Energy Assessment, Evaluation and Conservation of an Architecture, Fine Arts and Design Building in the Philippines

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***Abstract*— For the past years, the University of Santo Tomas had an increasing energy consumption. Through an energy audit, possible energy conservation opportunities and programs may help decrease the energy expenses of the university. After calculating the 4-Academic Year Monthly Average of the buildings in the university, it was shown that instructional buildings contributed the largest. Among these instructional buildings is Beato Angelico Building, the university's lone building for architecture, fine arts and design programs, which was chosen as the subject of the study. An ASHRAE Level 2 energy audit was used in the energy auditing process and showed that HVAC contributes 68.50% of total energy consumption while plug equipment, and lighting contribute 23.30%, and 8.21% respectively. The identified energy activity centers which contributed 80% to the total power consumption of the building were classrooms, art laboratories, computer laboratories, and offices. Energy conservation opportunities present in these areas were known after careful analysis. Through the energy audit, various energy policies, strategies and recommendations had been proposed, which contributed to an energy conservation of 19.21% that resulted to lesser energy expenses for the university.**

***Index Terms*—energy audit, energy conservation opportunities, energy consumption**

I. Introduction

The Philippines' electrical energy consumption has been increasing over the past years, from $75.27x10^6$MWh in 2013 to $94.37x10^6$MWh in 2017[1], which was according to the 2017 Power Statistics done by the Department of Energy. The University of Santo Tomas, founded in 1611, considered as the oldest university in Asia that still exists and has the largest population of a Catholic university in the world, is no exemption to this trend. Based on the record acquired from the University of Santo Tomas Facilities Management Office, the university had consumed a total of $77.14x10^6$kWh of power in 2013 which had increased to $77.37x10^6$kWh in 2017. It recorded a total monthly average power consumption of 2,575.169 MWh. Energy consumption is one of the main factors that contributes to the expenses of the university. Energy demand has increased considerably, and building sector is one of the leading sectors in energy consumption[2]. Pro-active actions are necessary, and facilities must be modified to enable easier management[3].

Monitoring the energy performance of existing buildings is crucial to ensure that its energy consumption is efficient[3] especially now that there are a lot of emerging new technologies. These lead the researcher to conduct a study of the energy consumption of Beato Angelico Building of the University of Santo Tomas.

Among the different classifications of buildings in the university, instructional buildings contributed the largest which was 34% of the university's total consumption. One of the instructional buildings is Beato Angelico Building, the university's lone building for architecture, fine arts and design programs, which was chosen to be the subject of the study.

An energy audit was conducted for gathering data on the Beato Angelico building which helped in providing Energy Conservation Opportunities (ECOs). According to the Bill of Energy Efficiency and Conservation Act of 2017, energy audit refers to the "evaluation of energy consumption and review of current energy cost to determine appropriate intervention measures and efficiency projects in which energy can be judiciously and efficiently used to achieve savings". An energy audit (EA) is a process to detect operating problems, improve occupants comfort, and optimize energy use of existing buildings[5]. Achieving energy savings leads to lessened costs for electricity bill, helping the university allocate the funds to other aspects like improving the educational facilities of the university to improve the quality of education.

Manuscript received January 21, 2019; October 20, 2019.

doi: 10.18178/ijscer.9.1.91-94

II. Energy Audit Process

The researchers used ASHRAE Level 2 Energy Audit. This Audit includes the ASHRAE level 1 analysis, with more detailed analysis and collection of data. Twelve to 36 months period of utility bills were collected to allow the auditor to evaluate the facility's energy/demand rate structures, and energy usage profiles. This type of audit will identify all energy conservation measures appropriate for the facility, given its operating parameters[6] .

It also provides a listing of potential capital-intensive improvements that require more thorough data collection and engineering analysis as well as an assessment of potential costs and savings. This level of analysis will provide adequate information for the owner or operator to act upon recommendations for most buildings and for most measure [7].

The data gathering focused on conducting an ASHRAE Level 2 energy audit. The main type of auditing used is capacity auditing, where the capacity of the plug equipment, the length of use and the usage factor were considered to get the energy consumption. Several steps were considered when gathering the needed data. Firstly, a request access to the different rooms and facilities of the Beato Angelico building is needed. Then, checking of the plug equipment was done via observation and interview. The researchers inquired for the duration of use of the facility and plug equipment to the personnel in-charge. The researchers also gathered the needed data for the different energy management opportunities using the lux meter, to measure of the illumination of the space, and the relative humidity meter, for the measurement of relative humidity in the air. The gathering of data was done in different times and the frequency depends on how much data is needed. The gathering of data for the HVAC systems was done every hour using the power quality analyzer, and for the lights and plug equipment, it was done only once but has multiple data depending on the area of the room.

III. Data and Results

A. Monthly Power Consumption of the Beato Angelico Building

The energy audit showed that the Beato Angelico Building resulted to a total monthly power consumption of 132,119.29 kWh. The highest contributing system to the total power consumption is the HVAC system with a total consumption of 90,495.83 kWh and a percentage of 68.50%. Next to it is the plug equipment with 30,777.69 kWh consumption, 23.30% and with the least contribution is the lighting system which resulted to a 10,845.77kWh consumption and a percentage of 8.21%.

