# 16

# Assessment of Economic and Environmental Impacts of Energy Conservation Strategies in a University Campus

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***Abstract***

Large institutions, such as universities, consume large amounts of energy daily. The quantity of energy consumed is continually rising due to an increase in student enrolment and expansion of energy facilities. Energy conservation practices are essential at the university campus as they decrease environmental impact and also reduce energy cost burdens on university management. Hence, it is essential to understand the pattern of energy consumption in the university campus to ensure the sustainability of energy usage, reduction in its costs and environmental impacts. This study takes a look at the energy consumption in Covenant University to provide recommendations that would help to decrease the energy consumption in the university. An energy audit was conducted on 18 selected buildings to determine the electrical appliances responsible for energy consumption in the selected buildings. Building energy models were constructed for each of the buildings using Quick Energy Simulation Tool (eQUEST Software) to run parametric simulations on the generated models. The utility bills of the university for the past five years (2014 – 2018) were examined for seasonal variation of energy consumption. The study revealed that there are several ways of energy wastage in the university.

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Additionally, suggestions on possible solutions to energy conservation strategies to reduce energy consumption in the facilities are presented. A qualitative analysis of two recommendations showed that over N30 million ($81,000) could be saved annually with a payback time of fewer than six years. Also, the implementation of these suggested recommendations could eliminate about 500 tons of CO2 emissions annually.

***Keywords:*** Energy efficiency, environmental impacts, energy consumption, energy audit, building energy models

## 16.1 Introduction

Campus energy potential studies entail an energy auditing process that provides an opinion of the availability of energy efficiency resources on campus and allows the development of cost and savings strategies. On university campuses, the vast majority of the energy consumption takes place within buildings, and the environmental consequences of this consumption are considerable [1]. One of the major environmental issues resulting from energy consumption is the emission of carbon dioxide ($CO_2$) which contributes to global warming [2].

In university campuses, there is a considerable amount of population, including students, academic and administrative staff, researchers, and others who work or study there. Thus, a large amount of energy is needed for operations, including teaching and research, provision of support services, and in residential and hostel areas; it is almost comparable to a "mini-city" [3]. Hence, active energy management consumption in higher institutions is necessary to incur the minimum cost and reduce environmental impacts [4]. University campuses comprise a large number of building users and energy-intensive facilities. Hence, the environmental degradation caused by the huge amount of energy consumption by universities is getting to be a major concern. Thus, it is imperative for university authorities to establish energy management programs to integrate sustainability into campus operations to act more responsibly in practice for a sustainable future [5]. Moreover, with the help of several measures such as organizational, technological and energy optimization, the energy waste on the university campus can be considerably reduced [6].

Due to the existence of old buildings and other sources of energy wastage on university campuses, the potential of efficient energy utilization in such colleges is usually meagre. Therefore, it is vital to assess energy consumption patterns on the university campus to determine ways of improving energy efficiency [7]. Energy consumption patterns on the university campus have been investigated and documented by researchers. Escobedo *et al.* [8] evaluated the energy consumption pattern and the resulting greenhouse gas emission in the main university campus of National Autonomous University of Mexico (UNAM) to identify energy-saving strategies on the campus. The study suggested that the energy use in the university buildings could not be compared with that of most other universities because most of the other universities are in regions where space heating and cooling are more relevant. The energy audit carried out in the study identified several forms of energy wastage through inefficient lighting systems, refrigerators, and water heating. Ishak *et al.* [9] evaluated the energy consumption patterns among students in the four selected universities in Malaysia. The mean daily energy consumed per student was estimated as 6.1 kWh. The study classified energy users into four groups—High, Medium, Low and Conserve. A Centro visual approach was used to analyze the behavioral factors affecting energy consumption. A prediction model was developed from the study, and a potential energy saving of about 55 kWh was reported. Wen and Palanichamy [10] evaluated the energy consumption profile of Curtin University Malaysia intending to suggest ways of reducing and controlling the university's energy expenses. An energy audit which was performed on the campus showed that HVAC systems consumed the highest amount of energy (>70%) followed by office equipment (>13%). The load profile of the university showed that the maximum power demand is at noon just before lunchtime, while the average load per day is 942.10 kW. The minimum requirement was observed to be 174 kW at night (9:00 p.m.) and then remained constant until the next morning.

