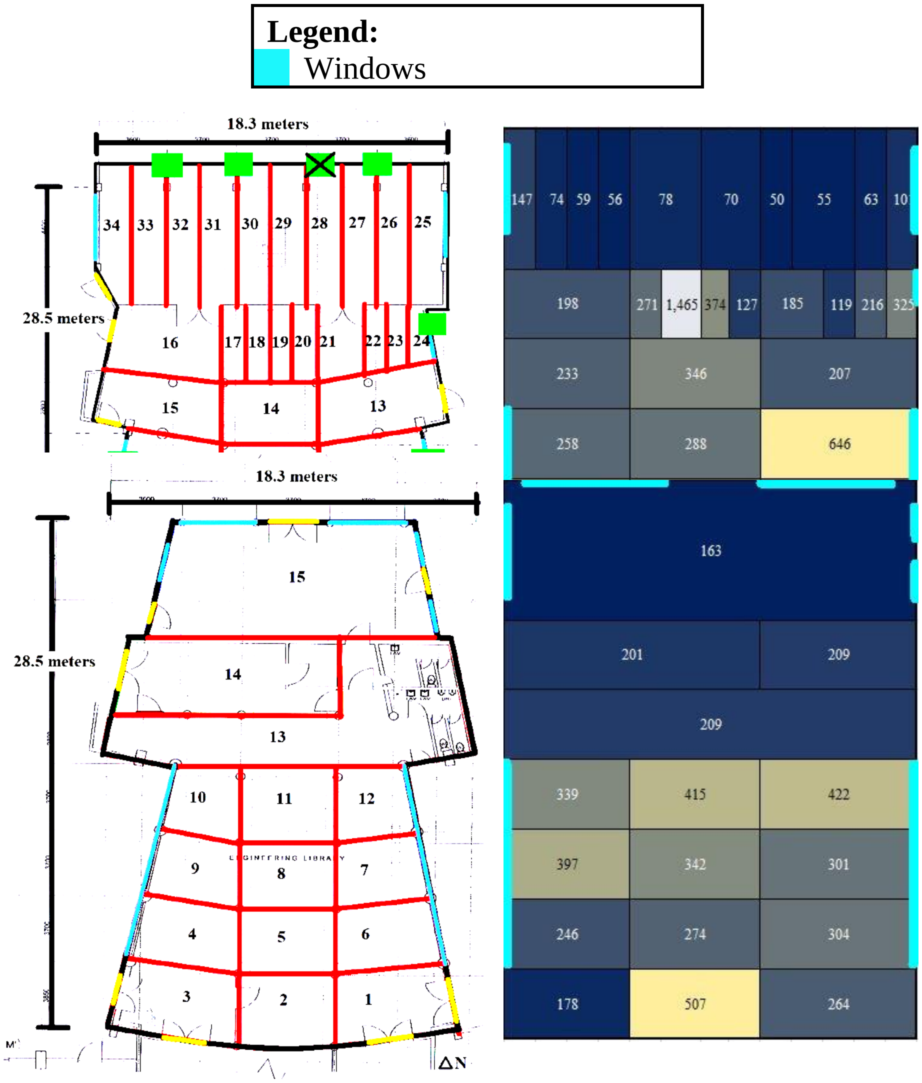

Figure 3. Light Intensity per Division – Ground Floor and Basement (Lux)

From the light intensity measurements obtained during the data gathering, it was found that 34 out of 49 divisions in the university library do not comply with the standard lux requirements, amounting to 426 m^2 of the library area. This is due to the distance between the tables and ceiling, particularly in the Basement, as well as the position of the lighting fixtures which does not maximize the luminance of the units (Fig. 4). Aside from this, it was observed that some shelves were placed directly below the light bulbs, thus blocking the luminosity of the units.

