Design of Residence Hall for Electricity Conservation

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Abstract – *The reduction of electricity consumption of residence halls in a university without compromising the level of comfortability and nurturing environment and or increasing the level of comfortability and nurturing environment at optimal electricity consumption are the goals of efficient and sustainable university residence hall administration. This paper presents the results of the study for all the residence halls in the University of the Philippines Diliman campus. The established framework for determining the energy intensity of residence halls is used to determine factors that contribute to the current level of electricity consumption. Using Pareto analysis, ventilation is identified as the most energy intensive process contributing to 37% of the total monthly electricity consumption of all the residence halls, followed by lighting at 25% and then computing at 24%. The average electricity consumption per resident is 46.9 kWh per month with a standard deviation of 10.6 kWh per month. Another two surveys were conducted to determine the preferences of the residents in terms of the design of residence hall rooms and common areas, and on different categories describing residence hall characteristics. Some of the results from the respondents are: 52% chose rooms with both task and accent lighting to comply with user's requirements; 62% chose a balance between comfort and efficiency with personal closets, desks and storages; and 43% chose two residents per room with an area of 25 m^2. Sample residence hall room designs as well as energy consumption models for two different scenarios are presented. Air conditioned room is more expensive by 2.5 times compared to electric fan ventilated room. It is recommended to identify the effects of different residence hall architectural features in the academic performance of residents; to develop design protocols incorporating the survey results; and to develop the level of comfortability that the university is willing to subsidize.*

Keywords—Residence Hall Energy Consumption, Academic Dormitory Energy Intensity, Building Energy Conservation

I. INTRODUCTION

1.1 Rationale

With the continuous challenge to be the leader in research and innovation in the academe for both public and private institutions, the University of the Philippines Diliman (UPD) is expected to be the hub for energy policy development that can be implemented in various residence halls. The increase in enrolment and the worsening traffic situation in the metropolis necessitate an increase in accommodation on campus and hence an increase in energy requirements. Student enrolment has risen from 57,009 in academic year 2008 - 2009 to 65,356 in academic year 2015 - 2016 [16]. For the last seven decades, the accommodation capacity increased by approximately 50 persons per year while the total number of students increased by 215 students per year [16] which approximately translate to 4.3 times the need for accommodation compared to the level of accommodation in the 1940s.

The energy consumption of UPD directly increases due to its multi-role function as mandated by Republic Act 9500 in 2008 [12], due to climate change and the shift in academic calendar, and the ever increasing need and desire for comfortable and nurturing environment. The average increase in atmospheric temperature of the Philippines is around 0.1 degree per decade from 1949 up to the present [11]. The change in academic calendar in 2015 resulted to additional 40 days approximately at higher temperature [14]. Such conditions lead to higher energy consumptions in the residence halls.

1.2 Objectives

The objective of the study is to evaluate the energy consumption of all the residence halls, establish energy consumption patterns, and identify opportunities to reduce the amount of energy use. Specifically, the study aims to: characterize residence halls usage, occupancy, and size; analyze historical energy consumption; conduct energy audit; survey preferences of residents; identify factors affecting the level of energy consumption; and evaluate energy savings for different residential plan.

1.3 Significance

It is a state university's civic responsibility to be a role model in being stewards in energy efficiency and sustainability not only to the academe but also to the country. A study by Manegdeg [10] predicts an increase in electrical energy consumption of UPD. There are currently 133 buildings in the University, of which 16 buildings are residence halls. As the residence halls are all subsidized, any measure to reduce electricity consumption without compromising quality, is deemed a significant step towards achieving a decrease in the overall electricity usage of the University.

The study is the first of its kind and finds its significance in optimizing the current energy consumption without compromising the quality of learning environment of the students living in the residence halls. The efficient use of resources is one way that the University is contributing towards a sustainable future for the country. The output of this research will equip the decision makers and administrators with choices and quantifiable parameters to draft and implement policies, and to identify the degree of subsidies the University will shoulder for residence halls given the changing nature and settings of the university students. By optimizing the electricity consumption of residence halls, a progressive design and set of policies can be made to address the needs of the growing population of the University.

1.4 University Residence Halls

The University of the Philippines in Diliman started providing lodging benefits to its students in 1949 with Narra Residence Hall as the pioneer, accommodating about a couple of hundred students. Narra Residence Hall has been demolished and to date, there are 14 residence halls with a capacity of about 3,800 [17]. However, the International Center is undergoing renovation. The residence halls operate to provide a caring, safe, secured, clean, and comfortable place for students to live in away from their homes. They serve as the second and nurturing home to students as they pursue academic excellence. They also create an environment that contributes to their integral development as future leaders of the nation and active members of the community.

Yearly, during the start of the school year, the Office of Student Housing processes about 6,000 applicants for the 13 residence halls. With the increasing number of residents and residence hall rates that did not increase since 13 years ago, energy consumption has increased but heavily subsidized by the University. The Office of Student Housing receives a measly PhP 1,350,000.00 (US$ 25,424 [2]) per quarter or PhP 355.26 (US$6.69) per resident per quarter, as maintenance and other operating expenses (MOOE) for all the residence halls. The MOOE is really insufficient to cover all the repairs and maintenance of the residence halls. In fact, the cost of utilities alone in most of the residence halls, is higher than the collected residence hall fees in 2014. However, with increased operational costs particularly energy consumption and repairs and maintenance, the current administration has made adjustments on a per need basis. Thus, the University assumes the cost of utilities. With this scenario, a study on the energy profile of the residence halls will provide insights on how energy is consumed. Energy conservation methods can then be identified for efficient energy management and usage that could lead to reduction in the cost of utilities without compromising the comfort of the students.

II. METHODOLOGY

The 13 residence halls were all included in the study. The research activities started by reviewing the energy management requirements for a residence hall; developing the energy audit framework; assessing the end users' needs by means of surveys; auditing the buildings; computing, evaluating and validating the data; understanding the influencing factors to electricity consumption; identifying building design criteria; and formulating energy conservation policy for effective implementation.

The methodology of the study was guided by the flow chart of activities as shown in Figure 1. The duration of the project was done from January 2017 to June 2018. Discussions and orientation with resident hall managers were done prior to the survey. Three surveys were conducted: Physical Characteristics, Equipment, and Energy Usage. Physical characteristics also accounted for the deviation of existing layout of residence halls with respect to the as-built plans. Equipment survey noted the different electricity consuming devices present in each room while energy usage detailed on how equipment present in the residence halls are being used.

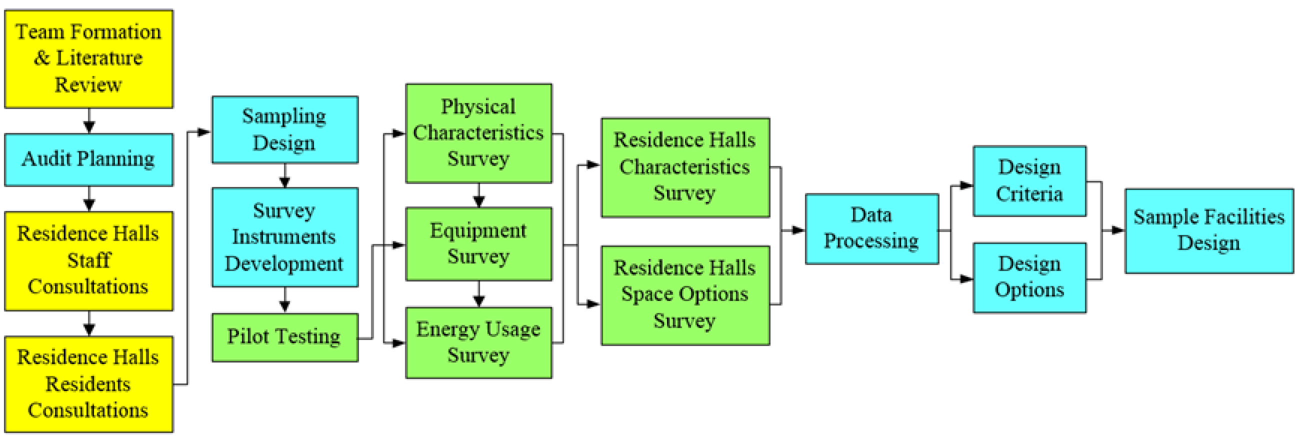


Figure 1. Flowchart of Activities.

