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Energy Consumption Analysis in Rural School Buildings in Surigao Del Sur, Mindanao Philippines

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors have extended equal responsibilities and efforts upon the completion of the study. Author OCE managed the design, analyses and literature searches. Author ASDP completed and wrote the protocol, data gathering and statistical analysis. Both authors read and approved the final manuscript.

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ABSTRACT

The study is focused on preliminary analyzes of the energy consumption in rural school buildings, particularly in Surigao Del Sur, Mindanao, Philippines. The study looked into the determination of different contributory factors on energy consumption, conservation practices of employees and annual average energy consumption records. The exploratory research design was used where secondary data from the annual energy consumption bill of selected rural school buildings served as primary source of data. The data covered the records from years 2014 to 2019 indicating the fluctuation of energy consumption of the university. Consecutive sampling method was also employed in the selection of participants to be surveyed and interviewed for conservation practices. Based on the results, the number of occupants and their behaviors significantly contributes on the fluctuation of energy consumption in school because it pertains to the working hours extended when important activities are scheduled. Some of the identified contributory factors on energy consumption can be sourced out from how faculty and administrative personnel utilized the school lighting (84%), air-condition (51%) and number of operating hours occupying the schools (78%) and operating electronic equipment (25%). Although there are records on high increase of energy consumptions in buildings, faculty and personnel are still aware on conservation practices they could contribute to reduce the energy operating cost.

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Keywords: Energy consumption; conservation practices; contributory factors; secondary data; energy source.

1. INTRODUCTION

Large establishments are among the largest consumers of energy. In fact, numerous studies focused on analyzing large commercial buildings' energy performance have proven that a need to consistently investigate its performance is a necessity, Roslizar, Alghoul, Bakhtyar, Asim, Sopian [1]. According to Salleha* , Kandarb , Sakip [2], buildings can be used for a variety of functions, for instance, school buildings have administrative offices, faculty offices, classrooms, laboratories for research and classes, food services, conference rooms, study areas and so on. Many campus buildings are much more energy intense spaces than typical buildings, as most of commercial establishments don't include laboratories or industrial kitchens. Relative to this concern, there are only few records on assessing the energy consumptions focusing on school buildings, despite of their large areas covered and contribution to overall energy use, Mulville, Jones and Huebner [3].

In the study conducted by Madison Gas and Electricity Company [4], colleges and universities in the US use an average of 18.9 kilowatt-hours (kWh) of electricity and 17 cubic feet of natural gas per square foot (ft2) annually, and typical US higher-education buildings sized around 50,000 ft2 consume more than $100,000 worth of energy each year. As a result, these areas are among the best targets for energy savings. In 2018, a study comparing three campus buildings of the same typology was made in France using statistical analysis tools, aiming to identify the main energy drivers and their relative weight in the overall energy consumption, Bourdeau, GuoNefzaoui [5]. The results were supported by the study of Khoshbakht, Guo, Dupre, [6] in 2018, that aimed at comparing 80 university buildings with different typologies using stochastic frontier analysis (SFA) to establish an energy benchmarking system. Based on the results, the buildings used mostly for research had the highest indicator value at 216 kWh/m2/yr, whereas, buildings for academic offices had the lowest indicator value at 137 kWh/m2/yr.

The same situation was observed in countries located in tropic regions like Philippines. Based on the Philippine Green Building Spreadsheet [7], schools (119 kWh/m2/yr) and offices (262 kWh/m2/yr) are part of the top 5 identified establishments with high energy consumptions in the country. According to Lopez, Gonzaga and Lim [8], energy auditing in school buildings revealed that most of the electricity consumption is due to air conditioning (51%), followed by equipment use (35%) and lighting (14%). A few of the factors can increase the energy efficiency of a building**,** including upgrading the mechanical equipment, type of insulation, windows, and the sophistication of the temperature control system (thermostats and sensors). Salmon, [9] noted that some factors are difficult to change because they affect the people in the building, such as the use of a building, its occupancy, and the need for specialty equipment.

From the project summary report of International Energy Agency [10], one of the most significant barriers for substantially improving the energy efficiency of buildings is the lack of knowledge about the factors determining the energy use. There is often a significant discrepancy between the designed and real total energy use in buildings. But, the reasons for this divergence are generally poorly understood and often have more to do with the role of human behavior than with building design. This discrepancy can lead to misunderstandings and miscommunication between the parties involved in the topic of energy savings in buildings. In general, building energy consumption is mainly influence by different factors.