Figure 4. Lighting fixtures placement over tables and shelves at the UPD College of Engineering Library 1

3.1.2 Computer Usage

Currently, the university library has 18 and 16 units of Windows and Mac computers, respectively. The states of these computers (e.g. in use, idle, and off) during the 35 random observations per day conducted over a period of six days were collected and summarized. Figure 5 below shows that the Windows computers were in use 21.1% of the time on average. However, the units were found to be idle in over half of the observations. This can be linked to the current practice of the staff wherein all the Windows computers are left open throughout the day. On the other hand, the Mac computers exhibited a lower rate of consumption at 10.6% on average as seen in Figure 6 below. Six units were opened alternately per day with four back up units should there be a need for more than six computers at a time.

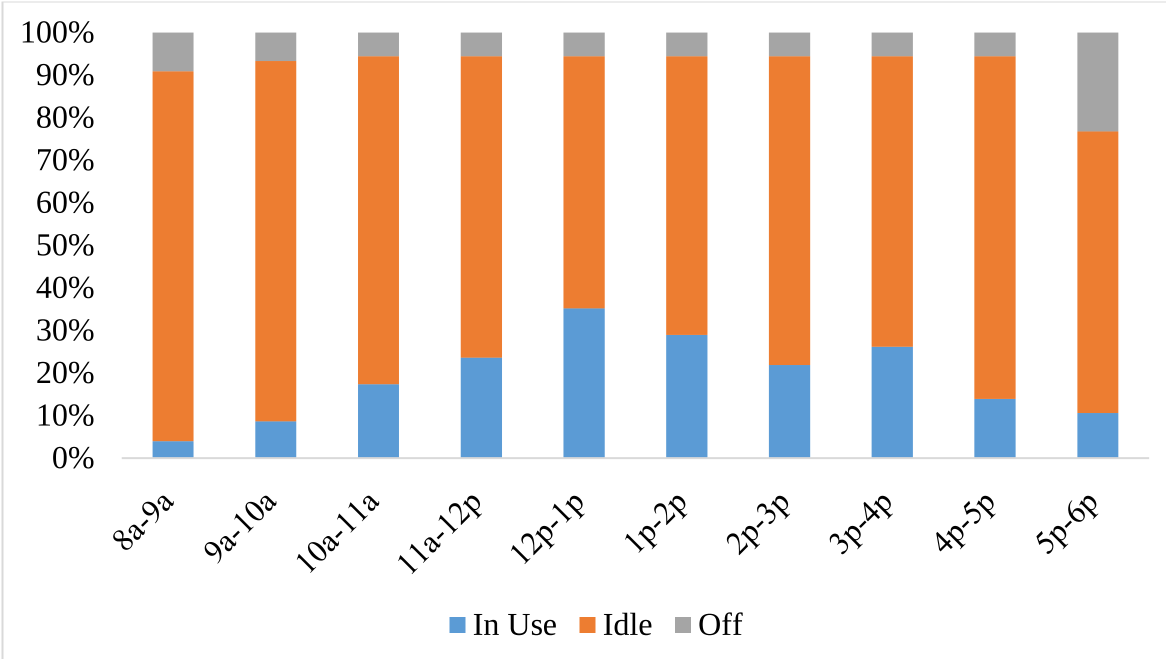

Figure 5. Summary of Windows Computers Usage

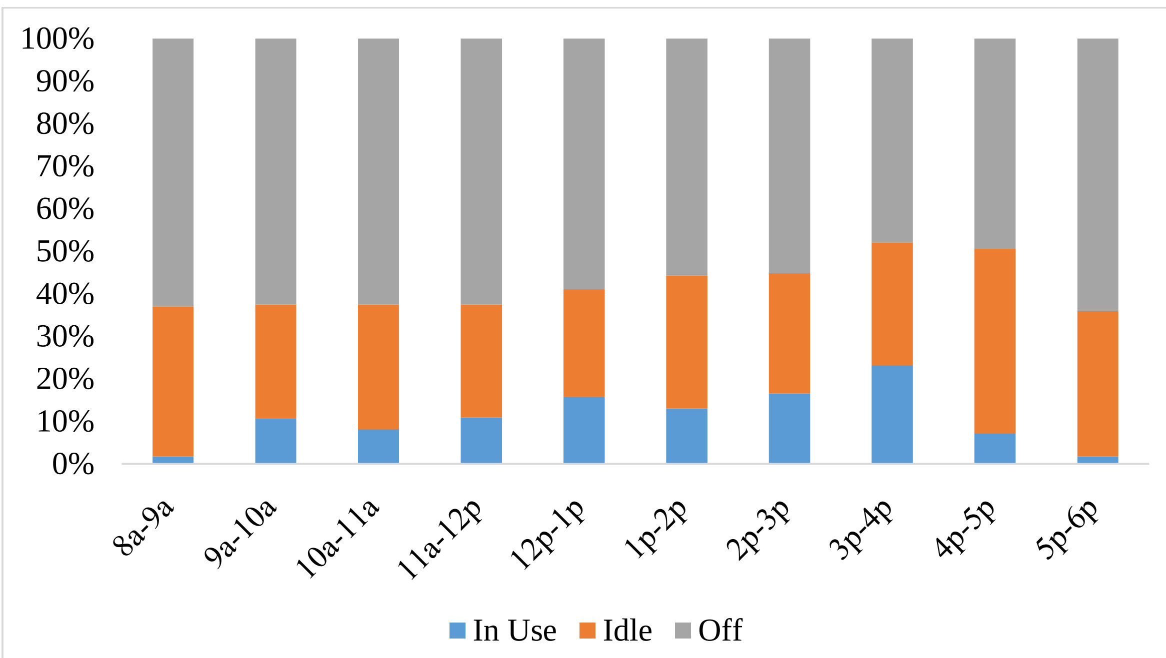

Figure 6. Summary of Mac Computers Usage

For the Online Public Access Catalogue (OPAC) units, 5 units are available for use. From the work sampling, the computers were at idle state at 96% of the time (Fig. 7).

