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Energy Performance of Liceo de Cagayan University Buildings

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ABSTRACT

The energy performance indices of the buildings in the two campuses of Liceo de Cagayan University were determined to address the design and utilization options in the management of building facilities to increase performance in terms of cost and service. Data on the physical, operational and environmental characteristics of the buildings were used to determine salient factors that contributed to energy usage. The mean Energy Efficiency Index for all the campus buildings was 32.3 kWh/m^2/y and was considered as the internal benchmark for energy performance improvement for each building and the entire institution. Age of the building correlated strongly with energy utilization among the physical characteristics of the building while occupancy and occupant load correlated well for the operational characteristics of the building. Both temperature and relative humidity weakly correlated with energy utilization.

Keywords: Energy performance, energy efficiency index of buildings, energy audit.

INTRODUCTION

One of the high consumers of electricity are universities. This is due to the need of providing comfortable levels of thermal and optical comfort of students, faculty, staff and administrators as well as for the preservation of equipment and facilities (Santamauris *et al.*, 2006). In developed countries, energy consumption in buildings are estimated to be around 30 - 40% of the energy requirement (Asdrubali, *et al.*, 2014), while in the Philippines it is around 15 to 20% (Energy conservation measures in government, 2015 September 11) and is considered by the government to be one of the most energy intensive sectors in the national economy. Philippine government programs are therefore directed towards the implementation of energy initiatives. One of the recent advocacies geared towards energy conservation is the National Energy Efficiency Conservation Program (NEECP) of the Philippine Department of Energy which is where guidelines are sourced for implementing the design of buildings and their services. Relative to this function, it is observed that utilities providers are into information dissemination on conservation practices benefit consumers especially the residential and commercial sectors. Hence, local energy consumers adopt various means and ways to implement measures to improve their energy use efficiency. One measure is to study the energy performance of buildings since buildings use energy.

A common parameter in comparing energy utilization in buildings is the Energy Efficiency Index (EEI), determined as the annual energy consumption in kWh per square meter of floor area of the building. This is used quantitatively to assess the energy performance of buildings based on actual measurement of energy consumption. A study on energy performance in universities can address a large portion of the running cost in the operational expenses. In fact international programs advocating energy management of schools are already established to address energy issues. Two examples are the Bright Schools Program (Bright schools program, n.d.) and the Alliance Green Campus Program (Alliance green campus program: pathway to green careers, n.d.) to name a few.

In this study, the Liceo de Cagayan University (LDCU) buildings energy efficiency index is determined and the results are correlated with the physical, operational, and environmental factors. The relationship between these factors with the energy efficiency of the LDCU buildings can be used to address the design and utilization options in the management of building facilities to increase performance in terms of cost and provision of excellent service to the clientele.

FRAMEWORK

The study focused on the investigation of the degree to which the physical and operational characteristics of school buildings correlate with energy utilization.

In a study by Priyadarsini *et al.* (2009), hotel building features and operational characteristics highly correlated with electricity consumption such as worker density, star rating, and years after energy retrofit. School buildings likewise have physical and operational characteristics that may have effects on energy consumption such as energy retrofit, age of building, intended use, number of levels, occupants, and others. Thus, this study includes variables under the categories of physical and operational and characteristics of the school buildings. Environmental factors are also considered which include average temperature and relative humidity. These are prevailing indicators of levels of comfort for building occupants. A study conducted in Spain discussed how electricity demands were affected by factors related to daily air temperature where non-linear relationship was observed between these variables (Valor, *et al.*, 2010). Similar comparable results were observed by Hor, *et al.* (2005) with the consideration of relative efficiency as a variable that helped improve their forecasting model.