The preferences of the residents were elicited by conducting another two surveys: residence hall characteristics and residence hall space options. The surveys determine the preferences of the residents in terms of the design aspect of the different zones in the residence halls and their preferences on the different residence hall characteristics. Together with the data gathered, insights from the residence hall managers and the residents were collected to incorporate their preferences in the model. A sample residence hall room layout was then presented incorporating the result of the survey. Energy consumption of the proposed residence hall room was also presented to compare two scenarios addressing two different levels of comfortability.

The residence hall managers were consulted to discuss the relevance of the study and the activities that will be conducted as part of the data gathering. Comments and suggestions from the residence hall managers were acknowledged and were taken in consideration during the conduct of research. Access to the common areas in residence halls was requested to gather necessary information for the energy audit. These areas included hallways and lobbies, mess halls, recreation areas, and offices. The residence hall managers willingly cooperated and were present during the scheduled energy audit. Another meeting was held with the residence hall managers, staff, and the residence halls' resident council to formally introduce the study to the residence hall community. The objectives and deliverables were discussed during the meeting.

Feedback and questions were entertained to clear any possible issues such as residence hall security and privacy. The action plan was presented so as to inform the residence hall community on the importance of their involvement and cooperation. Survey materials were finalized and pilot-tested prior to the actual conduct of the survey. The final survey questionnaire was revised to incorporate the pilot survey experience. The pilot samples accounted to 2% while the survey samples totalled to 8.1% of the 3,737 residents. As a representative value, a minimum of 5% of residence hall resident population were sampled per residence hall.

The framework [10] adopted for energy audit used process analysis and the ranking of the processes was done using Pareto concept [7]. The actual energy audits were conducted using calibrated measuring equipment for consistency and accuracy. The energy audit involved site inspection to determine the physical characteristics of the residence halls, as well as interview of the staff to determine the number of hours of usage of the installed appliances in common areas like hallways, lounges, offices, and mess halls. To determine the consumption of the residents, a survey of electricity consumption was conducted. The survey required information such as the list of appliances that are within the individual residence hall rooms, appliance wattage, number of hours the appliance is used in a day, and number of days the appliance is used in a week. Using the information provided by the residents and the data gathered from energy audit of the abovementioned common areas, monthly electricity usage were modelled and validated against the consumption history averaged over a period of 6 years.

Processes were identified and categorized into different energy cost centers such as air-conditioning, ventilation, lighting, computing and others. Pareto analysis was used to determine energy cost centers or processes that contributed to 80% of the consumption. This will enable the study to focus the conservation measures on factors that will provide the greater positive outcome on electricity consumption that is due to lighting, ventilation, computer usage, and others. These consumptions were analyzed on the assumption that the percentages are the same historically over the period of reckoning. The established electricity consumption model may be used to provide a forecast of electricity consumption on a business as usual scenario. Electricity conservation measures were identified and implementation policies were then formulated. Energy savings was estimated using the consumption model and compared against the business as usual scenario.

The total energy requirement, E_{total}, in Mega Joules (MJ) of a residence hall is the sum of the embodied energy and the process energy as shown in Equation (1). The energy used to produce the product or the building is termed as the embodied energy, $E_{embodied}$ in MJ. The process energy is the energy consumed in the residence hall. Equation (2) shows the relationship of the embodied energy with respect to the energy used in manufacturing and producing the raw materials, where in some cases, transportation and extraction of the raw materials are included in the value of the embodied energy.

$$E_{total} = E_{embodied} + E_{process} \tag{1}$$

$$E_{embodied} = \sum_{i=1}^{n} m_i e_{intensity,i} \tag{2}$$

The total embodied energy of a residence hall is then computed by summing all the products of materials with their respective energy intensities, where m_i (mass in kg, or area in m^2 or volume in m^3) is the approximate total mass, m, or area, A, or volume, V, of the product, and $e_{intensity,i}$ (MJ/kg or J/m^2 or J/m^3) is the energy intensity of the material from construction to actual installation, and i is the number of materials from 1 to n. Most energy intensity values of the raw materials used in the construction industry are publicly available.

The energy consumption is arranged into major processes or energy cost centers composed of the following: Ventilation, Lighting, Computing, Water and Food Preparation, Air-conditioning, Communication, and Entertainment. The total energy consumption is achieved using Equation (3) where $E_{process}$ in MJ, is the total process energy, $P_{factor,j,q}$ is the power rating, $f_{usage,j,q}$ is the usage factor, $N_{j,q}$ is the number of units, and $t_{j,q}$ is the average time of use, $_q$ is the number of equipment from 1 to r, and $_j$ is the number of processes from 1 to k.

$$E_{process} = \sum_{j=1}^{k}\sum_{q=1}^{r} P_{factor,j,q} f_{usage,j,q} N_{j,q} t_{j,q} \tag{3}$$

Equations (4) to (8) are used in the computation of the residence hall cooling loads:

$$q_{lighting} = P_{light} F_u F_b CLF \tag{4}$$

$$q_{sensible\ load} = Gain_{per\ person} N_{persons} CLF \tag{5}$$

$$q_{solar\ enetering\ the\ transparent\ area} = A(\tau I_t + N\alpha I_t) \tag{6}$$

$$q_{solar\ on\ opaque\ area} = U_w A(t_e - t_i) \tag{7}$$

$$q_{wall\ heat\ gain} = UA(CLTD) \tag{8}$$

where $q_{lighting}$ is the heat generated from room lightings, P_{light} is the power rating of lighting equipment, F_u is the utilization factor, F_b is the ballast factor, and CLF is the cooling load factor. The heat generated from the occupants is accounted in the $q_{sensible\ load}$ where $Gain_{per\ person}$ is the heat gain per person and $N_{persons}$ for the number or occupants. Solar heat penetration to the room is classified into solar entering the transparent area ($q_{solar\ enetering\ the\ transparent\ area}$) and opaque area ($q_{solar\ on\ opaque\ area}$). Factors to be considered in solar heat penetration are Area A, transmittance τ, irradiation I_t, fraction absorbed by conduction, convection and radiation N, absorptance α, heat transfer coefficient of wall U_w, and temperature equivalent t_e and inside temperature t_i. For walls, the heat gain ($q_{wall\ heat\ gain}$) is a function of Area, heat transfer coefficient U, and cooling load temperature difference, CLTD. The formula and necessary tables were published by Stoecker, et al. [13]. The required cooling load was computed to determine the maximum cooling load of the room and the building in case an option of fully air-conditioned facility is considered and for comparison with other options.

Energy savings, in %, were calculated by comparing the computed existing consumption against the calculated efficient design. Equation (9) provides the formula in determining the percent savings:

$$Energy\ Savings = \left(\frac{E_{current} - E_{designed}}{E_{current}}\right) x\ 100 \quad (9)$$

where $E_{current}$ in kW, is the current average energy consumption and $E_{designed}$ in kW, is the approximate energy consumption of the proposed design in accordance to the recommended energy policies.

Energy consumption of the building is primarily based on the total electricity consumed by the equipment or operations by considering the number of units, efficiencies, manner of usage, and energy rating. To come up with an acceptable design, the study aimed to incorporate the most efficient equipment available today. With this, it is necessary to quantify the existing design of structures and performance of equipment. To do an assessment, profiling of the physical characteristics of the facility must be taken into account. Also, analysis of the user profile and requirement must be considered to have a higher chance of acceptance.

The primary challenge in this study is getting the actual electricity consumption of individual residents. That will entail that all the residents go through the survey which takes a minimum of one week to accomplish. Another challenge is the fact that building energy is dynamic and is affected by several factors. Energy consumption is measured on the assumption that it is steady state implying that the number of hours of usage of all the equipment and appliances were also steady over a given period.