Spending less on operating costs enables schools to redirect its budgets to more critical needs. Energy saving can be used to hire additional teachers, purchase new computers and instructional materials or pay for necessary capital improvements based on Department of Energy, USA [11]. For the energy consumption reduction in university campus, the energy consumption analysis has to be executed. Fundamental device to reduce energy consumption in university campuses is reducing energy consumption in buildings. Reduction of energy consumption in buildings is expected to bring in big profits. If universities reduce energy consumption in buildings, they can be expected big profits such as energy conservation, reduced operating costs and so on. Dong, Jae Woong, Ho Tae, Jeong Hoon [12] reiterated that such university's efforts are even more important considering the ripple effect to society.

There have been various studies on energy audit and analysis on school buildings in many countries, which is indicative of interest around the globe. However, the situation in the Philippines, particularly in rural school buildings differs as variety of factors is considered. Identified problems with previous studies and results is not categorically applicable to provide sufficient solutions in full understanding of how energy is used in rural school buildings and what particular factors may have caused the inflation of energy consumptions. The schools also have big role to solving climate change issues and should be model of society in terms of energy consumptions. Hence, this study focused on analyzing the energy consumption in rural school buildings, particularly in one of the big university campus – Surigao del Sur State University (SDSSU) Cantilan Campus in Surigao Del Sur, Mindanao Philippines. The campus is chosen due to its vast size and population. The studies specifically focused to conduct a preliminary analysis on the energy consumption in the selected rural school buildings. The study also looked into the determination of different contributory factors on energy consumption, conservation practices of employees and annual average energy consumption record. The results provided high contributions to the administration; stakeholders, employees and community identify the potential energy usage reductions and cost savings of the school buildings.

2. METHODOLOGY

This study employed the exploratory research design where the researchers gathered secondary data on the annual energy consumption bill of SDSSU. The secondary data covered the records from years 2014 to 2019 indicating the fluctuation of energy consumption of the university. The design was deemed appropriate because it went through all the information available to describe the situation and practices of the respondents with respect to energy consumption in SDSSU. Consecutive sampling method was also employed in the selection of participants to be surveyed and interviewed.

The research study made use of both secondary data and structured questionnaire as the main instrument in the data gathering. The secondary data on the annual energy consumption bill of the university was derived from the person in-charge of records. The structured questionnaire contained the standards that led the participants' to identify their best practices in energy conservation in SDSSU and contributory factors on energy consumptions.

Entry protocol among the authorities concern was done. Pre-planning was conducted before the implementation of the study. Phase I focused on the investigation of the fundamental information about the energy consumption in SDSSU, through the secondary data on the annual energy consumption records of the university. Data were analyzed and presented in tables and graphs. Phase II was done through the conduct of survey and one on one interview with the employees of SDSSU on the contributory factors in energy consumption and their conservation practices. Data were analyzed using frequency count, percentage distribution and mean. The results will be of great help in formulating energy conservation measures for the potential energy usage reductions and cost savings of SDSSU.

3. RESULTS AND DISCUSSION

The study was conducted in two phases: Phase 1 covers the profile and analysis of the energy in SDSSU-Cantilan Campus in terms of the number of buildings, the land area, electrical facilities utilized the number of operating hours from the different offices and its annual energy consumptions records collected from SURSECO II and School Administrative Office. The different contributory factors in terms of energy consumption were also sought. Meanwhile, the Phase 2 involves the identification of employee's energy conservation practices in the campus.

Table 1 shows the profile of Surigao Del Sur State University Cantilan Campus in terms of its total number of buildings and land area. The school is considered as one of the big schools in Northern Part of Surigao Del Sur, Mindanao having thirty-three (33) buildings established in 53, 958 sq.m land area. The thirty-three buildings are grouped into four (4) main buildings, which include the Administrative Building, Research and Laboratory Building, and two Academic Buildings (A and B). The Administrative Building composed the administrative offices, guidance office, student admission office, and computer laboratories 2, 3 and 4, Planning Office and Office of Students Affairs and Services. Computer laboratories are however separated into two buildings, where computer laboratory 1 belongs to the Research and Laboratory Buildings, which also include Research Office, Science Faculty Office, Chemistry Laboratory,

Physics Laboratory, Biology Laboratory and Auto Care shop. The school is also divided into two Academic Buildings. Academic Building A that is completely composed of College of Teacher Education building, Cafeteria, Apartelle, Mini Hotel, Students Supreme Governance Activity Center, Grand Stand, Business and Management Building, Library, ROTC building, Fish drying building and TLE/THE Laboratory. College of Industrial Technology Building, Audio Visual Center, Electrical and Automotive Shops and Convention hall buildings are all connected to the Academic Building B.