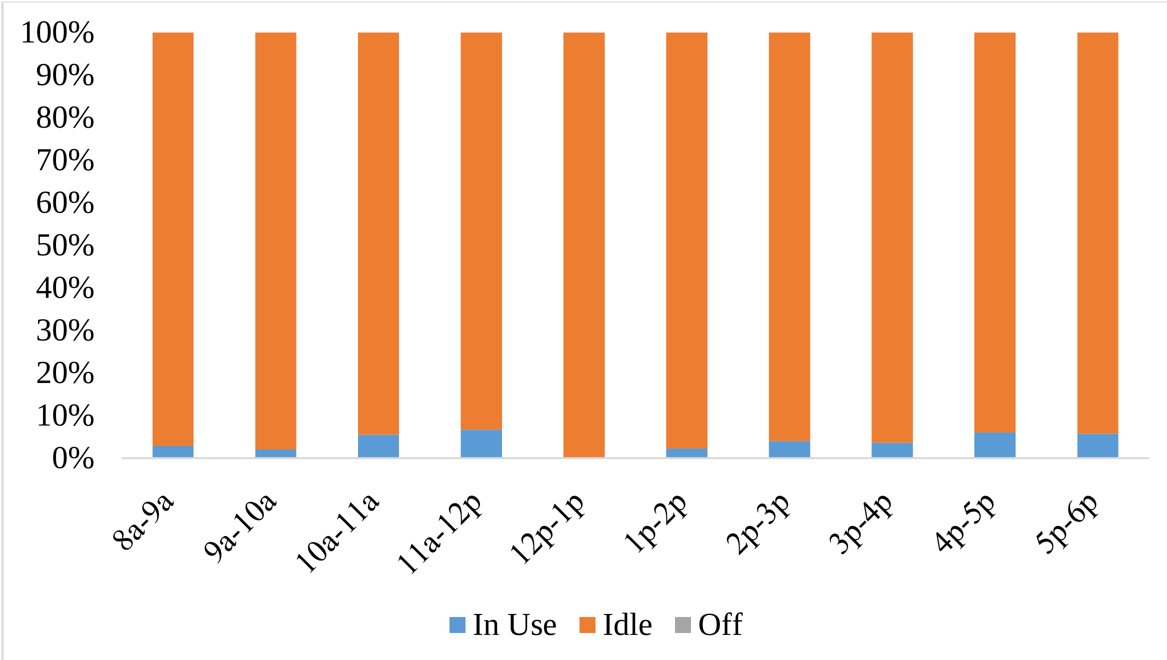

Figure 7. Summary of OPAC Computers Usage

3.1.3 Ambient Temperature

Over a span of five days, the temperature of the ground floor of the university library was measured three times during the day, specifically at 10:00 am, 1:00 pm, and 4:00 pm. Each of the 34 divisions in the ground floor of the library was measured during the three designated time slots in order to obtain a representative measurement for the morning, noontime, and afternoon (Fig. 2). In Figure 8, the temperature trend of the sections with the blinds rolled down were observed to be consistent across the three time slots and throughout the five weekdays. From the results, there was a plunge in temperature at Division 24 relative to the values in the other sections. This drop in temperature may be attributed to the air conditioning unit located directly in front of a bookshelf, blocking the cooled air from reaching other areas of the library. From the temperature measurements obtained during the data gathering with the blinds rolled down, it was found that 85.29% of the ground floor in the university library did not comply with the standard indoor