Regarding energy-saving strategies on the campus, a few pieces of research have been carried out to identify possible energy-saving strategies. Saleh *et al.* [11] investigated the efforts taken by several universities towards sustainability and energy management. The study concluded that the efforts of these universities towards sustainability have not been very productive; hence, they identified five clusters of 23 critical success factors that would help the university tailor its efforts towards sustainability. Deshko and Shevchenko [12] affirmed that energy certification is one of the major ways to improve the energy efficiency of buildings on university campuses. The study emphasized that university campuses are in different classes hence require different approaches to energy certification. The methodology chosen for the energy-efficiency assessment includes: selection of the determining factors; collecting and verifying information; distribution of university campuses by types; adaptation and normalization of the data on energy consumption; development of an energy consumption and efficiency assessment scale and finally, choosing the best optimal variant. Faghihi *et al*. [13] studied the relationship between energy savings in the university campus and the funds required to provide these savings. The study observed that funding is the major challenge campuses face in designing and operating sustainability improvement programs. Two main categories of improving sustainability were identified: energy efficiency and energy conservation. The study discovered that both energy efficiency and conservation save significant amounts of money; however, the latter requires maintenance to extend the energy-saving practices since it deals with human behavior, which is not constant. Finally, they developed a dynamics model that helps to improve the understanding of sustainability programs that lead to an increase in energy and monetary savings. In other studies, Zhou *et al*. [14] discovered that the energy consumption in private universities per student or building area is higher than that of public universities because of better conditions of teaching and research. Hence, there is a lot of potential for energy saving in these universities. The study also identified five significant energy conservation measures in the university campus, which includes electricity sub-metering, utilization of renewable energy, installation of energy-saving appliances, etc. Spirovski *et al*., [15] identified ways in which the South-East European University (SEEU) could implement a climate action plan to help to reduce the university's greenhouse gas (GHG) emissions and carbon footprint. A GHG inventory then took possible measures to reduce GHG emissions identified. The study identified 13 methods of reducing GHG emissions, which include the use of solar thermal, the replacement of the lamps, the use of solar photovoltaic, etc. It further classified these methods based on the corresponding payback time. Lastly, the study suggested the use of several educational strategies such as teaching, climate change seminars, study programs, research, etc., to solve the challenge of GHG emissions.

This study is an extension of Oyedepo *et al*. [16] and Oyedepo *et al*. [17]. The aims of the current study are to (i) assess the energy usage pattern in Covenant University, Nigeria; (ii) identify areas of energy wastage on the campus buildings; and (iii) determine energy cost savings and GHG emission reduction through energy conservation strategies.

## 16.2 Materials and Methods

In this study, the employed methods in data acquisition include physical observations and identification of the various electrical appliances, lighting fixtures, and HVAC systems in the selected buildings in the Covenant

University campus. Different measurements were carried out to determine their energy consumption, then the observations and analysis of the data were done, and energy conservation measures suggested. Utility cost details of the whole campus were obtained from Canaanland Power plant, which was, in essence, the utility vendor of Covenant University over five years. Then this data was then used to analyze the monthly variation in energy consumption of the university.

Furthermore, an energy modelling software, eQUEST, was used to build energy models of each selected building. Then the Energy Efficiency Measure Wizard in the software was used to simulate and predict the impact of the variations of key energy parameters such as lighting density, and window properties on the energy consumption of the building.

The selected buildings in this study comprise ten Student Halls of Residence, University Library, Health Center; four Engineering Buildings and two Cafeterias.

### 16.2.1 Study Location

Covenant University is a modern campus that includes several types of buildings of different functionalities and purposes. The major buildings selected for this study are, four college buildings (College of Business Studies College of Engineering, College of Science and Technology, and the College of Development Studies), four engineering buildings (Chemical/Petroleum, Mechanical, Civil, and Electrical and Information Engineering), one University Library, two Lecture Theatres, and a University Chapel. Other buildings audited include ten Student Halls of Residence, two Cafeterias and the University Guest House.

The energy demand of Covenant University is increasing with developmental activities and progress. There is an increase in building structures and modern equipment being introduced into the university purposely for carrying out different functions varying from lecture delivery to researches on campus. It is, therefore, necessary to understand the status of energy consumption in Covenant University, to ensure the sustainable use of energy usage, and to reduce the cost and environmental impacts associated with its use.

This study used the detailed energy audit method to analyze the energy savings opportunities in the campus. The data collection for this study was in three stages, which include the walkthrough survey stage, utility bill stage, and energy model parameters stage.

### 16.2.2 Instrumentation

The systems audited include electrical energy consumption, lighting, heating ventilation, and air-conditioning (HVAC systems). The parameters measured are:

- Light; measured with a lux meter
- Temperature; measured with an infrared thermometer
- Electric power consumption; measured with a wattmeter.

#### *16.2.2.1 Building Energy Simulation Tool – eQUEST Software*

Different building energy modelling software are available with each having its strength. These softwares include Building Loads Analysis and System Thermodynamics (BLAST); BSim; Designer's simulation toolkits (DeST); DOE-2.1E; ECOTECT; Ener-Win; Energy Express; EnergyPlus; ESP-r; Hourly analysis program (HAP); HEED; TRACE 700; TRNSYS; eQUEST. The considered software in this study is eQUEST. One of the most appealing features of eQUEST is the availability of workflow within the GUI, from high-level information about the building to the more detailed modifications of each object in the structure. Moreover, it carries out energy performance, conceptual design, performance analysis, simulation, energy-efficiency calculation and other applications. It is an easy-to-use software compared to other software such as EnergyPlus, TRNSYS, etc., and it is free software courtesy of the State of California's Energy Design Resources Program.

The software performs hourly simulation based on plug loads, lighting, refrigeration, HVAC systems, usage schedule, building envelope, etc. Simulations based on different variables can also be performed, and the result would be displayed graphically to enhance easy interpretation. The energy-efficiency measure wizard provides a stepwise guide for the user on how to create simulation runs to improve the energy efficiency of the building. The software also has a 3D viewer. Furthermore, the simulation tool can be used to perform economic analysis, daylighting control, building automation control, etc.