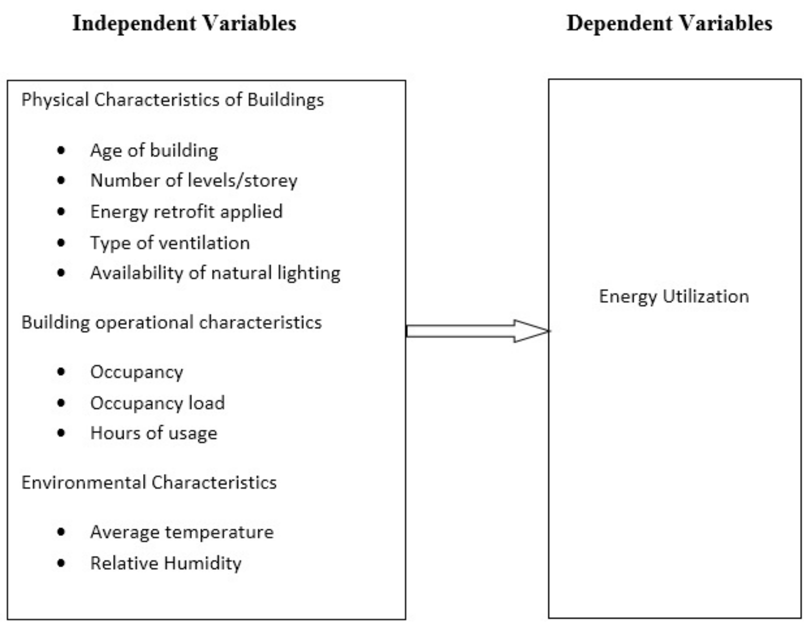

Figure 1. The Schema of the Study Showing the Relationship between the Independent and Dependent Variables of the Study

OBJECTIVES OF THE STUDY

This investigation aimed to provide insights into improving the energy performance of the school buildings in the two campuses of Liceo de Cagayan University by providing quantitative information as to how efficiently energy is consumed in the operations providing an informed basis to management to implement continuous improvement initiatives on energy conservation. The researchers determined the following: (1) the Energy Efficiency Index (EEI) of the school buildings to serve as the baseline energy performance indicator; and (2) the correlation of the physical, operational, and environmental characteristics of buildings on energy utilization.

METHODOLOGY

A facility and energy audit was conducted in the two campuses of Liceo de Cagayan University comprising nine buildings. Building maintenance personnel were interviewed and office records were collected to establish information on the physical and operational aspects of the buildings including the complete historical data on the monthly electricity bills. Actual observation and measurements were also conducted on the campus buildings while environmental data for the whole year of 2015 such as the air temperature and relative humidity, were sourced from the local PAGASA weather agency in the province.

Physical characteristics of the buildings include the following: the total Floor Area measured in square meters; the Age of the buildings categorized using numerical codes, with code 1 being ten years old and below, code 2 for eleven to fifteen years, code 3 for sixteen to twenty years, code 4 for twenty-one to twenty-five years, code 5 for twenty-six to thirty years, and code 6 for thirty years up; the number of Levels or storeys; the Retrofit applied and referred to as the use of energy-saving devices, with no retrofit coded as 4, lamps retrofit as 3, inverter-type air-con as 2, and the lamp plus air-con combination as 1; the Type of Ventilation being coded as 1 for natural ventilation, 2 for the use of combined ventilation system and 3 for fully air-conditioned ventilation system; and the Type of lighting system being coded as 1 for use of natural light, 2 for use of combined lighting systems and 3 for use of solely electrical lighting.

Operational characteristics of the buildings included the following: the Occupancy or the intended use of the building being coded as 1 for office use, 2 for combined classroom and laboratory use, 3 for combined office and large hall use, 4 for combined classroom, laboratory, and office use, and 5 for combined classroom, office, and large hall usage. To determine the combined occupancy, a particular usage must occupy not less than 10% of the total floor area of the building; the Occupant load, that was measured as the average number of users per day for the whole year based on the following assumptions. Classrooms held an average of 40 students, laboratories 35 students, offices 5 to 10, and halls on actual capacity; the maximum Hours of usage being the period that the building was available for use.

Certified data taken from the monitoring facility of PAGASA in the province were used for the environmental variables, Temperature and Relative humidity.

The ratio of the annual electrical energy consumption in kWh to the floor area of a building in square meters determined the energy efficiency index of the individual buildings in units of $kWh/m^2/year$. The mean EEI served as the benchmark value to which the individual EEI building of buildings were compared.

Correlation coefficient, r, were determined to examine the effects of physical, operational, and environmental factors on the energy consumption of buildings.

RESULTS AND DISCUSSION

Data collected from PAGASA and the operational and physical information of the campus buildings of the University are shown in the following tables.