III. RESULTS AND ANALYSIS

3.1 Residence Halls

All the 13 residence halls on campus were surveyed. The total resident capacity is 3,737, averaging around 287 residents per residence hall. Residence hall capacity ranges from 50 to 538 residents as shown in Figure 2.

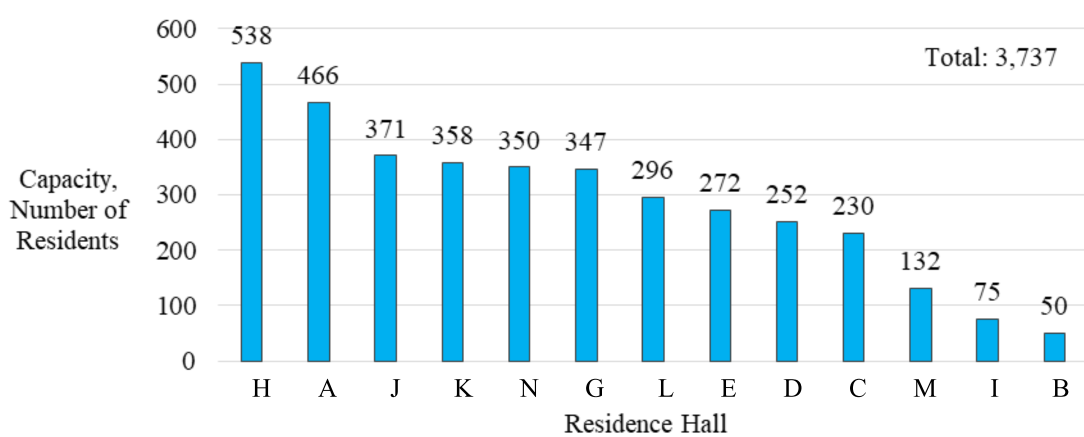


Figure 2. Residence hall capacity.

Residence halls provide shelter to students from a variety of social strata, and courses from all academic clusters. The residence halls cater to undergraduate students, graduate and post graduate students, and faculty members. Ages of residents range from 16 to 65 years old, of which 74.4% is in the age bracket of 16 to 20 years old as shown in Figure 3.

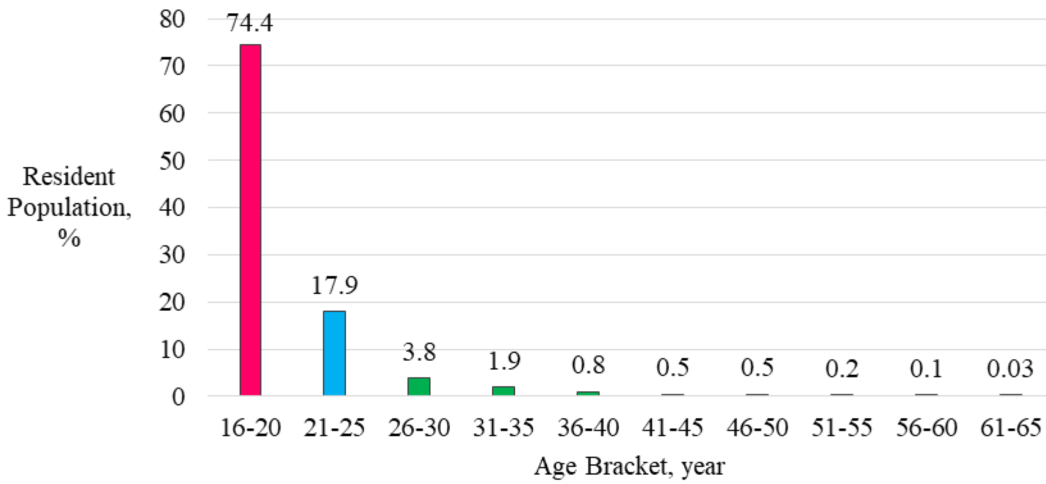


Figure 3. *Age demographics of residents.*

Majority of the student-residents from graduate and undergraduate levels belong to the Science and Technology Cluster which includes Archaeological Studies Program, College of Architecture, College of Engineering, College of Home Economics, College of Science, School of Library and Information Science, and School of Statistics, accounting to 62% as shown in Figure 4.

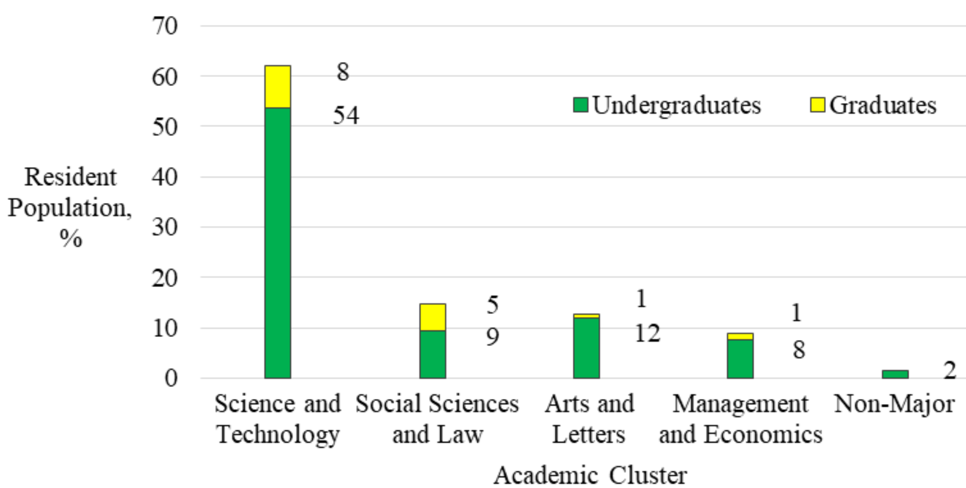


Figure 4. *Demographics by academic cluster.*

3.2 Rooms

Room sizes in all the residence halls vary in floor area and in ceiling height. The number of occupants per room varies depending on the size of the room. Room floor area ranges from a minimum of 13.5 m^2 to a maximum of 36.19 m^2, with an average room size of 24.5 m^2. Figure 5 shows the room area frequency distribution with a total of 1,257 rooms. The smallest range of 10 - 15 m^2 floor area accounts for 38% of the rooms while the largest range of 36 - 40 m^2 totals for only 2.5% of the rooms. The average occupancy per room is 3 persons.

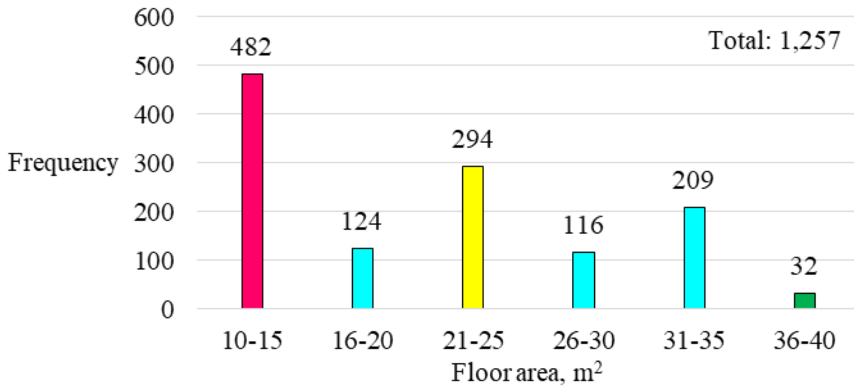


Figure 5. Distribution of room area

Floor to ceiling height of rooms also ranges from 2.4 m to 3.9 m, with an average of 3 m. The distribution of room volume frequency is shown in Figure 6. The smallest range of 30 - 40 m^3 volume accounts for 10% of the rooms while the largest range of 111 - 120 m^3 totals for only 2% of the rooms. The range of 41 - 50 m^3 volume accounts for 28% of the rooms while the range of 71 - 80 m^3 totals for 27% of the rooms.