### 16.2.3 Procedure for Data Collection and Analysis

The data collection for this study was in three stages: the walkthrough survey stage, utility bill stage and energy model parameters stage. The collected data includes the electricity consumption of the selected buildings in the university, utility bills of the university for five years and energy model parameters of the selected structures. The utility bills were investigated to determine recurring patterns in energy use and how weather variations or seasonal changes affect energy consumption in the university. The electricity consumption data collected from each building was analyzed using Microsoft Excel, then individual contributions of each electrical appliance to the energy mix was determined. Besides, the energy usage of the different types of buildings was compared.

Finally, results of simulations in eQUEST were obtained from the software; then an energy baseline model was developed from which energy-saving strategies evaluated. The energy consumption data collected from eQUEST simulations cannot be validated since buildings in the university do not have meters, which can be used to calibrate the energy models. However, reasonable values of energy consumption produced by the simulation runs suggest that the models are accurate. Furthermore, a minimalist approach was used when gathering data regarding energy consumption in the buildings. This method ensures that the model does not yield exaggerated values of energy consumption, which could hamper the economic analysis. The summaries of the data analysis are presented in figures and graphs to ensure ease of comparison.

### 16.2.4 Analysis of Electrical Energy Consumption

In this study, the electrical energy consumption of Covenant University campus between 2014 and 2018 is examined and analysed critically in its economic and environmental impacts. Based on the data obtained from the walk-through energy audit conducted before making energy reduction plans, the hourly, monthly, and yearly energy consumption pattern per electrical appliances in the selected building was analyzed. The electricity consumption is determined by using equation (1.16) [18, 19]:

$$E = \sum_{j=1}^{n} Pr_k . h_j \tag{16.1}$$

Where,

E = electrical energy consumption of equipment/ electrical device (kWh)

$Pr_k$ = power rating of equipment/electrical device k

hj = hour of use per day and

n = number of users

### 16.2.5 Economic Analysis

An economic evaluation involves the comparison between competing alternatives from which the best option is selected. The alternatives are judged based on various financial performance indicators such as payback time, present net worth, rate of return, benefit-cost ratio, life cycle cost analysis, etc. This study makes use of the simple payback time because it is simple to calculate and suitable for situations in which the energy market is relatively stable.

The parameters needed in calculating the payback time include:

- The investment cost of purchasing the energy retrofits
- The unit cost of energy
- The amount of energy saved by using the retrofit

Relevant equations needed for the economic analysis are:

$$\text{Energy Saving} = \text{Present Energy Consumption} - \text{Energy} \\ - \text{Efficient Solution} \tag{16.2}$$

$$\text{Simple Payback Period} = \frac{\text{Net Project Cost}}{\text{Regular Annual Cost Saving.}} \tag{16.3}$$

$$\text{Percentage Saving} = \frac{\text{Net energy-saving}}{\text{present energy consumption}} \times 100\% \tag{16.3}$$

$$\text{Cost of Replacement} = \text{Unit Cost of LED Lamp} \\ \times \text{Number of Fixtures} \tag{16.4}$$

$$\text{Annual Energy Saving} = \text{Daily Energy Saving} \\ \times \text{Active school days in the year} \tag{16.5}$$

$$\text{Annual Cost Saving} = \text{Annual Energy Saving (kWh)} \\ \times \text{Unit Cost of Electricity} \tag{16.6}$$

$$\text{Estimate Project (Solar Panel) Cost} = \text{Cost of Solar Panels/W} \\ \times \text{Power Rating in W} \tag{16.7}$$

$$\text{Annual Energy Saving} = \frac{\text{Power Rating in W} \times \text{Sun hours} \times \text{Active school days in year}}{1000} \tag{16.8}$$

### 16.2.6 Environmental Impacts Analysis

A simultaneous problem associated with energy consumption is environmental degradation as a result of greenhouse gas emissions. In computing, the volume of $CO_2$ emission from active energy consumption requires a conversion factor. For electricity, the conversion factor is 0.523 kg $CO_2$/kWh. In this study, the UNEP formula for $CO_2$ emissions calculations was adopted, and the equation is given as [20]:

$$CO_2\ emission\,(tons) = \frac{Annual\ Electricity\ Consumption(kWh) \times Emission\ Factor}{1000} \tag{16.9}$$

The $CO_2$ emission saving (tones) from annual energy saving is computed using equation (16.10):

$$\text{CO}_2\ \text{emission}\,(\text{tons}) = \frac{\text{Annual Energy Saving} \times \text{Conversion factor}}{1000} \tag{16.10}$$

## 16.3 Electricity Consumption Pattern in Covenant University

The campus receives electricity from the micro-grid system comprises of a gas turbine, gas generator as well as a diesel engine. The primary source of electricity generation in Covenant University is the gas turbine engine.