temperature requirement of 22.5 to 25.5 °C [14]. The higher ambient temperature is attributed to the higher outdoor temperature during the summer months as well as the increase in students using the library during midterm season.

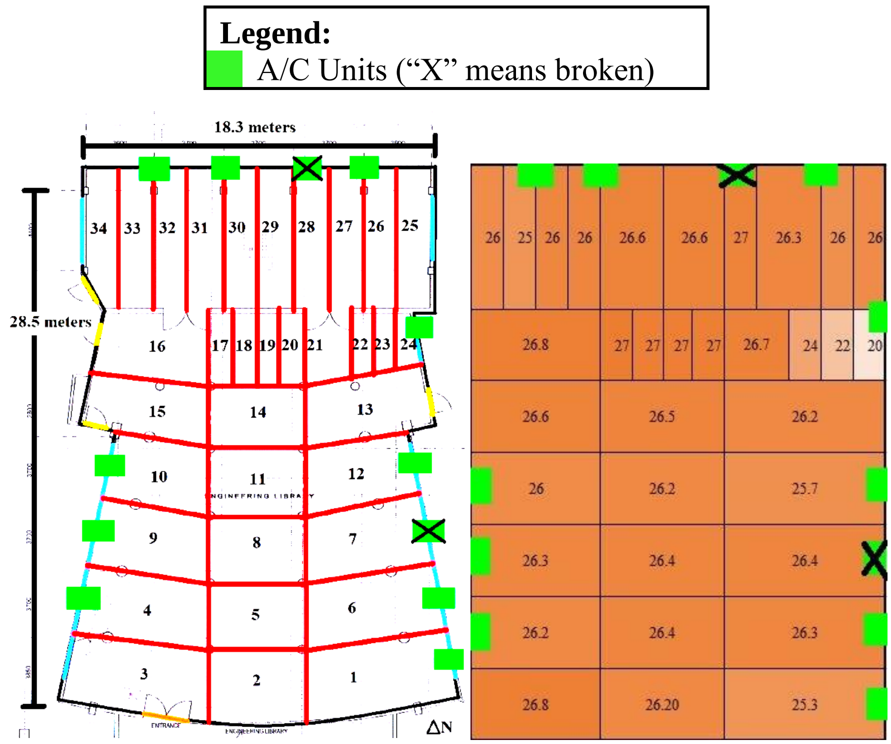

Figure 8. Ambient Temperature per Division - Ground Floor (Celsius)

3.1.4 Air Conditioning Units Usage

During the energy audit period, the voltage and current of each air conditioning unit in use during the period of observation were measured. From these, the actual power consumption was computed and compared to the rated power value listed in their respective specifications. It was found that all units were working above their respective rated power. The main factor that would contribute to this would be the age of the units since these were purchased more than five (5) years ago from period of observation. This would imply that the components of the air conditioning units, particularly the compressor, would need more power to keep the ambient temperature in the library within 25-27 Celsius. Table 2 summarizes the percent excess of the actual power consumption from the rated value of each unit.