Table 1. Profile of the School

Name of School	Surigao Del Sur State University – Cantilan Campus
Total number of buildings	33
Total Land area	53,958 sq. m.

Figs. 1 and 2 reflect the distribution of school's electrical facilities based on the composition of the four (4) main buildings. Common electrical facilities found in administrative and research-laboratory buildings are computer desktop and window type air condition. Laptop computers are also in high demand among administrative offices. While academic buildings, most of the time, required the use of LCD projectors, computer laptop and LED television.

Bernardo and Oliveria [13] described school buildings to have specific characteristics that make the task of performing an energy audit different from that performed in other types of buildings. These include buildings dedicated to lecturing, offices, canteens, laboratories and other research facilities, libraries and others. These buildings are usually grouped into campuses, and sometimes shared the energy supply infrastructure.

The number of operating hours for the different offices is presented in Table 2. The usage hours of the electrical equipment depends on the operating hours of the school. Generally, a school operates from Monday to Friday for teaching and office transactions and on Saturday for Graduate Studies classes and other extracurricular activities. Regular school's operation covers the 180 days for the faculty and 250 days for administrative personnel, completing the one academic year. Moreover, graduate school's classes and other extracurricular activities operate only in a limited day, particularly only every Saturday. Extension of operating hours, in some cases, is occasionally observed during and on the conduct of major school's events such as accreditation, monitoring and assessment; and the like. It is assumed that the calculation of electrical usage is relevant on the operating hours of the school followed by the utilization of electrical facilities.