The active energy data presented in Figure 16.1 is the total electrical energy consumption in Covenant University campus during five fiscal years from 2014 to 2018 expressed in kWh (computed from equation (16.1)). The trend of electricity consumption shows the seasonal variation

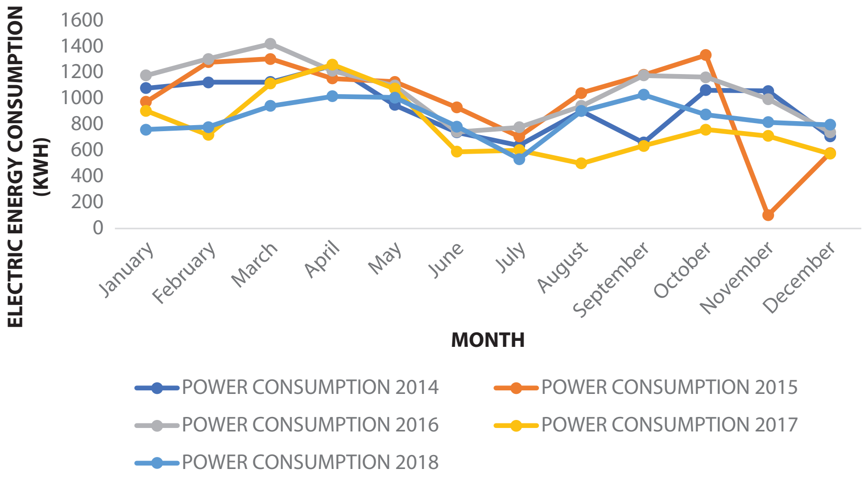


**Figure 16.1** Active Energy Consumption in Covenant University from 2014 to 2018.

with each season depicting the times when the University is in academic session and out of academic session.

The highest energy consumption occurs from January to April (1,853,001.3 kWh – 3,430,824.1 kWh) and August to December (1,853,001.3 kWh – 2,885,727.1 kWh) while the least electricity consumption occurs during the summer break from May to July (334,040.1 kWh – 496,965.1 kWh).

During the summer break, electricity consumption is considerable because faculty/staff and some postgraduate students stay on campus during the holiday. The data in Figure 16.1 includes energy demand in the staff residential areas.

### 16.3.1 Result of Electricity Demand in Covenant University for Various End Uses

#### *16.3.1.1 Results of Energy Audit in Cafeterias 1 & 2*

The energy model of both cafeterias 1 & 2 are similar; hence, the electricity demand of cafeteria 1 is assessed and analyzed, and the results presented as follows.

Figure 16.2 shows the building envelope of Cafeteria 1. The building envelope is made up of windows and walls. The windows occupy a large area towards the entrance and to the sides, thereby making the building suitable for daylighting recommendations. Also, there is a courtyard in the middle of the building to allow natural ventilation towards the kitchen side.

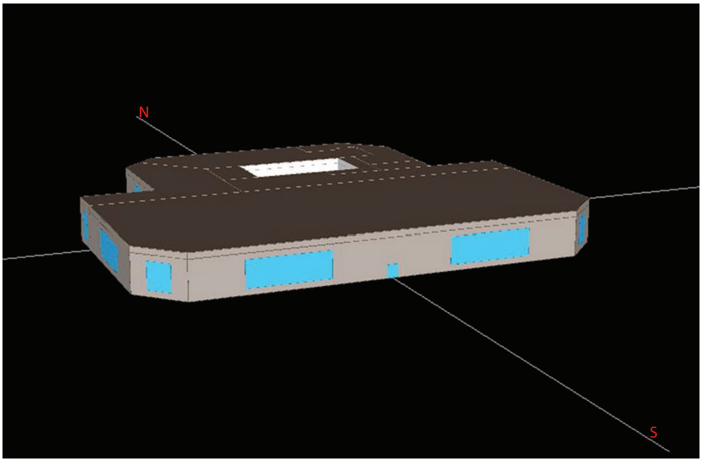


**Figure 16.2** Building envelope of Cafeteria 1.

The energy end-use pattern of Cafeteria 1 is presented in Figure 16.3. These results generated from eQUEST are based on energy consumption data and occupancy profile provided. The software was then able to predict what the energy consumption of the building for a year would be. The results show that the refrigeration system is the highest consumer of electric energy.