From the data that was gathered, the actual consumption of the air conditioning units was found out to be running at an average of 23.06% above their rated consumption of 1.86 kW.

Table 2. Air Conditioning Units and Percent Excess from Rated Power

Aircon	Voltage (V)	Current (A)	Average Actual Power (kWh)	Average Rated Power (kWh)	% Excess
1	217.9	10.5	2.29	1.86	22.7%
2	217.8	12.3	2.68	1.86	43.9%
3	217.2	10.5	2.28	1.86	22.1%
4	216.3	9.2	2.01	1.86	9.3%
5	216.1	8.1	2.11	1.86	17.3%
6	214.6	10.5	2.24	1.86	20.3%
7	220	10.9	2.39	1.86	28.2%
8	216.4	10.0	2.17	1.86	26.4%
9	214.7	10.8	2.31	1.86	24.0%
10	221.6	8.9	2.16	1.86	16.7%

3.2 Evaluation of Alternatives

Given the following results, the current utilization of equipment in the university library failed to meet the standard operating conditions required for this type of facility. The computers were idle 57% of the time while the lighting intensities in the library did not meet their respective standards of at least 200 lux for shelves and 500 lux for tables by an average deviation of 30%. Also, 85% of the library's ground floor did not comply with standard indoor temperature requirement of 22.5 to 25.5°C by an average deviation of 3% despite the air conditioning units running at an average of 23% above their rated consumption of 1.86 kW. Given this, the following alternatives were proposed to optimize energy consumption within the library. The ideal alternatives would have a higher NPV and a shorter payback period, while using a discount rate of 10% over a period of five years [20]. In choosing between capital-intensive energy upgrades, the NPV is recommended for guiding decisions since the total value of the investment would be analyzed [20].

3.2.1 Lighting Fixtures

The university library utilized 222 units of 28-watt and 38 units of 35-watt T85 fluorescent tube lights in the Basement and Ground Floor areas. Operating approximately 66 hours per week, it was estimated that the library's lighting units consume 3,817.30 kWh per month. Despite the large number of lighting units presently running in the facility, 34 out of 49 divisions still did not comply with the proper lighting standards due to the distance between tables and the lighting fixtures as well as the shelves that are directly below the light bulbs. According to the library maintained staff, the current light bulbs were procured more than five years prior, thus the lumens of the bulbs have reduced. To address these issues, the following alternatives were developed.

L1. Replacing Lighting Fixtures with T8 Fluorescent Tubes
L2. Replacing Lighting Fixtures with Light Emitting Diode (LED)

Fluorescent bulbs are relatively low maintenance and energy efficient, however a ballast and starter is required for them to operate [21]. For LED bulbs, these normally have a longer lifespan and consume less energy compared to fluorescent bulbs, albeit being more costly [22]. Taking into account the total number of tube lights, initial investment, estimated energy use per month, and estimated energy savings per month relative to the current, the net present value (NPV) of each alternative was computed (Table 3). The specifications and costs for the lighting alternatives were obtained from a light bulb supplier while adhering to the PHILGEPS lighting criteria [23].

Table 3. Comparison of Proposed Alternatives for Light Bulb Units

	Baseline	**L1**	**L2**
Bulb type	T85 Fluorescent	T8 Fluorescent	LED
Power Rating per Bulb (W)	28, 35	36	20
No. of Required Light Bulbs	260	108	108
Estimated Energy Use (kWh/month)	3,817.30	1,758.72	549.60
Energy Savings (kWh/month)	-	2,058.58	3,267.70
Cost Savings (PhP/month)	-	19,270.29	30,589.85
CO_2 emissions reduction ($ktCO_2$/month)	-	1.03	1.64
Initial Investment (PhP)	-	70,378.00	131,112.00
NPV (PhP)	-	897,985.00	1,503,055.00
Payback Period (years)		0.30	0.36

From the two alternatives, using LED lights would be the better option given that its NPV is almost double that of changing to fluorescents. Even if the payback period of using T8 fluorescents is shorter, the difference between both payback periods is relatively minimal. If this is to be implemented, a decrease of 85.6% in energy consumption of lights will be realized every month.