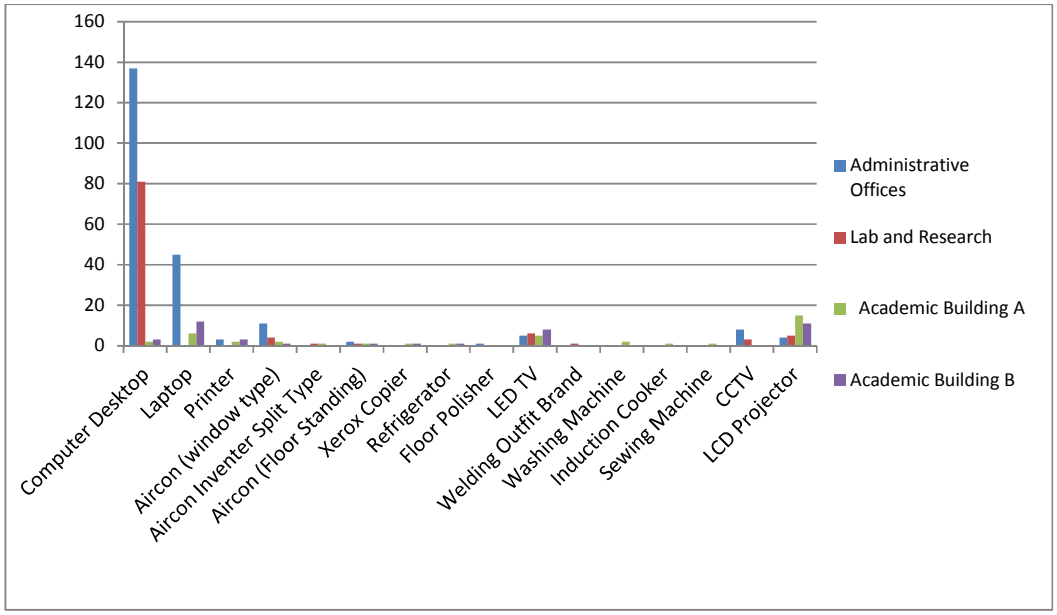

Fig. 1. School's electrical facilities at the study site

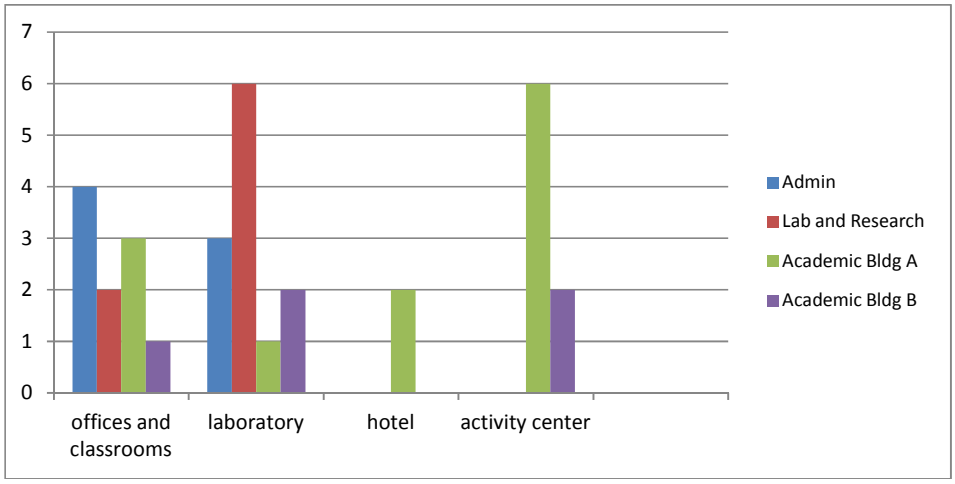

Fig. 2. Types of building and their uses at the study site

Table 2. Number of operating hours for the different offices

Building	Types of Area	Weekdays	Weekend	Overnight
Administrative Building	Administrative office	8		
	Guidance office	8		
	Student Admission Office	8		
	Computer Lab 2, 3,4	8	4	
	Planning Office	8		
	Office of Students Affairs and Services	8		
Research-Laboratory Building	Computer Lab 1	8	4	
	Research Office	8	8	4.5
	Science Faculty	8		
	Chemistry Lab	4.5		
	Biology Lab	4.5		
	Physics Lab	4.5		
	Autocare Shop	8		
Academic Bldg A	Cafeteria Bldg	8		
	Apartelle	4		
	Mini Hotel	4		
	SSG Activity Center	4		
	College of Teacher Education Bldg	8		
	Grand Stand	2		
	Business and Administration Bldg	8		
	Computer Science Bldg	8		
	Library	8	4.5	
	ROTC Bldg		4	
	Fish Drying Bldg	4		
	TLE/THE Lab	4		
Academic Bldg B	College of Industrial Technology Bldg	8		
	Audio Visual Center	4		
	Electrical Shop	8		
	Convention Hall	4.5		
	Automotive Shop	8		

Fig. 3 shows the annual energy consumption in Administrative Building of Surigao del Sur State University – Cantilan Campus from years 2014 to 2019. It can be gleaned in the figure that there is an irregular electrical consumption in months and years. An increasing pattern of energy consumption happened only in 2014 to 2015, except in the month of February, May and June. Significant increase of consumptions is observed in months of February 2016, September 2017 to 2019, October 2018 to 2019 and November 2019. However, an observable decrease of consumption is noticeable in the month of December 2019.

This administrative building with predominantly administrative functions has a predetermined schedule of operating hours with a number of computers and pieces of office electronic equipment. There was a significant increase of energy consumption on November 2019 due to considerable activity on standardization surveillance or monitoring visit and school related accreditation activities. During the said months, offices in administrative building have widespread use of information technology equipment, air conditioning equipment and lighting since administrative personnel were also required to extend their working hours to meet the requirements. Nevertheless, on the Month of December 2019, energy consumption significantly dropped since it was the highlighted month of the year where faculty and employees take their Christmas season break.