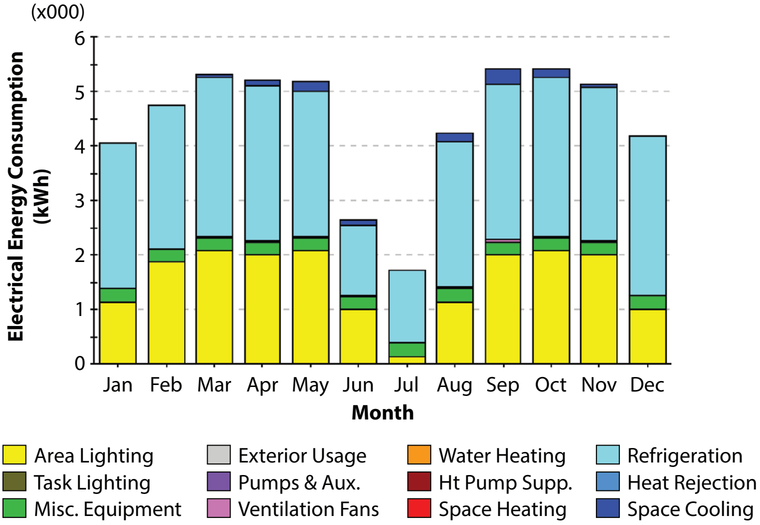


**Figure 16.3** Energy end-use Pattern in Cafeteria 1.

Results of the walk-through energy audit carried out in Cafeteria 1 is presented in Figure 16.4. As earlier mentioned, the highest consumer of energy in cafeterias is a refrigeration system. This is because a lot of perishable goods and drinks need to be kept fresh, and this could only be done with a refrigerator. Also, the cold rooms in the cafeteria take a lot of power hence making them the highest consumers of energy.

Table 16.1 shows the results of the parametric analysis carried out on the energy model of Cafeteria 1. It was observed during the walk-through energy audit that the lighting fixtures used in cafeterias are majorly incandescent bulbs and fluorescent tubes, which are not energy efficient. Hence, a high amount of energy is consumed by these lighting fixtures. Daylighting with dimming was applied to the building to determine the impact this would have on the energy consumption of the building. A daylighting control of 30% dimming resulted in a 2.5% decrease in energy consumption.

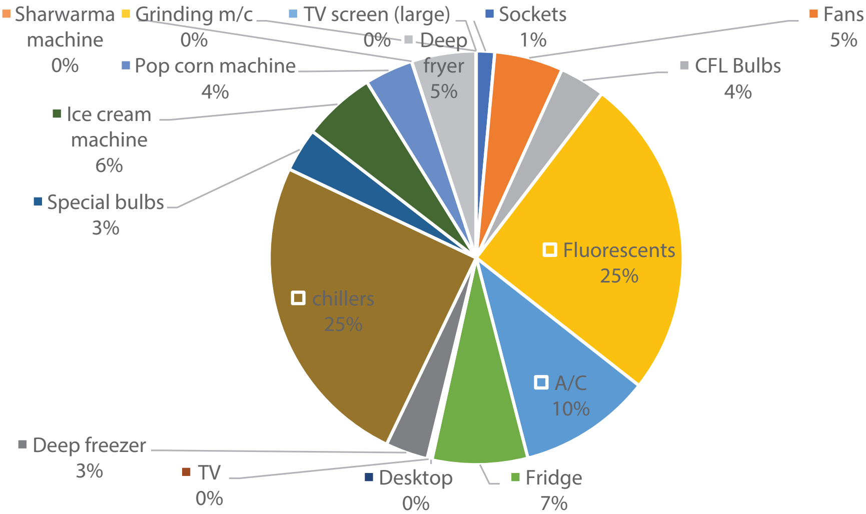


**Figure 16.4** Results of Energy Audit in Cafeteria 1.

**Table 16.1** Daylighting control for Cafeteria 1: dimming up to 30%.

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baseline ($\times 10^3$ *kWh*) | 4.05 | 4.74 | 5.31 | 5.2 | 5.18 | 2.64 | 1.71 | 4.22 | 5.41 | 5.42 | 5.12 | 4.19 | 53.2 |
| Daylighting ($\times 10^3$ *kWh*) | 3.94 | 4.54 | 5.06 | 4.93 | 4.9 | 2.5 | 1.69 | 4.07 | 5.17 | 5.19 | 4.92 | 4.1 | 51.03 |

This result shows that daylighting could help to reduce energy consumption in the cafeteria.

#### *16.3.1.2 Results of Energy Audit in Academic Buildings (Mechanical Engineering Building)*

The Mechanical Engineering building was selected to represent the academic buildings in this study. This is because the energy consumption pattern in academic buildings is similar. Figure 16.5 shows the building envelope of the Mechanical Engineering building. The building envelope is also primarily made up of windows and walls. However, the building is more closed than Cafeterias; daylighting was not considered as a practical recommendation. The building has a large corridor with a lot of open space; hence, sensors are recommended to control lighting on the passages.

The end-use energy pattern of the Mechanical Engineering building is presented in Figure 16.6. This result was generated from eQUEST software based on energy consumption data and occupancy profile provided. The energy consumption pattern of the building for a year was predicted by the eQUEST software. The results of the energy model for the building showed that the space cooling system is the highest consumer of energy.