B. Standard Deviation

A standard deviation was used to determine if the audited total monthly power consumption of the Beato Angelico building is within range and can be considered acceptable. Using the 4-Academic monthly average of 102,447.02 kWh, the standard deviation resulted to a value of 35,683.06 kWh, with a range of 66,763.96 kWh to 138,130.08 kWh shown in Table I.

TABLE I. Standard Deviation of the 4-Academic Year Monthly Average of Beato Angelico Building

4-Academic Year Monthly Average	Std. Deviation	Minimum	Maximum
102,447.02 kWh	35,683.06 kWh	66,763.96 kWh	138,130.08 kWh

C. Energy Activity Center

The Beato Angelico Building's energy profile was classified according to its different energy activity centers. The energy activity centers are: Classrooms, Art Laboratory, Computer Laboratory, Offices, Faculty, Conference, Art Gallery, Hallway and Lavatory. The energy centers that were chosen to be focused on for the energy conservation opportunities are the Classrooms, Computer Laboratory, Art laboratory and the Offices with a total power consumption of 35,390.77kWh, 27,934.08kWh, 25,746.99kWh and 14,316.14kWh respectively. They were chosen based on the pareto analysis done on the different energy activity centers mentioned as shown in Fig. 1.

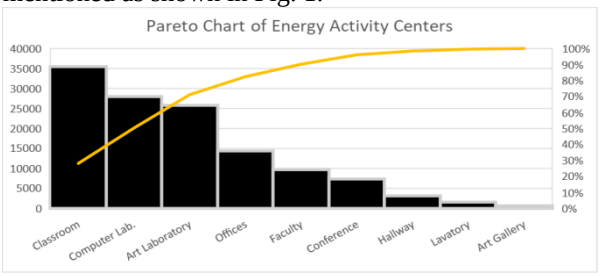

Figure 1. Pareto analysis of the energy activity center

1) *Pareto* analysis of energy activity centers according to the basic audit *systems*

The result of the pareto analysis determined which basic audit system is the major contributor to the activity centers included in the pareto analysis in Fig. 1. It revealed that the HVAC system is the Highest contributor to the classrooms, art laboratory and offices with a power consumption of 32,101.98 kWh,23,051.50 kWh and 10,347.47 kWh respectively. Moreover, the analysis of the computer laboratory showed that the major contributors are the miscellaneous equipment and the HVAC system with a consumption of 15,243.93 kWh and 11,975.09 kWh respectively. It is due to the amount of the computer units installed and their need for a controlled and reliable conditioning. Similar results were found on the study performed by Lopez, N et. Al. entitled, "Energy audit and analysis of the electricity consumption of an educational building in the Philippines for smart consumption". The study revealed that the largest part of the electrical consumption is due to air conditioning (51%), second is the equipment use (35%) and lastly the lighting which is (14%)[8]. Another study by Li, L. et. al. garnered the same result, in which the air conditioning system and the indoor office equipment posed as the

major factors contributing to the high power consumption[8].

IV. Energy Conservation Opportunities (ECO) & Recommendation

As per the definition of the Level 2 Energy Audit, the findings for the different energy activity centers, specifically the classrooms, art laboratories, computer laboratories and offices were determined for energy conservation opportunities. Findings on the HVAC system were: the setting of the air-conditioning at the lowest temperature. There is an unmaintained air-conditioning filter as well as outdated air-conditioning unit installed. Also, several computer units found on the computer laboratories were discovered to be outdated.

A. Energy Conservation Opportunity on HVAC System

According to the ASHRAE standard 55, temperature setting of air-conditioning units should be prearranged to 23°C[10]. Applying this will result to a percent energy reduction of 0.85% with an energy saving of 1,122.99 kWh and by multiplying the energy saving to the average peso per kWh with a value of 7 Php for commercial buildings taken from MERALCO, the monetary savings would be Php 7,860.95 per month. Cleaning of air-conditioning filters and air-conditioning units once every two weeks and every six months, respectively will have a percent saving of 8.64% with an energy saving of 11,413.64 kWh and an equivalent monetary saving of Php. 79,895.51 per month. Lastly, replacement of existing air-conditioning unit to a VRF air-conditioning unit will result to a 7.79% saving with an energy saving of 10,294.22 kWh and an equivalent monetary saving of Php. 72,059.57 per month.

B. Energy Conservation Opportunity for Computer Laboratory

It was discovered that if the old computer units currently installed on the computer laboratory will be replaced with a more updated model, there would be an energy saving of 3,547.29 kWh a percent saving of 2.68% and an equivalent monetary saving of Php. 24,831.01

Collectively, if all ECO's were applied, the result would garner an energy saving of 25,385.87 kWh. That is 19.21% saved from the original consumption of 132,119.29 kWh per month. It will then result to an equivalent monetary saving of Php 177,701.11 per month.