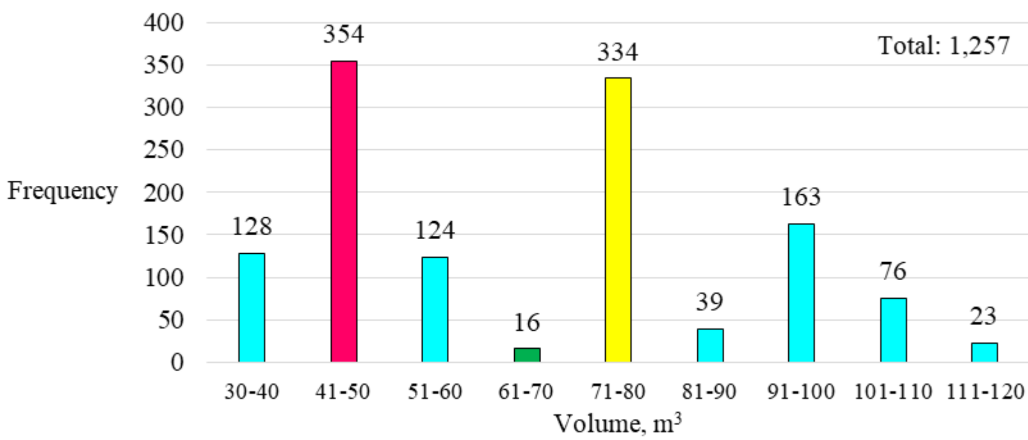


***Figure 6.** Distribution of room volume frequency.*

3.3 Energy Consumption

The monthly electricity consumption of the residence halls was provided by the Utilities Management Team of the University. It is important to note that during the 6-year period of reckoning, 2010 to 2015, some residence halls were lacking in data due to renovation. Only the three newest residence halls had data for less than 6 years. Figure 7 shows data for the periods of 2014 and 2015. The graph shows that the energy consumptions of all residence halls increases with time.

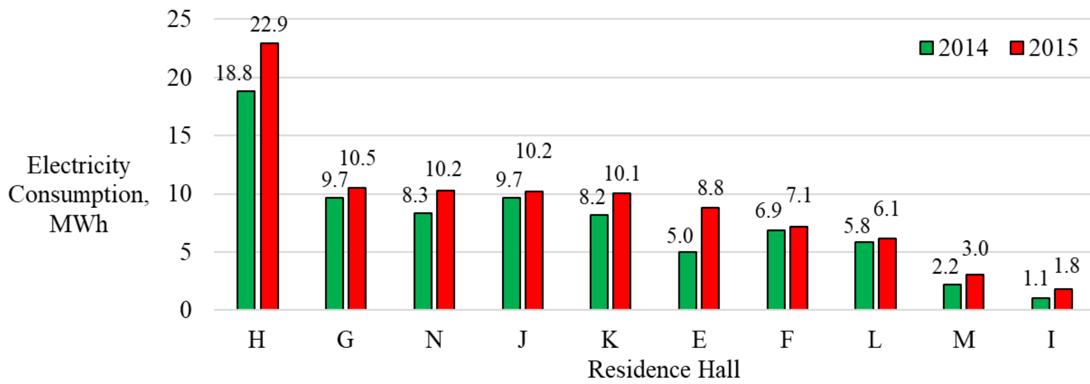


Figure 7. *Mean monthly electricity consumption (2014 and 2015).*

Pareto analysis of mean monthly electricity consumption identifies which residence halls have sizeable contribution to the overall level of consumption. This allows prioritization of those residence halls which will have larger impact in terms of overall energy savings. Figure 8 shows that Residence Hall H has the highest electrical consumption which can be attributed to various factors: bigger capacity of more than 500 residents; dark, longer and narrower hallways, and dark-colored floor tiles which require lighting even during daytime. Lighting is also needed day and night for its basement rooms.

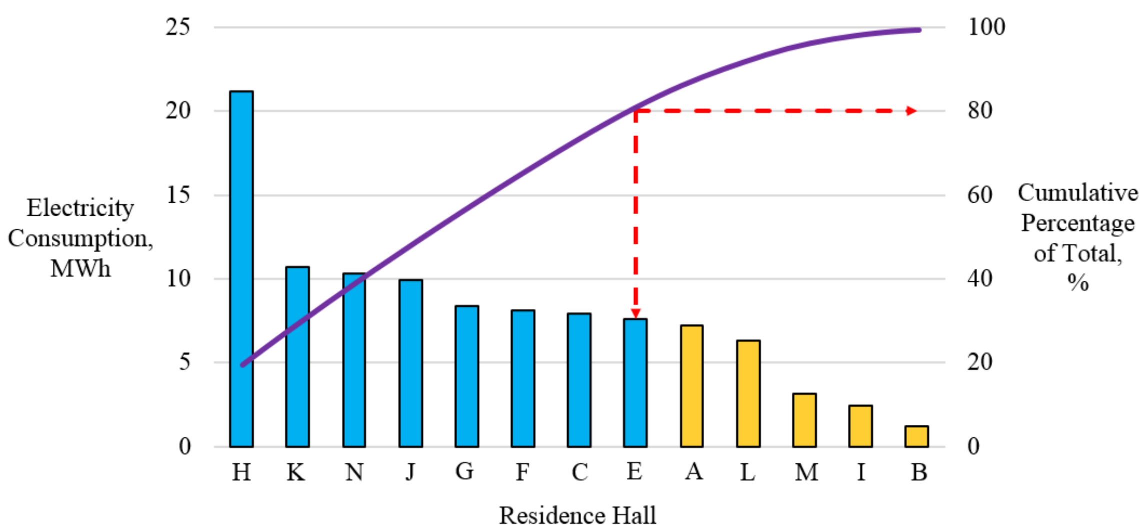


Figure 8. *Pareto of 6-year (2010-2015) mean monthly electricity consumption.*

The energy intensity of residence halls, in kilowatt-hours (kWh) per resident, is E_{total} divided by the number of residents. Considering $E_{embodied}$ is constant as the residence halls were already constructed, the energy intensity is only based on the energy consumption of the processes. Figure 9 presents the energy intensity of all the residence halls, with the mean line representing the average for all 13 residence halls. Residence Hall J has the highest energy intensity at 65 kWh per resident, while Residence Hall I has the lowest at 31.6 kWh per resident. The average electricity consumption per resident in kWh is 46.9 per month with a standard deviation (σ) of 10.6 kWh per month. As shown in Figure 9, 3 residence halls are within mean-2σ to mean-σ, 3 residence halls are within mean-σ to mean, 5 residence halls are within mean to mean+σ, and 2 residence halls are within mean+σ to mean+2σ.

Residence Hall I is within the range of mean-2σ to mean-σ which exhibited the least energy consumption per resident and is the most efficient.

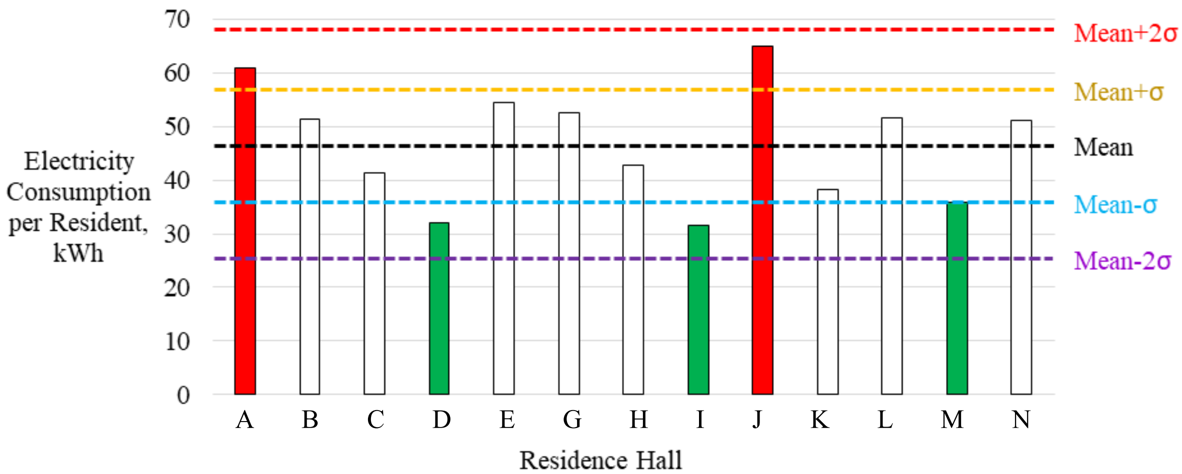


Figure 9. Energy intensity.