The nine buildings in the two campuses were reduced to seven since some buildings share one source of electrical service line and consequently have combined electrical consumption and bills for the period in this study. Actual measurements of floor areas of the buildings were conducted and the total area was calculated for multi-storey buildings.

Table 1. Electrical Energy Consumption for the Buildings for the Year 2015

Building	kWh	Floor Area sq.m.	EEI $kWh/m^2/yr$
SAC/ Eng'g-PT	161,784	15,940	28.7
NAC	72,148	6,300	17.2
ASB	170,580	15,360	28.8
HB/ Library	293,536	27,516	54.4
Rodelsa	152,475	13,545	44.3
Gym	32,520	3,200	17.1
RNP	375,340	32,640	35.6
Average			32.3

Table 1 shows the consumption of electrical energy in kWh per building for the year 2015. The RNP Hall that housed the Basic Education classes had the highest consumption followed by the HB/ Library buildings. Air-conditioned spaces like classrooms, laboratories libraries and large halls that were used continuously for long periods during the day had the highest energy consumption. The least electricity consumption was in the Gymnasium or the Civic Center where the utilization was mainly for occasional large convocations held throughout the academic year, beside it having a few air-conditioned spaces as offices.

Energy Efficiency Indices were calculated and the variations are charted below.

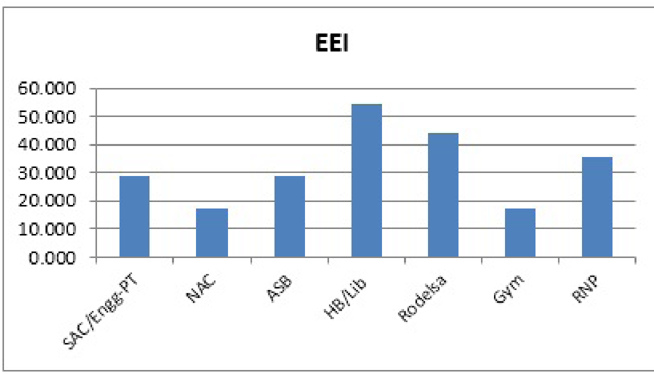

Figure 1. EEI pattern of campus buildings in the year 2015

The HB/Library building registered the highest EEI at 54.4 kWh/m^2/y followed by Rodelsa Hall then RNP. Regarding electricity consumption, RNP registered the highest, but this was distributed over a large floor area being a three-storey building, thus lowering the EEI as contrasted to Rodelsa Hall and HB/Library with lesser floor area. The mean EEI for all the campus buildings, determined to be 32.3 kWh/m^2/y, was taken to serve as a benchmark for energy performance to which all EEI of the buildings will be compared. This value is relatively lower compared to 149-167 kWh/m^2/y for Universiti Teknologi Malaysia (UTM) Abu Bakar *et al.* (2014). A study for school buildings in Greece also showed that EEI was close to 57 kWh/m^2/y for heating and 20 kWh/m^2/y for electricity while the values are 32 kWh/m^2/y for heating and 10 kWh/m^2/y for electricity in best practice buildings (Santamouris *et al.*, 2015). In another study conducted in Argentina, the EEI was found to be 122.7 kWh/m^2/y as compared to UK standards which range from lower than 173 kWh/m^2 to as high as 235 kWh/m^2/y for secondary schools (Filippin, 2000). In this study, the lower EEI for the campus buildings are attributed to energy saving measures of the University, the use of natural ventilation and lighting for buildings, and the fact that heating is not needed to maintain the ambient conditions in the building spaces.

Table 2. Physical characteristics of the campus buildings

Building	Energy Consumed	Physical characteristics				
	kWh/m^2/y	Age	levels/ Storey	Retrofit	Ventilation	Lighting
SAC/ Eng,g-PT	161,784	3	5	2	2	2
NAC	72,148	2	5	2	2	2
ASB	170,580	4	4	1	3	3
HB/ Library	293,536	4	2	2	2	2
Rodelsa	152,475	2	2	1	3	3
Gym	32,520	2	1	3	2	2
RNP	375,340	6	3	1	3	3

Table 2 shows the energy consumption variations with Age, Levels, Retrofit, Ventilation, and Lighting. All buildings are above ten years old, with HB/Library and ASB over 20 years and RNP over 30 years old.