Figure 16.7 shows the results of the walk-through energy audit carried out in the Mechanical Engineering Department building. From Figure 16.7, the air conditioner has the highest energy consumption (68%), followed

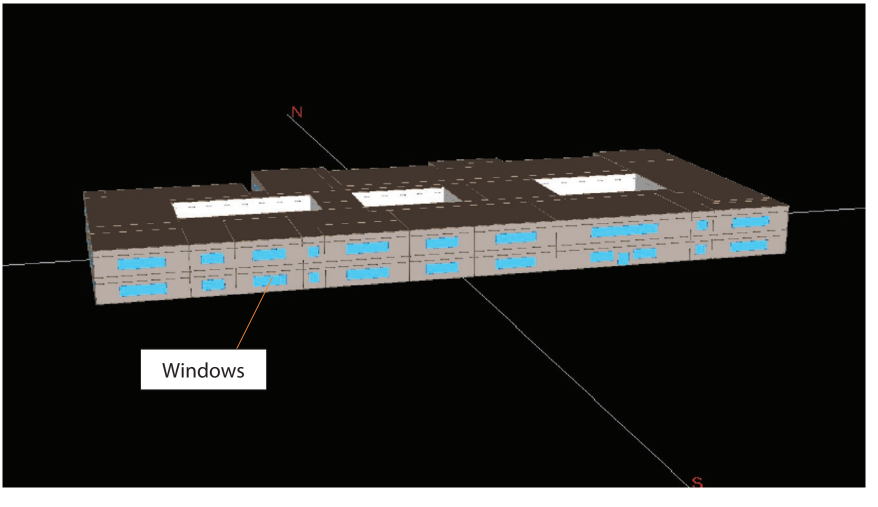


**Figure 16.5** Building envelope of Mechanical Engineering Department building.

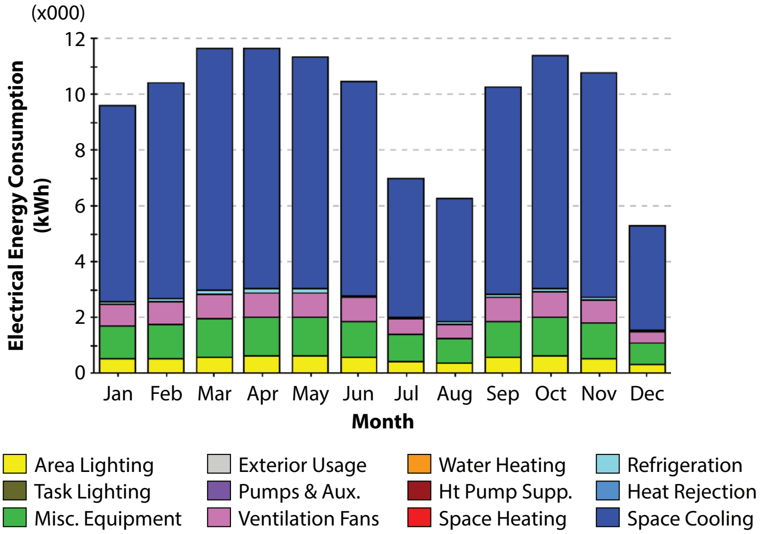


**Figure 16.6** Energy end-use of the Mechanical Engineering Department building.

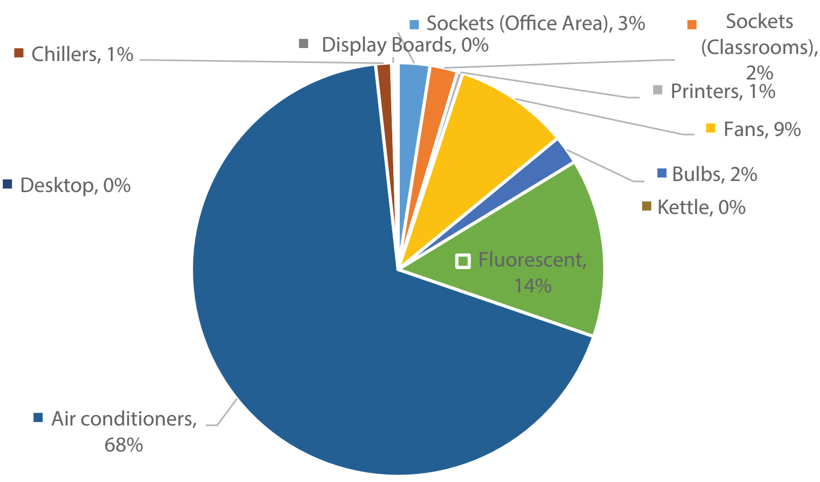


**Figure 16.7** Energy audit data of the Mechanical Engineering Department building.

by lighting fixtures (fluorescent bulbs) (14%). The reason for this result is because each academic building houses over 30 offices fully equipped with air-conditioning systems. The air-conditioning systems are always on throughout the office working hours. Also, the large number of fluorescent bulbs fixed around the corridors in the academic building (Mechanical

Engineering building) are not always turned off even in the daytime. This is responsible for the fact that a lighting fixture is the second-highest energy consumer.

For energy conservation in the academic buildings in Covenant University, solar PV panels could be installed on the large roof surface areas on the educational premises to offset energy peak during the day. Windows in each office in the buildings could be replaced with double-glazed ones to reduce the energy required for cooling. Also, automated control devices such as proximity sensors could be installed to turn off corridor lights when no one is there.

#### *16.3.1.3 Results of Energy Audit in University Library*

The building envelope of the University Library is shown in Figure 16.8. The building envelope is primarily made of windows and walls. The building is also an open space; hence, lighting and space cooling systems consume the highest amounts of energy in the building.