The comparison of the annual energy consumption in Research-Laboratory Building is reflected in Fig. 4. High fluctuation of energy consumption is generally observed in Months of September, October, November and December in varying years. Nevertheless, months of January 2018 and December 2014 showed an observable reduction of energy consumptions in the school. A consistent manifestation of high energy consumptions was shown in September to December 2019 for the Research-Laboratory Building. The very high pattern of energy consumption in research-laboratory building is dependent on the type of activities conducted on the specific month and the behavior of occupants in utilizing the facilities. It was during the month of September up until November when SDSSU-Cantilan Campus submitted for another level of school accreditation, followed by the visitation and monitoring of personnel from the Commission of Higher Education (CHED). From accreditation and monitoring activities happened in three consecutive months, another surveillance visit for standardization was scheduled last December 2019. The mentioned activities require the school personnel to render overtime services, hence, extending hours of stay while utilizing the various information computer technology and electronic equipment, for the completion and settling of the requirements.

A 6-year distribution of energy consumption in Academic Building A is presented in Fig. 5. The energy consumption's pattern is almost the same in Research-Laboratory Building (ref. Fig. 4), where significant increase in energy consumption is observed in the Months of September, October and November 2019. A high record of consumption is also seen in March 2015 and September 2016. Nevertheless, months of January, April and May in year 2014 show the least record of energy consumption in Academic Building A. Surprisingly, a drastic reduction of energy consumption is shown in December 2019. The results are congruent to the results in annual energy consumption of research-laboratory building (Fig. 4), where most of the focal faculty and staff involved in the academic accreditation, monitoring and standardization were coming from academic building A. Hence, most of the faculty during the period, have served overtime for the completion of tasks for efficient outcomes. However, the noticeable low record of energy consumption in the month of December 2019 can be depended on the nature of activities and occupancy. Academic activities become limited every December since faculty and students have to concentra only half month transactions because they opt to have their Christmas break. The short period Christmas break limits the access and occupancy of school personnel and students in the building; hence, actual energy usage decreases relatively to the limited occupancy and access to building equipment.

Pedagogical buildings have variable occupation patterns, according to the way classes are conducted (tutorial, laboratory or classroom) and scheduled, showing very different energy performance levels, Bernardo and Oliveria [13].

Fig. 6 displays the annual energy consumption of Academic Building B in six (6) years period. The energy consumption in semi-unison pattern is similar to the energy consumption of Administrative Building in Fig. 4. There is a

significant high consumption of energy in December 2014, followed in July the same year, February, March and August 2015. The least recorded consumption of energy is observed in October and November 2014; and April and June 2019. This implies that a specific activity was conducted on the month of December 2014. Based on the record of activities conducted last 2014, it was the time when academic programs hosted in Academic Building B were submitted for another level of academic accreditation. Similar to the practice of occupants in Academic Building A, faculty and students that time busied themselves in accomplishing requirements for accreditation. Relevantly, an overtime stay and utilization of schools equipment by the faculty were done on the specified month.

According to Bernardo and Oliveria [13], academic buildings have variations in occupancy, since they can have evening classes and, in some cases, buildings of the same typology are also equipped with different types of laboratories that sometimes resemble industrial facilities rather than services buildings, even if in most cases those types of equipment do not operate continuously.