All of the buildings had energy retrofit, but only RNP, Rodelsa Hall, and ASB had inverter-type air-conditioning units installed.

Ventilation and lighting systems in the buildings are mostly combination of natural and electrical. None of the buildings solely use natural ventilation or natural lighting. ASB and RNP, however, were observed to have rooms, offices, and laboratories that are electrically lighted and ventilated.

Table 3. Correlation between Energy Consumption and Physical Characteristics of the Campus Buildings

	Age	Levels	Retrofit	Ventilation	Lighting
r	0.908	0.046	-0.565	0.415	0.415
r^2	0.824	0.002	0.320	0.172	0.172
p	0.0018	0.913	0.144	0.306	0.306

Table 3 shows the correlation coefficients for energy utilization in each building with the physical characteristics. The age of the building showed a significantly strong correlation with energy utilization which means that older buildings tend to consume more electricity. The RNP building, being the oldest, has the highest electricity consumption being retrofitted with lightings and air-conditioning. Consumption was high which might due to the installed ventilation and lighting systems that were mostly electrical as compared with the HB/Library which though relatively old, the ventilation and lighting systems are of the combined types. The Number of levels of the buildings and Retrofit applied weakly correlated with energy utilization which suggests that the energy consumed in each building during the period studied differed, regardless of the number of levels or floors. This suggests that other physical and operational variables, not considered, may have affected energy consumption. On retrofitting, the result was a moderate negative correlation which means that more retrofitting applied will reduce energy consumption. For ventilation and lighting systems, there was a moderate correlation with energy consumption though insignificant as seen in the p-value. This suggests that along with other variables, the natural ventilation and natural lighting may lessen the energy consumed in the buildings.

Table 4. Operational Characteristics of the Campus Buildings

Building	Operational characteristics		
	Occupancy	Occupant load	Hours of usage
SAC/ Eng'g-PT	2	838	13.5
NAC	2	551	13.5
ASB	4	2346	13.5
HB/ Library	5	1332	11.5
Rodelsa	1	217	9
Gym	3	949	12
RNP	4	2073	9

Table 4 shows data on the Occupancy, Occupant load, and Hours of usage of the campus buildings of the University. Two buildings, namely, SAC/Eng'g-PT and NAC, are classified as combined classroom and laboratory occupancy, and also two buildings, namely, ASB and RNP are classroom, laboratory, and office occupancy.

ASB has the highest occupant load due to the laboratory and the AVR occupancies followed by the RNP due to the combined basic education population under one building, followed by the HB/Library owing to the number of library users combined with classrooms in the HB. The least is Rodelsa Hall which, most of the time, is utilized for office and intermittently, theater.

For the hours of usage, classrooms had the highest duration of 13.5 hours owing to the class schedules that start at 07:30 A.M. to 9:00 P.M. This was followed by the Gym at 12 hours due to extended hours for clinic services. The Library followed at 11.5 hours with HB being relatively unoccupied towards the evening.

Table 5. Correlation between Energy Consumption and Operational Characteristics of the Campus Buildings

	Occupancy	Occupant load	Hours usage
R	0.586	0.792	0.029
r^2	0.344	0.628	0.001
P	0.127	0.019	0.945

The Table 5 above shows that occupant load had a significantly strong correlation with energy utilization of the campus buildings. It reflects how the usage of facilities corresponds to energy demands. A moderate correlation exists between occupancy and energy utilization. Hours of usage of the buildings very weakly correlated with energy utilization owing to the nearly comparable hours of usage of the buildings due to combined occupancies of the available spaces.

Table 6. Environmental Variables: Monthly Temperature (°C) and Relative humidity (%) for the year 2015

Month	Energy Consumption/mo. (kWh)	Temp (°C)	Humidity %
Jan	114,501	26.60	88.0
Feb	108,722	25.85	84.0
Mar	69,866	26.55	81.0
Apr	83,300	26.80	82.0
May	88,268	27.70	80.0

Jun	125,964	26.90	82.0
Jul	118,254	28.15	80.0
Aug	111,520	28.20	80.0
Sep	110,098	27.60	82.0
Oct	117,722	27.65	80.0
Nov	115,200	27.90	83.0
Dec	94,968	27.40	84.0
Average	114,501	27.30	82.2

Table 6 shows the total monthly energy consumption for the buildings in the year 2015 with respect to the prevailing environmental conditions as reflected in the values of the air temperature and relative humidity. Highest temperatures were in the months of July and August at over 28 degrees while the lowest was in February at 25.85 degrees. For relative humidity, the highest observation was in the month of January at 88% while the lowest during the months of May, July, August, and October at 80%.