Figures 16.9 and 16.10 show the energy use pattern and walk-through energy audit result of the University Library. The results show that the air-conditioning system is the highest consumer of energy (71%) in the building, and this is followed by fluorescent bulbs (24%). This is due to ample open space in the library which requires a substantial amount of energy to be cooled. Moreover, adequate illumination is needed for library

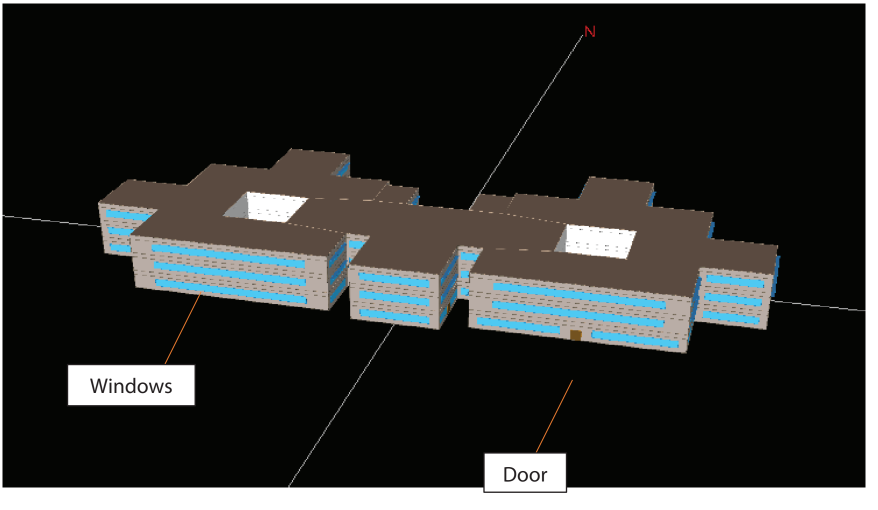


**Figure 16.8** Building envelope of the University Library.

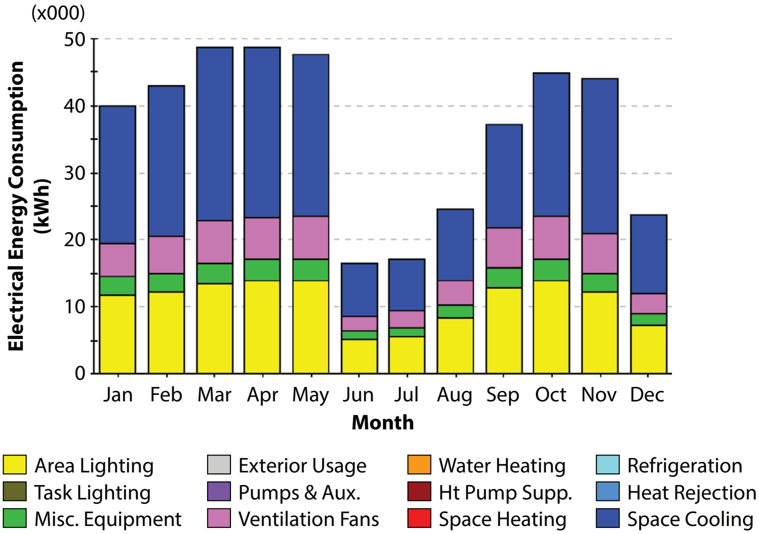


**Figure 16.9** Energy end-use of the University Library.

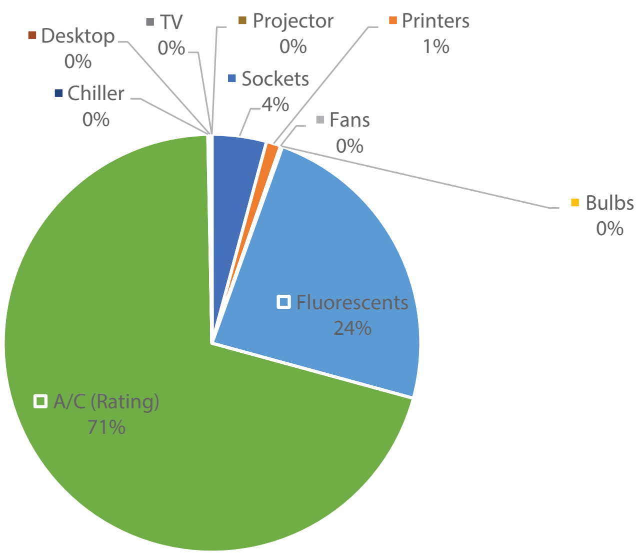


**Figure 16.10** Energy audit data of the University Library.

users, and presently, inefficient fluorescent tubes are being used. These lighting fixtures consume a massive amount of energy. Hence, the fluorescent tubes could be changed to LED tubes to reduce energy consumption.

### *16.3.1.4 Results of Energy Audit in Health Center*

The Health Center building envelope is primarily made up of windows and the walls. The building is highly compartmentalized, and it does not have a lot of open space. Hence, daylighting would not be suitable here. Figure 16.11 shows the building envelope of the Health Center.