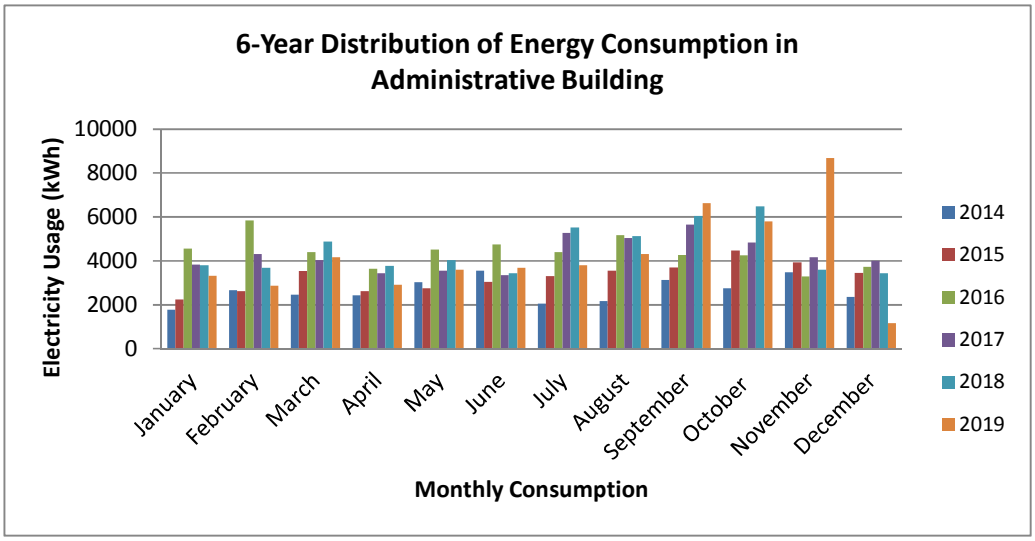

Fig. 3. Annual energy consumption in administrative building

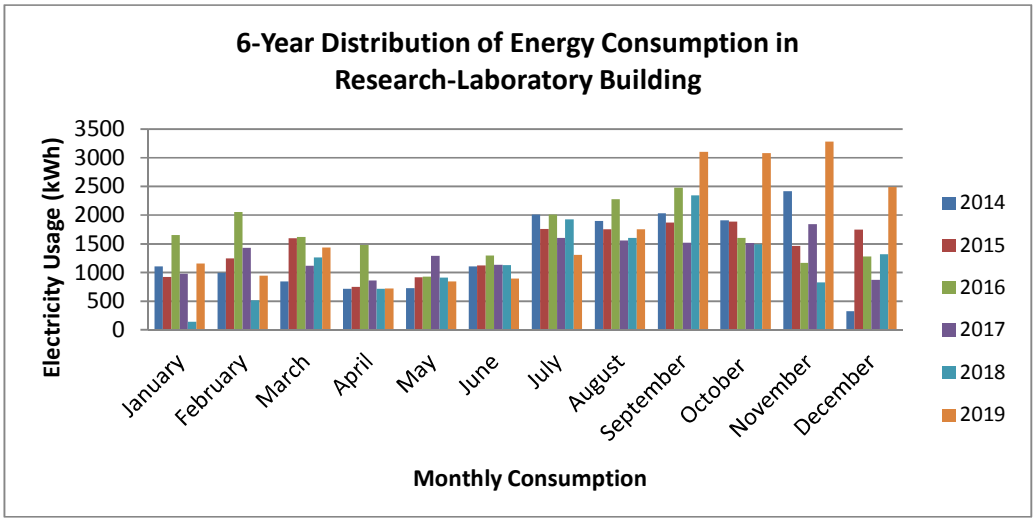

Fig. 4. Annual energy consumption in research-laboratory building

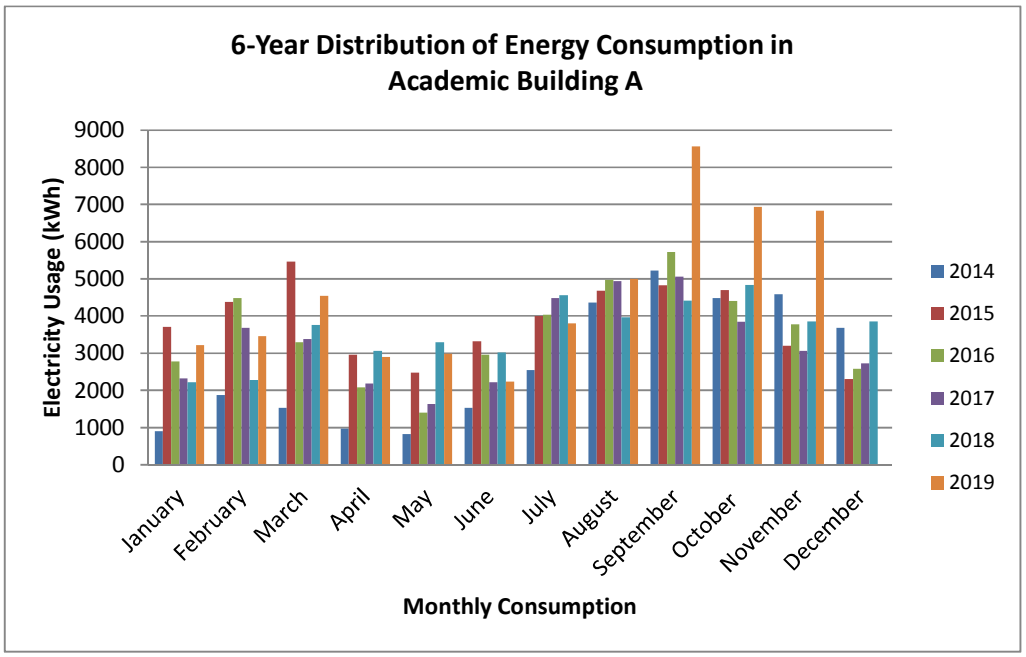

Fig. 5. Annual energy consumption in academic building A

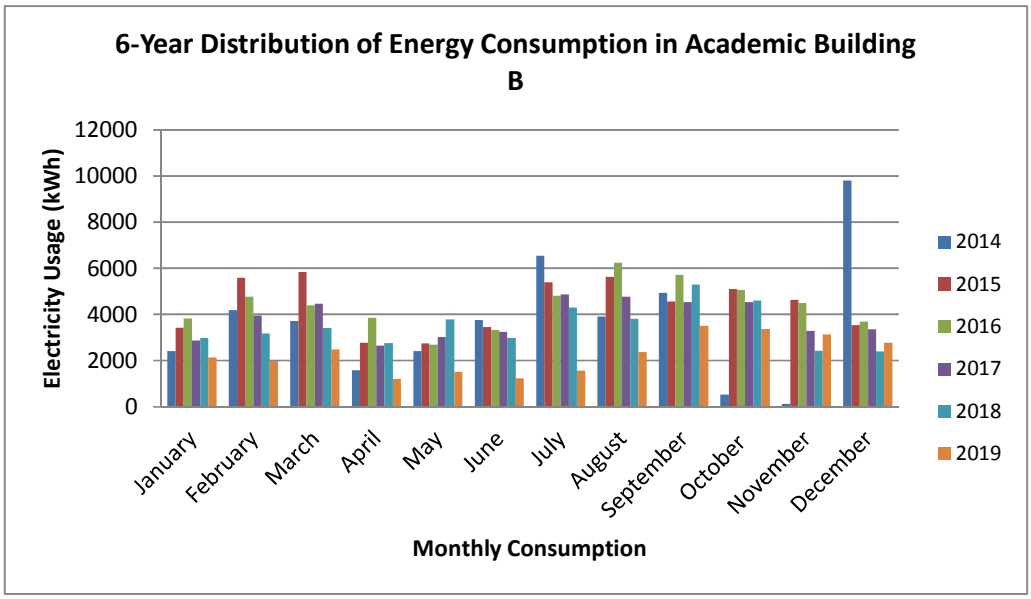

Fig. 6. Annual energy consumption in academic building B

Based on Figs. 3-6 presented, common of the buildings manifest energy consumption decrease in the Month of April and May consistently within six years. Particularly, energy consumption reduces as the summer term begins due to fewer population of faculty and students going to schools, thus, the consumption reduce. Oppositely, the three buildings (Administrative, Research-Laboratory Building and Academic Building A), have most records of high energy consumption in the period of September to December within six consecutive years because of different situation. Classes in the province usually start on June to November for the first term, and November to March for the second term. The duration and type of activities within

the two terms play an important role in the varying amount of energy consumed in the buildings, as well as the occupant's behavior and control over the utilization of school's facilities and systems.