V. Conclusion

The monthly electrical power consumption of the University of Santo Tomas was acquired from the Facilities Management Office and was used in calculating the 4-academic year monthly average power consumption of the various buildings in the university from A.Y. 2013-2014 to A.Y. 2016-2017. The study showed that among the different classifications of buildings, the instructional buildings had the highest contribution, from which the chosen subject, Beato Angelico building, was one of the highest.

The performance of an actual audit on the chosen subject, using the ASHRAE Level 2 energy audit, showed that among the identified energy activity centers, classrooms, computer laboratory, art laboratory and offices contributed 80% to the total monthly power consumption based on the pareto chart conducted. These energy activity centers were the top subjects to focus on in identifying energy conservation opportunities and formulating energy policies.

The study also showed which basic audit systems had greatly contributed in the energy consumption in the particular energy activity centers. The research showed that the basic audit system that contributes the most to the total consumption for classrooms, art laboratory and offices, is the HVAC system. Meanwhile, it is the HVAC system and plug equipment that contributed the most for the computer laboratory. This led the researchers to identify energy conservation opportunities in the top energy activity centers in which various energy policies, strategies and recommendations were made to have both energy and cost savings.

Formulation of energy policies, strategies and recommendations had resulted in a total energy savings of 25,385.87 kWh and a monetary equivalent of Php 177,701.11 per month. The study had shown that implementing all proposed policies, strategies and recommendations will save up to 19.21% of energy from the original total consumption of the Beato Angelico Building. Implementing it to all the buildings will be of great help to the university in terms of both energy and cost savings.

Due to a range of diverse information to be gathered and analyzed in the performance of an energy audit, it is suggested that an electronic data logger will be used. By means of an Electronic Data logger, it can automatically monitor parameters including power usage, Voltage, Ampere, temperature and humidity simultaneously for 24 hours a day without the need of a person supervising the data collection. It would greatly help the researcher in collecting the data due to its high precision, convenience and wide array of parameters. To further improve the study, it is also recommended that an ASHRAE level three energy audit entitled, detailed analysis of capital-intensive modifications, will be used in the performance of an energy audit in not just one building in the university (as done by the researchers) but all of the buildings in the University of Santo Tomas. It will provide a more detailed energy data and economic analyses as well as an even more accurate energy and monetary savings of the entire university. It will also help in understanding the energy systems of the different building categories and the method of the implementation of its energy policies, which can be applied in the future.

Acknowledgements

First, we would like to thank University of Santo Tomas Facilities Management Office, for providing us the data on the university's electrical consumption for the past 4 academic years. We would also like to express our gratitude to the administration of the College of

Architecture and College of Fine Arts and Design of the university for giving us the permission to conduct an energy audit in the Beato Angelico Building. To University of Santo Tomas' Department of Mechanical Engineering and Department of Electrical Engineering, thank you for lending us the needed instruments to conduct our energy audit and finish our research. To our dearest parents, who have given all their love, support and understanding throughout the whole process of this research, we cannot be thankful enough to all of you. And above all, to our Almighty God, who has always been guiding and protecting us, may you always bless us with your grace.

REFERENCES

[1] Department of Energy, "2017 Power Statistics", 2018, [Online]. Available : https://www.doe.gov.ph/sites/default/files/pdf/energy_statistics/05_2017_power_statistics_as_of_30_april_2018_electricity_consumption_05042018.pdf

[2] R. A. Lara, G. Pernigotto, F. Cappelletti, P. Romagnoni, and A. Gasparella, "Energy audit of schools by means of cluster analysis," *Energy Build.*, vol. 95, pp. 160–171, 2015.

[3] H. H. Sait, "Auditing and analysis of energy consumption of an educational building in hot and humid area," *Energy Convers. Manag.*, vol. 66, pp. 143–152, 2013.

[4] M. M. Ouf and M. H. Issa, "Energy consumption analysis of school buildings in Manitoba, Canada," *Int. J. Sustain. Built Environ.*, 2017.

[5] A. Alajmi, "Energy audit of an educational building in a hot summer climate," *Energy Build.*, vol. 47, pp. 122–130, 2012.

[6] L. N. Ramya and M. A. Femina, "Energy auditing – A walk-through survey," pp. 406–411, 2014.

[7] M. Deru, J. Kelsey, D. Eldridge, and K. I. Emerson, *Procedures for Commercial Building Energy Audits*. 2011.

[8] N. S. Lopez, J. Gonzaga, and L. A. G. Lim, "Energy audit and analysis of the electricity consumption of an educational building in the Philippines for smart consumption," 2017.

[9] L. Li, Z. Tong, Z. Linhua, and S. Hongchang, "ScienceDirect ScienceDirect Energy Consumption Investigation and Data Analysis for one university of Guangzhou," vol. 00, 2017.

[10] Atlanta, GA: ASHRAE Research, "Standard 55-2013 users manual: ANSI/ASHRAE standard 55-2013, thermal environmental conditions for human occupancy," 2016.

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