3.2.2 Air Conditioning Units

At present, the university library has 12 units of 1.86 kW window type air conditioners installed in its Ground Floor. The staff switches on six air conditioners a day and schedule the units to operate every other day. From the data gathered in the temperature sampling of the 34 sections, it was found that an average of 85% of these divisions were beyond the standard temperature range of 22.5 to 25.5°C; thus, other options were explored in order to come up with a better cooling system for the Ground Floor area. The current air conditioning units were more than five years old and though regularly cleaned, these were prone to breakage as confirmed by the library staff. To address these issues, the following alternatives were developed.

AC1. Replacing air conditioning unit with Window Type (Inverter)
AC2. Replacing air conditioning unit with Floor Mounted (Not Inverter)

AC3. Replacing air conditioning unit with Floor Mounted (Inverter)

Inverter technology for air conditioners has massive energy saving potential, particularly for facilities with longer operating hours such as libraries [24]. Taking into account the total number of air conditioning units, initial investment, estimated energy use per month, and estimated energy savings per month relative to the current, the net present value (NPV) of each alternative was computed (Table 4). It is noted that ceiling type air conditioning units were not considered in the development of alternatives since the architecture of the library would make this solution infeasible. The specifications and costs for the air conditioning unit alternatives were obtained from a home appliance distributor. From the three alternatives, the most efficient system for the university library would be to replace the current units with six inverter window type air conditioning units. If this is to be implemented, a decrease of around 36.5% in energy consumption from air conditioning would be attained monthly.

Table 4. Comparison of Proposed Alternatives for Air Conditioning Units

	Baseline	**AC1**	**AC2**	**AC3**
A/C type	Window (No Inverter)	Window (Inverter)	Floor (No Inverter)	Floor (Inverter)
Power Rating per unit (kW)	2.29	1.46	3.92	3.96
No. of Required Air Conditioning Units	6	6	3	3
Estimated Energy Use (kWh/month)	3,299.04	2,095.20	2,822.40	2,851.2
Energy Savings (kWh/month)	-	1,203.84	476.64	447.84
Cost Savings (PhP/month)	-	11,267.94	4,461.35	4,192.06
CO_2 emissions reduction ($ktCO_2$/month)	-	0.28	0.60	0.22
Initial Investment (PhP)	-	269,988.00	173,364.00	416,094.00
NPV (PhP)		242,584.29	94,317.00	(164,570.40)
Payback Period (years)		2.00	3.24	8.27

3.2.3 Computers

3.2.3.1 Windows and Mac Computer Units

Currently, the university library starts up all 18 units of Windows computers and 6 units of Mac computers at 8am to cater to the needs of the students. Only staff members are authorized to start up and shutdown these computer units in order for them to ensure that these operations are properly executed. In analyzing the current utilization of these two sections from the work sampling results, the proponents determined that it would be ideal for the library to start up four (4) units and two (2) units of Windows and Mac units, respectively while opening more computers as the user demand increases. This is based on multiplying the current number of computers by the proportion of time the units were in use. Tables 5 and 6 highlight the scheduling of Windows and Mac computers, respectively based on the work sampling data.

Table 5. Scheduling of Windows Computers

	8am to 11am	**11am to 12pm**	**12pm to 4pm**	**4pm to 6pm**
Startup	4 units	5 units	7 units	4 units
Off	14 units	13 units	11 units	14 units

Table 6. Scheduling of Mac Computers

	8am to 11am	**11am to 12pm**	**12pm to 4pm**	**4pm to 6pm**
Startup	2 units	3 units	4 units	2 units
Off	14 units	13 units	12 units	14 units

The scheduling was based on the computer usage over time obtained in the work sampling proper (Fig. 6 & 7) wherein the peak time for computer use would be between 11am to 4pm for both Windows and Mac.