Analysis of the result of energy audit enables the identification of processes that contribute to the higher levels of electricity consumption of residence halls. Pareto diagram of the different energy cost centers as shown in Figure 10, identifies ventilation, lighting, and computing as the primary contributors to the existing electricity consumption level.

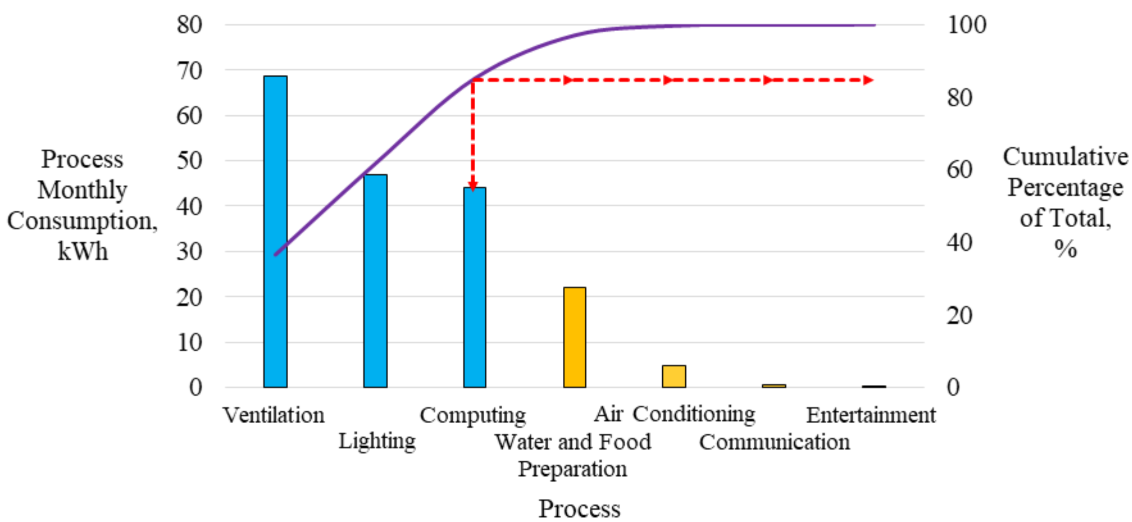


Figure 10. *Pareto of process monthly consumption.*

Ventilation takes up 37% of the total electricity consumption of all the residence halls followed by lighting at 25% and computing at 24%. Ventilation energy pertains to electricity consumption of exhaust fans in restrooms, ceiling fans in lounges and lobbies, and the individual electric fans that residents bring in. Lighting energy pertains to electricity consumption of all installed luminaires and lamps in all common areas such as hallways and corridors, offices, lobbies, restrooms, as well as those installed in all the rooms for general lighting and task lighting. Computing energy consumption comes from the use of computers and its peripherals like monitors and a few printers.

3.4 Energy Conservation Measures

Residence hall energy consumption is influenced by various factors such as design, location, orientation, age, and occupancy. Different equipment installed in the halls as well as the usage profile of the occupants also affect energy consumption. The most straight forward solution to lowering energy consumption is through energy efficient practices. This involves using efficient alternatives to replace existing appliances/processes without sacrificing performance. It is suggested that most efficient electric fans and computers should be used since electric fan and computers are dependent on the residents. The need for ventilation is more sensitive on the design of the building.

Only a few electric fans are installed in the residence halls at the time of the study. The residents provided their own stand fan. Since the rooms of residence halls are meant for sharing, each room is assumed to have a single stand fan. If a policy is adopted to have a maximum 60W electric fan, a 20% electricity savings will be attained as shown in Table 1.

For the computing process, the residents bring their own computers with specifications and power requirement based on their needs. If a policy is adopted that only laptop computers are allowed, between 87 to 92 % electricity savings will be realized as shown in Table 1.

Table 1. Energy Savings for Ventilation and Computing

Process	Power Rating[a], (W)				Quantity	Electricity Savings, (%)
	Existing Equipment		*Proposed Policy*			
Ventilation	Stand Fan	75	Stand Fan	60	1,257[b]	20
Computing	Desktop Computer	450-500	Laptop Computer	40-60	3,737[c]	87-92

[a] based on residence halls survey
[b] assumed 1-unit electric fan per room
[c] assumed 1-unit laptop computer per student

Lighting on the other hand is fixed in the residence halls as lighting consumption is prioritized and intervention can be immediately implemented. Lighting in most common areas was found to consist of a combination of fluorescent lamps, compact fluorescent lamps (CFL), and light-emitting diode (LED) lamps. Replacement of fluorescent lamps and CFL with LED tubes and bulbs will result in the reduction of lighting energy of as much as 59%. Sample computation of energy savings is presented in Table 2 for Residence Hall H. Computation of payback period is based on electricity rate of PhP 9.00 or US$0.17 at US$1 = PhP53.10 [2] per kilowatt-hour.

Table 2. *Energy Savings for Lighting*

Existing	Replacement	Intensity (Lumen)	Power (W)	Quantity	Market Price [8] PhP (US$)	Payback Period months
Fluorescent (40W)	LED tube	2,000	16	633	894.75 (16.85)	17
Fluorescent (20W)	LED tube	950	8	432	544.75 (10.26)	21
CFL (18W)	LED bulb	600	9	117	150 (2.82)	8

Installation of occupancy sensor switches in rest rooms and laundry areas also help reduce the overall lighting energy consumption by ensuring that lights are switched on only when needed. Additionally, daylight sensor switches must be installed in lobby areas where natural lighting is available and should be used together with LED tubes. Most residence halls are laid out to maximize the use of space, thus, some hallways require artificial lighting even during daytime.

3.5 Residence Hall Characteristics

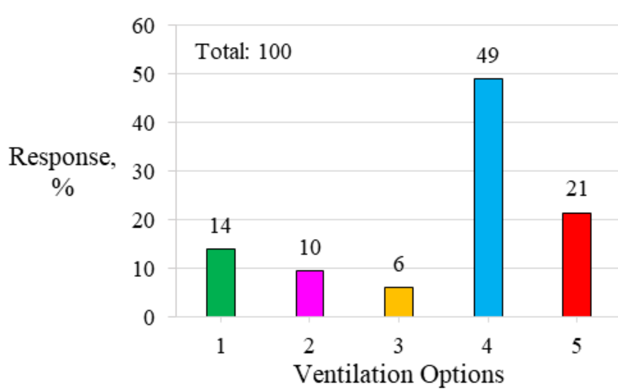
Majority of the buildings analyzed were constructed in the mid and late 1950s. One residence hall was built in the 1980s while three residence halls were built within the last 10 years. While most of the buildings have undergone renovations to remedy aging and deterioration, improvements in energy performance have not been prioritized.

A survey instrument was developed to measure the preferred residence hall characteristics of the residents. The residence hall characteristics are ventilation, lighting, facilities, and room size and circulation factor. Five options are provided for each category [6].

The responses on ventilation options are shown in Figure 11. Forty nine percent (49%) chose a balanced ventilation system that will both let out warm air and draw in outside air to flow throughout all the spaces in the building. Twenty one percent (21%) selected energy intensive systems that will artificially ventilate and cool the entire building while fourteen percent (14%) chose screened windows with provisions of outlets for user-supplied mechanical ventilation. Ten percent (10%) preferred exhaust ventilation that will let warm air disperse throughout the common areas of the building with rooms provided with screened windows, while six percent (6%) indicated a supply ventilation system that will draw in outside air into the rooms and common areas.