The determination of contributory factors on energy consumption in Surigao Del Sur State University-Cantilan Campus is presented in Table 3. A random selection of 150 employees was done and surveyed to gather information on contributory factors on energy consumption. It can be gleaned from the table that *lightings* (35%) followed by *air-conditioning operation* (31%) are the highest contributory factors of energy consumption in the school while there is a least emphasis on utilizing or setting of energy-efficient facilities (4%). The results are observable as it is one of the basic demands of faculty and students to be provided with a well-ventilated and conducive learning environment for effective learning process to take place. The areas that consumed the most energy through lighting are the classrooms and faculty offices. Similar finding from the study of Roslizar, Alghoul, Bakhtyar, Asim, Sopian [14], that lighting is one of the factors of energy consumption in school due to the design of the buildings. There are interconnected buildings that prevent natural light or sunlight from going into the classrooms and offices, hence lighting is necessary for luminance. Aside, the maximum operating hours of lighting and air-conditioning facilities lasts for eight (8) hours in a day. According to Enteria, Awbi, and Yoshino [15], Philippine has a tropical wet climate with hot and humid outdoor air, whereby the outdoor temperature of the country is hot and humid, typical of the tropical climate. The outdoor humidity ratio is high which results in the need for ventilation and air conditioning to maintain the indoor thermal condition.