Unlike the alternatives for lighting fixtures and air conditioning units, the reduction of computers operating would have immediate energy savings since there is no capital cost needed to implement this. To evaluate the alternatives for the computer units the following equation was used (Equation 2).

$$E = r\ x\ h\ x\ n$$

Where E = Energy consumption
r = rating of computers
n = no. of operating units
h = no. of hours used

(Eq.2)

Tables 7 & 8 highlights the comparison between baseline power consumption and electricity use when the proposed scheduling of Windows and Mac computers, respectively. For the computations, the energy consumption of the computers at idle mode would be 60% of the rated energy demand [25]. From the proposed allocation of computers for both Windows and Mac, the library can save 57.02% and 68.75% of their costs, respectively.

Table 7. Comparison of Proposed System for Windows Computers

No. of units switched on		Rating (W)	Estimated Energy Use (kWh/month)	Cost (PhP/month)	CO_2 emissions ($ktCO_2$/month)
Current	18	300	887.76	8,309.43	0.44
Proposed	4 to 7	300	381.60	3,571.78	0.19

Table 8. Comparison of Proposed System for Mac Computers

No. of units switched on		Rating (W)	Estimated Energy Use (kWh/month)	Cost (PhP/month)	CO_2 emissions ($ktCO_2$/month)
Current	6	359	799.56	7,483.93	0.40
Proposed	2 to 4	359	249.86	2,338.73	0.13

3.2.3.2 Online Public Access Catalogue (OPAC) Units

Based on the average usage, the university library should have at least one OPAC unit. Considering the possibility of breakdown, however, the library should have a backup OPAC computer bringing the ideal number of units to two (2). This is based on multiplying the current number of computers by the proportion of time the units were in use. Table 9 shows the comparison between the current and the proposed system for the OPAC computers. Equation 2 was also used to obtain the values for energy consumption. The proposed OPAC allocation will result in cost savings of 82.17%.

Table 9. Comparison of Proposed System for OPAC Computers

No. of units switched on		Rating (W)	Estimated Energy Use (kWh/month)	Cost (PhP/month)	CO_2 emissions ($ktCO_2$/month)
Current	5	445	359.38	3,383.82	0.18
Proposed	2	445	64.08	599.79	0.03

IV. CONCLUSION AND RECOMMENDATIONS

Conducting an energy audit allows further understanding the energy consumption of a facility. The process of obtaining lux and temperature values as well as current readings would allow engineers to analyse whether the energy consumed in the facility can be translated into an optimal working environment. Work sampling can also be used in gathering utilization data for plug-in loads such as computers. The baseline energy profile developed from the energy audit data can be used to study various energy conservation alternatives that may reap significant savings in terms of cost and CO_2 emission reduction. Researchers can use the energy audit method for more bottom-up studies on building energy use.

The recommendations from this study are expected to enable the university library to function within proper working conditions while reducing of electricity consumption. Replacing the current lighting of the library with LED will provide the facility with the appropriate luminescence of 500 lux for tables and 200 lux for shelves. Replacing current air conditioning units with six inverter window type air conditioners will reduce energy consumption by 36%. Furthermore, providing two OPAC, two Mac, and four Windows units in use will lower current energy expense without compromising the ability of the facility to address its demand.

Table 10 shows the summary of energy conservation measures and their corresponding savings and CO_2 emission reduction.

Table 10. Summary of Energy Conservation Measures for University Library

Alternative	**Monthly Electricity Savings (kWh)**	**Monthly Cost Savings (PhP)**	**% reduction in CO_2 emissions**
LED Lighting	3,267.7	30,590.00	85.6%
Inverter Window Type Air Conditioners	1,203.8	11,270.00	36.5%
4 Windows units	506.16	4,737.66	57.0%
2 Mac units	549.17	5,145.19	68.8%
2 OPAC units	295.30	2,764.01	82.2%
TOTAL	5,822.13	54,506.86	-

With these alternatives, the university library can save a total of 5,822.13 kWh and subsequently, ₱54,506.86 per month. In addition, a monthly reduction of 2.59 $ktCO_2$ can be achieved through the implementation of these recommendations. For future research, an energy audit can be conducted within the other facilities of the academic building so that the overall building energy consumption for such can be estimated. Given the academic nature of the building, the facility also can serve as a testing area for energy audit implementation.

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