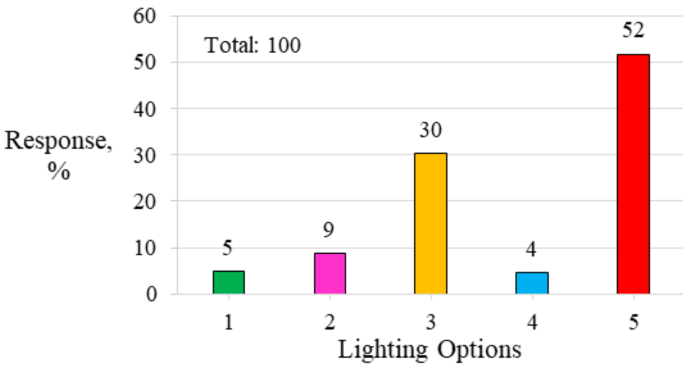
The considerable number of residents who still preferred to have natural ventilation is possibly dictated by economic reasons. They are actually given the option to install air-conditioning units in their rooms at their own expense. This is also subject to the installation of a sub-meter and approval by the Campus Maintenance Office of the University based on the buildings' electrical load. Only a few adopted this scheme with only four air-conditioned rooms in the newest residence hall.

Figure 11. Result of survey on residence hall ventilation.



Note: Ventilation Options
Screened windows with provisions of outlets for user-supplied mechanical ventilation
Exhaust ventilation to let warm air disperse throughout the common areas of the building; rooms will be provided with screened windows
Supply ventilation system to draw in outside air into the rooms and common areas
Balanced ventilation system to both let out warm air and draw in outside air to flow throughout all the spaces in the building
Energy intensive systems (air conditioners and other HVAC options) to artificially ventilate and cool the entire building

The responses for the lighting options are shown in Figure 12. Fifty two percent (52%) chose rooms with both task and accent lighting to comply with user's requirements. Thirty percent (30%) selected rooms with task lighting alone to aid in specific tasks. Nine percent (9%) picked rooms with general lighting for overall illumination, five percent (5%) preferred the rooms with one indirect fluorescent light, and four percent (4%) indicated common areas with accent lights to improve aesthetics. All of the residence halls are currently equipped with task lighting for practical reasons specifically to enable the residents to study properly.

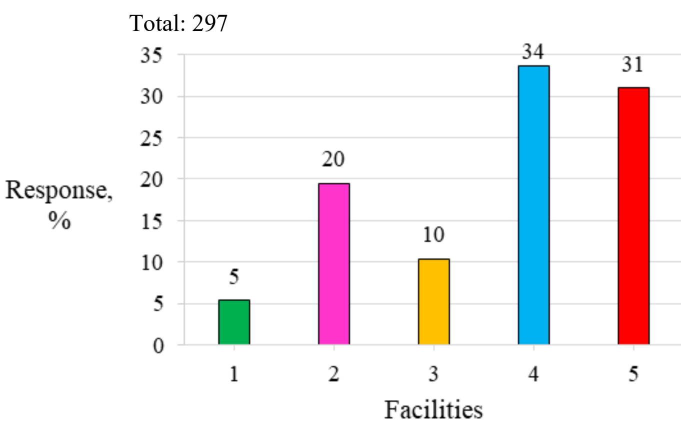


Note: Lighting Options
Each room is illuminated with one indirect fluorescent light
General lighting is provided for overall illumination in all spaces
Task lighting is included in rooms and common areas to aid in specific tasks
Common areas are given accent light to improve its aesthetics
Rooms are provided with both task and accent lighting to comply with user's requirements

Figure 12. *Result of survey on residence hall lighting.*

The responses for the survey on residence hall facilities are shown in Figure 13. Thirty four percent (34%) chose the addition of facilities for convenience and specific needs such as a gymnasium, laundry area or a conference room. Thirty one percent (31%) selected the provision of personal facilities for individual use such as Wi-Fi and a pantry with kitchen. Twenty percent (20%) picked additional facilities like a cafeteria and study areas. Ten percent (10%) preferred additional leisure spaces such as a TV room or a basketball court, and five percent (5%) indicated basic facilities for common use such as a lobby and parking spaces.

This result provides an important validation of the need to allocate adequate public spaces for the residents to socialize with each other and create a community. Only two residence halls have a basketball court. These facilities are being shared by all residents as some residence halls were not blessed with ample spaces. Also, parking spaces and gardens were provided especially for the graduate and/or newer residence halls. All residence halls except the newer residence halls have multi-purpose halls/rooms/areas. All residence halls use their ample open spaces for their events.



Note: Facilities
Basic facilities are provided for common use (parking spaces, lobby)
Facilities specifically for residents are included (cafeteria, study area)
Basic leisure spaces for common use are included (TV room, basketball court)
Facilities for convenience and specific needs are included (laundry area, gymnasium, conference room)
Personal facilities are provided for individual use (Wi-Fi, pantry with kitchen)

Figure 13. *Result of survey on residence hall facilities.*

The responses on room size and circulation factor are shown in Figure 14. Forty three percent (43%) chose two residents per room with an area of 25 m^2 while 29% selected two residents per room with an area of 20 m^2. Twenty five percent (25%) chose four residents per room with an area of 50 m^2. Two percent (2%) preferred four residents per room with an area of 40 m^2. Only one percent (1%) chose for six residents per room with an area of 50 m^2.

The result of this survey is indicative of the respondents' familiarity with the comfort that a 2-capacity bedroom provides. Except for 5 residence halls, all the rest offer 2-capacity bedrooms. Two residence halls have 3-capacity bedrooms but these are very spacious.

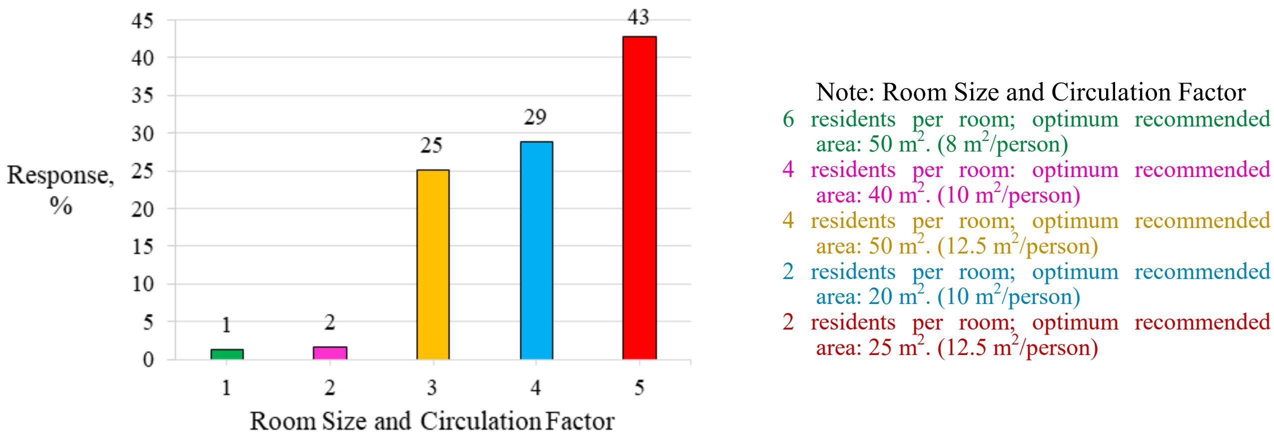


Figure 14. *Result of survey on residence hall room size and circulation factor.*

A receiving area or the lobby and other public areas are very important to the residents. These are areas where they interact with family members and relatives, and friends who visit them. The public areas like the lobby, pocket gardens and the TV areas serve as places for socializing with their co-residents, as study area and for building friendships.

Only three residence halls have installed CCTV cameras although the purchase of CCTV for all residence halls is awaiting public bidding. Two residence halls have been using key cards to regulate the entry of residents with the logbook system still being done for other transactions like late-night permits.

Most residence halls have common bathrooms per floor. Only three residence halls have restrooms per room with the newest residence hall having a water closet and a bathroom.