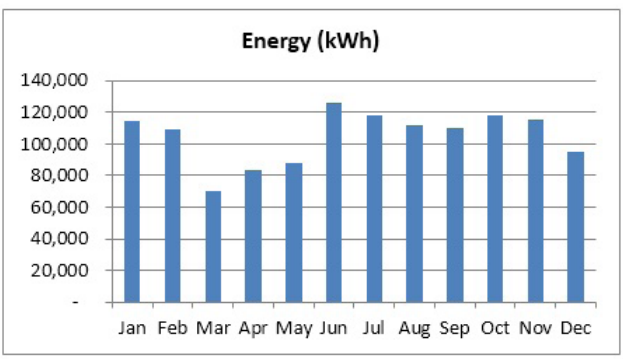

Figure 2. Monthly Energy Consumption for the Year 2015

The chart above shows how the demand for electricity changed throughout the year. The month of June showed the highest consumption coinciding with enrollment and the opening of the school year. Lean months were in March until May with only few students in their summer classes having less utilization of air-conditioned classrooms and laboratories.

Table 7. Correlation between Energy Consumption and Environmental Variables

	Temperature	Relative Humidity
R	0.283	0.133
r^2	0.080	0.018
P	0.349	0.665

The Table 7 above shows the correlation between energy utilization and environmental variables, temperature and relative humidity. Both variables weakly correlated with the energy utilization suggesting that variations in temperature as well as of the relative humidity were irrelevant to the monthly changes in energy consumption. A study in Fars province by Salehizade *et al.* (2015) showed a 0.88 correlation coefficient between electric load and maximum air temperature. This can be due to differences in geographic and climatic factors between Fars province and the Philippines. A study by Fazeli *et al.* (2016) on residential energy demand also discovered a limitation on energy demand prediction models using reported air temperatures since they may be different from actual temperatures felt by the building users. Also, as seen in Table 5, the variations in the temperatures and relative humidity on the monthly basis are rather small compared to the variations in the electricity demands.

CONCLUSIONS

This study presents the following conclusions:

1. The EEI for the campus buildings subjected to this study has a mean of 32.3 kWh/m^2/y. This is considered as the internal benchmark for all EEI of the campus buildings for continuous improvement program in energy conservation. Three buildings exceeded this value and therefore may be given the highest priority in any energy efficiency program.

2. Age and energy utilization strongly correlated which means that older buildings have priority in the implementation of energy management programs like retrofitting and energy saving practices of building users. Ventilation as well as lighting system moderately correlated with energy consumption. This means that combined use of natural light and natural ventilation helped save electricity demand. Energy retrofitting correlated moderately with energy utilization which

suggests that the application of retrofitting for light and air-conditioning may need further evaluation. A study may be conducted, the data of which should extend beyond one year.

3. For the operational characteristics, the occupant load showed a strong correlation with energy utilization while occupancy had a moderate correlation. Energy management programs may be directed towards operational policies that include increasing efficiency of space utilization for classrooms and laboratories, and implementation of guidelines on the usage of electrical devices for lighting and air-conditioning systems in the campus buildings.

4. For environmental variables, both temperature and relative humidity weakly correlated with energy utilization which means that in 2015, the variations in energy consumption were not influenced by the fluctuations in the prevailing weather conditions, such as temperature and relative humidity, as reported by the local weather station. However, studies may be undertaken to investigate further how actual temperature and relative humidity of ambient air correlate with energy demand.

RECOMMENDATIONS

1. It is recommended to conduct further study and evaluation of the application of retrofitting for light and air-conditioning covering the period of more than one year.

2. The University should develop energy management programs and operational policies on space utilization of classrooms and laboratories.

3. It is also recommended to implement guidelines on the usage of electrical devices and lights in the buildings.

4. Future researchers may investigate further how actual temperature and relative humidity of ambient air correlate with energy demand.

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