The common conservation practices of employees in SDSSU-Cantilan Campus are reflected on Table 4. Employees believed that energy consumption can be reduced through *turning off the lights when not in use* (84%), *unplugging of the electrical wires in the outlet when not in use* (78%), *limiting the use of lights during daytime* (65%) and *using of air condition at the scheduled time* (51%). While least practice among the energy conservation practice are on *limiting the charging period of personal gadgets* (25%) and *replacing damage facilities like computer, laptop, printers and projectors* (24%). The results imply that employees of SDSSU-Cantilan are aware of some common conservation practices of energy conservation in school. They believed that bringing their energy conservation practice at home could give the same results in school. Employees of SDSSU-Cantilan manifest discipline and adherence to the school's policy of conserving energy, however, there are a few, yet very important practice which they commonly neglect, and can be renowned on ownership issues. Faculty employees tend to have their personal gadgets used and charged in school than at home because doing this could cost cut their electric bills at home. Instead, personal gadgets like cell phone, power bank, laptop and other chargeable gadgets are brought most of the time for school and personal use while enjoying the free-billing of electricity. Worst scenarios are on staying longer in the office to enjoy the comfort of Wi-Fi and air-condition while waiting for the gadgets to be fully charged. On the other hand, employees pay less attention to dysfunctional facilities as they do not personally own it. Replacing damaged facilities is never a priority for the employees because after all, it is not their major concern but, the school should take responsibilities of checking the inventory of facilities.

Table 3. Contributory factors on energy consumption in Surigao Del Sur State University – Cantilan Campus

Contributory Factors	No. of responses	% Distribution
Lightings	52	35%
Air-conditioning operation period	46	31%
Number of school/university personnel	19	13%
Number of operating hours	27	18%
Setting of energy-efficient facilities/technology	6	4%
Total	**150**	**100%**

Table 4. Conservation practices of employees in Surigao Del Sur State University – Cantilan Campus

Conservation Practices	No. of responses (n=150)	% Distribution
1. Turning off the lights when not in use	126	84%
2. Using of air condition at the scheduled time	76	51%
3. Unplugging of the electrical wires in the outlet when not in use.	117	78%
4. Limiting the use of lights during daytime	98	65%
5. Utilizing energy-efficient technology	43	27%
6. Opening windows to allow natural ventilation and day lighting effect	83	55%
7. Replacing damage facilities like computer, laptop, printers and projectors	36	24%
8. Refraining from overstaying at the office after official time	63	42%
9. Limiting the charging period of personal gadgets	37	25%
10. Limiting the use of air condition, electric fan or any cooling equipment during rainy or wet season	56	37%

4. CONCLUSION

The energy consumption analysis in the selected rural school buildings in Surigao Del Sur Mindanao was done to provide well documented data as basis for establishing policy of effective energy reduction for local universities in rural areas. The ledger on the monthly energy consumption of SDSSU shows varying results. The four major school buildings have high energy consumptions in the month of September to December while very low in April and May for six consecutive years. The consumption pattern is relevant when it comes to how the school terms start and end; how specific academic and administrative activities are conducted. Reduction of energy consumption is usually observed from academic buildings A and B where its activities are concentrated more on pedagogy or classroom process. Contrary to the administrative building's energy consumptions differ from months and years because it operates in diverse and widespread manner. The number of occupants and their behaviors significantly contributes on the fluctuation of energy consumption in school because it pertains to the working hours extended when important activities are scheduled. Some of the identified contributory factors on energy consumption can be sourced out from how faculty and administrative personnel utilized the school lighting, air-condition and number of operating hours occupying the schools and operating electronic equipment. Although there are records on high increase of energy consumptions in buildings, faculty and personnel are still aware on conservation practices they could contribute to reduce the energy operating cost. Turning off lights when not in use or limiting the use of lights to maximize the daylight, using air-conditions at the scheduled time and unplugging wires after use to cut cost of the inflation. It is understood that even in rural context, schools are aware on basic conservation practices in energy consumptions. However, there is no evident of indicative interest on providing solutions for the schools to gain profit, modeling for cleaner environment and cost saving of the school.

CONSENT

As per international standard or university standard, Participants' written consent has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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