All residence halls except the newest residence hall have desks and closets (individual or shared).

3.6 Residence Hall Space Options

The residence hall space options survey elicited the preferred area types on the main zones of a residence hall, namely rooms, bathrooms, lobby, and hallways. These zones are common and basic among the residence halls. For each zone, five design options were shown with descriptions and pictures to denote the different types for each option.

The responses on room characteristics show that thirty three percent (33%) chose a room for two residents, has own bathroom, options for single bed or hybrid desk and bed, individual cabinets and desks, with air-conditioning and large windows for ventilation. This result reflects the residents' value for comfort and privacy with varying types of amenities. Unfortunately, the Office of Student Housing of the University offers practical accommodation to enable a greater number of students to avail of its services.

The responses on lobby characteristics show that forty one percent (41%) chose a lobby with spacious area for visitors or residence hall events. This result is indicative of how the residents value the look of the public spaces – well ventilated and with an ambience. The lobby is an important converging point of residents.

The responses on bathroom characteristics show that forty three (43%) chose a bathroom provided per room with one shower and one water closet. While it was not surprising that almost half of the residents preferred accommodation with separate toilet and bath per room for comfort and privacy, it is worthy to note that almost one-fourth chose a communal bathroom for every four rooms. The latter can be attributed to economic reasons, knowing that exclusive restrooms will translate to higher lodging fees. Only about 25 % of residents are housed in two residence halls which have separate toilet and baths. One residence hall which also offers this amenity, has a different profile with faculty members and graduate students as its residents.

The responses on hallway characteristics show that thirty six percent (36%) chose double and single-loaded hallways with windows and openings for both natural lighting and ventilation.

3.7 Residence Hall Design

Residence hall design plays an important role in the energy performance of its building throughout its lifetime. Incorporating energy conservation in residence hall design is one cost-effective way of ensuring optimum energy performance. Residence hall design is dictated by the functionality that is required of the building. This translates to the operating energy of a building, which is the energy used during the in-use phase of a building's life to satisfy the demands for ventilation, lighting, equipment and appliances.

The definition of collegiate housing facilities has changed over the years. Residence halls these days have kept to the demands of time by incorporating environments for socializing and learning outside the confines of a traditional classroom. Residential facilities have evolved to blend living and learning in their design by having not just sports and recreational facilities, but also common areas that serve multiple uses, as well as lounges, and study spaces. An example is the new residence hall at the University of Colorado that has a ground-level classroom that can be used for various learning formats, and has an adjacent grab-and-go café [5]. The classroom space can be expanded allowing for multi functionality and larger capacity.

Designs of new residential facilities have also moved towards addressing issues of sustainable energy consumption. The University of South Carolina [4], for example, spent millions on West quad dormitories that are powered partially by hydrogen fuel cells and have green roofs that serve as insulators. Eastern Mennonite University [3] in Harrisonburg, Virginia boasts of a 35,000-square foot residence hall that features extensive natural daylighting, low-flow water fixtures, reflective roofing, and solar hot water system. Real time data on the buildings energy and water usage and environmental characteristics may also be monitored through the video display installed in the lobby of the residence hall. Residence halls in St. Mary's University in Halifax, Nova Scotia [5] have incorporated low-flow showers, toilets, and faucets, as well as automated lighting controls. They also participate in university-sponsored energy conservation contest where the winner is determined by the highest percentage of reduction in energy consumption on a weekly basis [5].

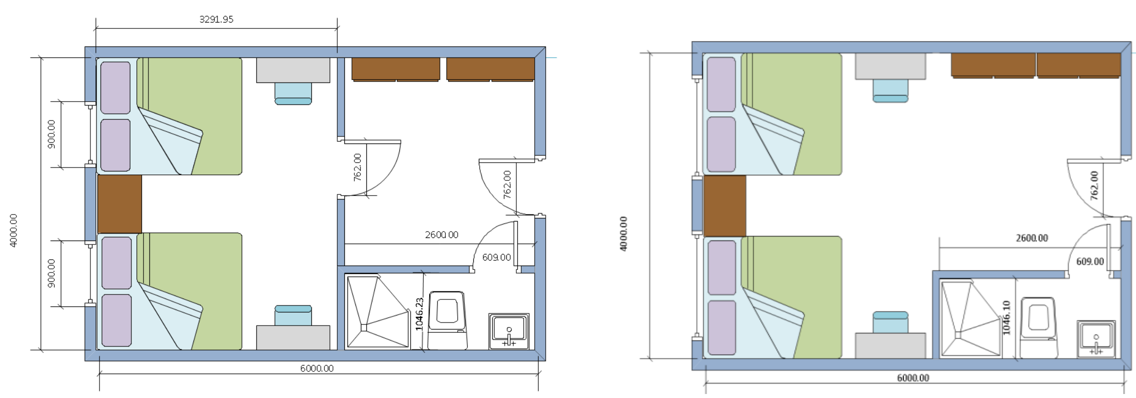
Taking inspiration from "green" dormitories mentioned, the results of the surveys, and keeping in mind the level of comfortability of the residents, a sample residence hall room layout is proposed. The floor size of the model residence hall room is approximately 24 m^2, which is the average floor area of rooms in all the residence halls audited. Occupancy is 2 persons per room, or 12 m^2 of floor space per occupant. Each room has its own toilet and bath. Beds, closet and storage, and study tables are provided just like in the existing residence halls in the University. Two scenarios were considered for the residence hall layout to separately address comfortability and energy conservation. Scenario A is when all rooms are air-conditioned, while scenario B is when the rooms are designed for natural and artificial ventilation using electric fans. Table 3 gives a summary of the residence hall room characteristics for the two scenarios.

Table 3. Residence Hall Room Characteristics for the Two Scenarios.

Criteria	Scenario A	Scenario B
Total floor area, m^2	24	24
Floor to ceiling height, m	3	3
Window size, m x m	0.9 x 1.2	1.44 x 1.2
Window type	Awning windows with overhang	Awning windows with overhang
Air-conditioned space, m^2	13.2	Not applicable
Toilet and bath area, m^2	2.72	2.72
Furniture	2 single beds with storage underneath	2 single beds with storage underneath
	Bedside table	Bedside table
	Study table	Study table
	Closet	Closet

For purposes of comparison, all features of the residence hall rooms for both scenarios were kept similar except for a few details. For Scenario A, a wall is placed to partition the room into two spaces. This reduces the floor area of air-conditioned space to just 13.2 m^2, thereby reducing the cooling load requirement. Window size is also smaller for Scenario A, to reduce solar heat gain and infiltration in the air conditioned space. This reduced window area is still compliant with the building code requirement on window to floor area ratio of not less than 10%.

Figure 15 shows the difference between the two scenarios in terms of basic layout. This layout is chosen due to ease in construction and simplicity. It also allows flexibility in rearranging the furniture as residents see fit.



(a) Scenario A (b) Scenario B

Figure 15. *Room layout.*

Lighting requirements are presented in Table 4, which is similar for both scenarios. This will be used in the computation of the energy intensity of the two scenarios. Figure 16 shows the different task areas in the proposed residence hall room that is used in the computation of required illuminance as per compliance to standard requirements. The lumen values are derived from Illuminating Engineering Society (IES) recommendations for horizontal and vertical illuminance task areas [9].

Table 4. Lighting Requirements for the Proposed Room Layout.

Task Area	Quantity	Power, W	Intensity, Lumens
Bedroom (general)	1	13	1,500
Desk	2	3	250
Entry/closet area	1	7	600
Bathroom (general)	1	11	1,050

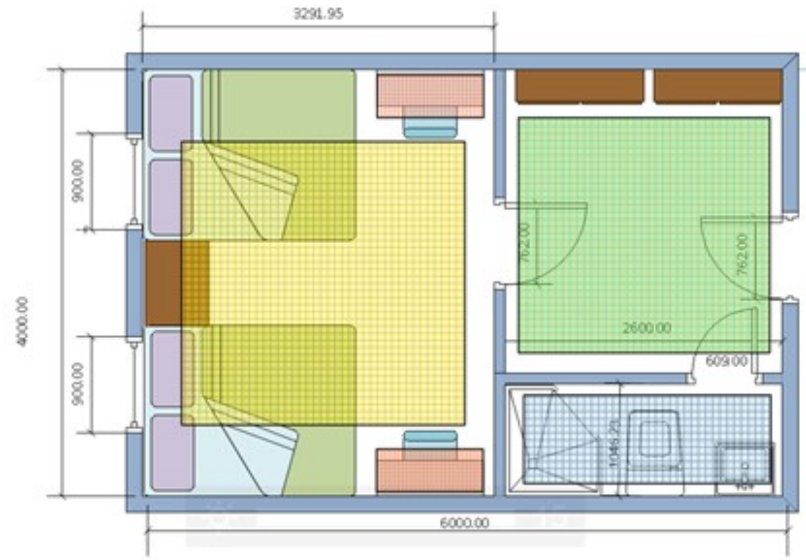


Figure 16. Task area.

Lighting, ventilation, and air conditioning are included in the computation of the energy requirement of the proposed residence hall room. For Scenario A, energy consumption of variable refrigerant flow (VRF) air conditioning system is modeled using a design-and-analysis software program [13], which allows for the evaluation of the effect of building orientation, size, shape, and mass, as well as climatic factors. The software calculates building heat gains and losses for all 8,760 hours in a year using weather data for a specific geographic location. Internal heat generation from appliances and equipment, as well as occupancy schedules are also accounted for in the computation. Sample building layout, as shown in Figure 17, is used in the computation of the cooling load requirement of the 5-storey residencce hall. Note that other building shape and orientation may be used in the analysis, but for purposes of comparison between the two scenarios, the chosen layout will suffice. Note also that with change in building shape and orientation, energy intensity will also change.

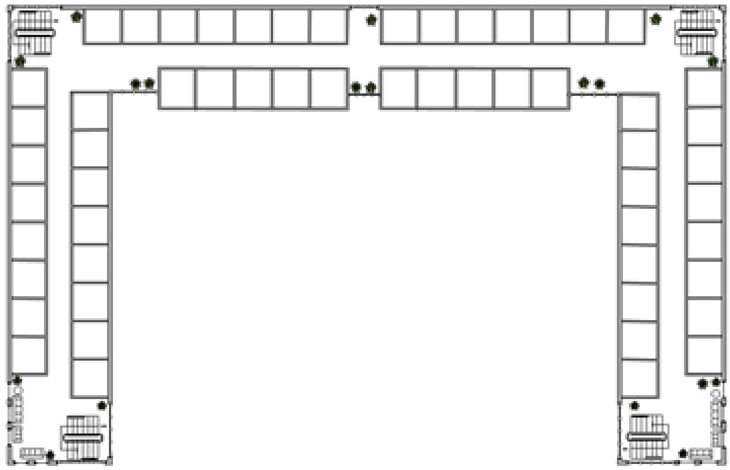


Figure 17. *Building layout used in cooling load calculation.*

Total kilowatt-hour of energy requirement per room in a year is computed, for both scenarios, by multiplying the number of appliance units by its rated wattage and by the number of hours of usage in a day, and by 365 days in a year. The computed peso per resident per month is only based on the cost of utility within the residence hall rooms. This does not include the electricity consumption in common areas such as hallways, lobbies, mess halls, lounges, gymnasium, conference rooms, and offices. This, however, provides a comparative cost estimate of two levels of comfortability: one that is fully air-conditioned, and another that uses a combination of natural and mechanical ventilation. The computed data is entered in Table 5. Obviously, Scenario A, the air-conditioned room is more expensive by 2.5 times.

Table 5. Computation of Energy Intensity of Proposed Residence Hall Room.

Appliances	Units	Rating W	Usage h/day	Scenario A	Scenario B
				Consumption kWh/year	Consumption kWh/year
Lighting					
Bedroom (general)	1	13	7	33.22	33.22
Entry and closet space	1	7	4	10.22	10.22
Task light	2	3	5	10.95	10.95
Bathroom (general)	1	11	2	8.03	8.03
Bathroom exhaust fan	1	30	2	21.90	21.90
Air conditioning unit (VRF System)		-	-	2,099.72	0.00
Electric Fan	2	60	10		438.00
Laptop	2	100	2	584.00	584.00
Total kWh/year				2,768.04	1,106.32
PhP/year				24,912.32	9,956.84
PhP/month				2,076.03	829.74
PhP (US$) per resident/month				**1,038 (19.55)**	**415 (7.82)**

IV. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

1. The total capacity of the 13 residence halls is 3,737 with capacity ranges from 50 to 538 residents. The total number of rooms is 1,257 with room floor area ranges from a minimum of 13.5 m^2 to a maximum of 36.19 m^2, with an average room size of 24.5 m^2. Floor to ceiling height of rooms ranges from 2.44 m to 3.9 m, with an average of 3 m. The average occupancy per room is 3 persons.
2. The highest energy intensity is at 65 kWh per resident, while the lowest is at 31.6 kWh per resident. The average electricity consumption per resident in kWh is 46.9 per month with a standard deviation of 10.6 kWh per month. Three residence halls are within mean-2σ to mean-σ, 3 residence halls are within mean-σ to mean, 5 residence halls are within mean to mean+σ, and 2 residence halls are within mean+σ to mean+2σ. Two residence halls are within the range of mean-2σ to mean-σ which exhibited the least energy consumption per resident and are the most efficient.
3. Ventilation takes up 37% of the total electricity consumption of all the residence halls followed by lighting at 25% and computing at 24%.
4. If a policy is adopted to have a maximum 60W electric fan is implemented, a 20% electricity savings will be attained.
5. If a policy is adopted that only laptop computers are allowed, between 87 to 92 % electricity savings will be realized.
6. The payback for changing a 40 W fluorescent tube to a 16 W LED tube is 17 months. The payback for changing a 20 W fluorescent tube to an 8 W LED tube is 21 months. The payback for changing an 18 W fluorescent tube to a 9 W LED tube is 8 months. The electricity savings is approximately 59%.
7. Air conditioned room is more expensive by 2.5 times compared to electric fan ventilated room.

4.2 Recommendations

1. Replace emergency exit doors with steel security gates that allow natural light to pass through for hallway daytime lighting.
2. Change the color of floor tiles from dark to light color. This step allows for natural and artificial light to diffuse towards the facility.
3. Before the start of the semester, teach the residents simple ways to reduce electricity consumption. Signages along the corridor will help to raise the awareness of the residents.
4. Create an energy management committee spearheaded by the resident council with the supervision of residence manager. The task of the committee is to lay down the energy conservation policies to the occupants.
5. It is recommended to identify the effects of different residence hall architectural features in the academic performance of residents.
6. Further, it is recommended to develop design protocols incorporating the results of the surveys.
7. Furthermore, it is recommended to develop the level of comfortability that the university is willing to subsidize.

V. ACKNOWLEDGMENT

The authors wish to express their deepest gratitude to the University of the Philippines Diliman Office of the Vice Chancellor for Research and Development for funding this study through the Outright Research Grant (Project No. 161613 PNSE) and Apolonio P. and Lorna L. Yson Professorial Chair in Engineering. For the support and cooperation of the Residence Hall Managers and staff in providing information on the residence halls are hereby truly and faithfully acknowledged.

For the exemplary help in generating the data: Ms. Gilda Asuncion C. Manegdeg, Ms. Jedah Mae P.

Averilla, Mr. Walter K. Mendoza, Ms. Toni Dominique B. Madulid, Mr. Michael P. Geromo, Ms. Joana Mae S. Tibayan, Asst. Prof. Roderaid T. Ibañez, Ms. Anjanette R. Canales, and the residents of Acacia, Balay Atleta, Centennial 1, Centennial 2, Ilang, Ipil, Kalayaan, Kamagong, Kamia, Molave, Sampaguita, Sanggumay, and Yakal Residence Halls who participated in the surveys, and for those various institutions and authors where their data and information were used, are sincerely recognized. Many, many thanks and more power.

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