An energy end-use pattern and walk-through energy audit data of the Health Center is presented in Figures 16.12 and 16.13, as it was for other previous buildings. This result generated from eQUEST is based on energy consumption data and occupancy profile provided. The energy consumption of the building for a year was predicted by the eQUEST software. From Figures 16.12 and 16.13, it is observed that the highest energy consumer is the air conditioners (84%) because the whole building is fully air-conditioned and the air conditioner runs for 24 hours every day as the Health Center is always open for patients.

Further to minimize energy consumption at the University Health Center, a recommendation is made that roof solar PV be installed on the large roof surfaces on the building to reduce energy consumption from the grid. Moreover, the fluorescent tubes could be replaced with LED tubes to reduce energy consumption by the lighting fixtures.

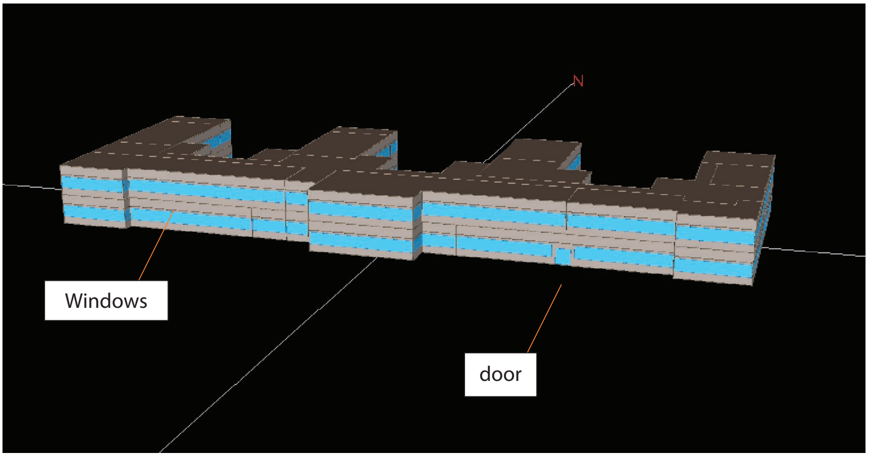


**Figure 16.11** Building envelope of Covenant University Health Center.

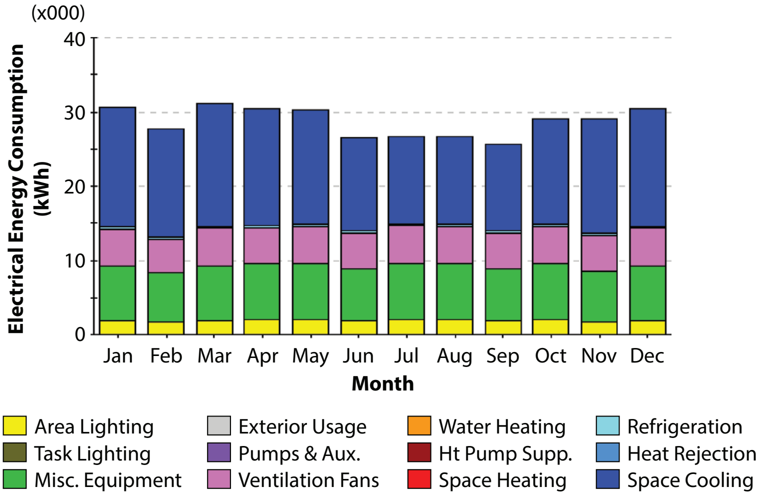


**Figure 16.12** Energy end-use of the Health Center.

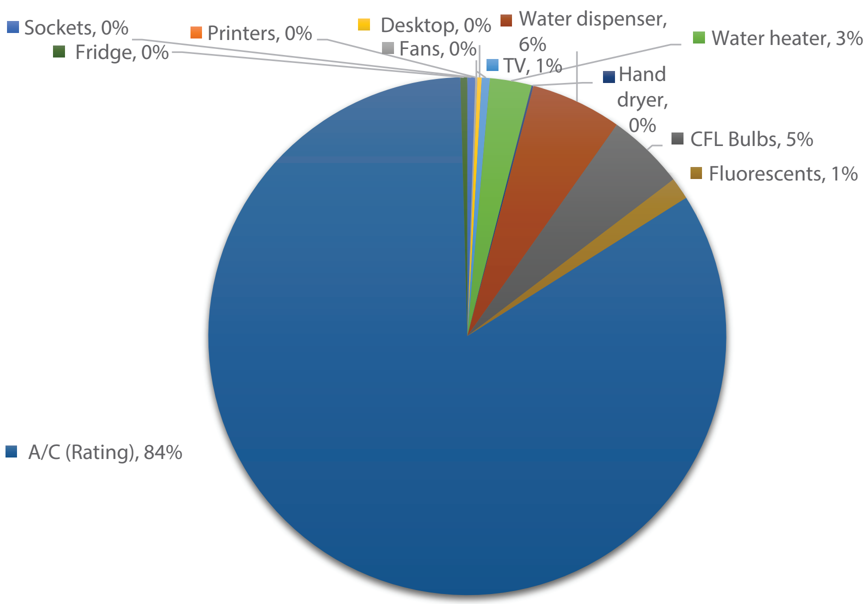


**Figure 16.13** Energy audit data of the University Health Center.

### *16.3.1.5 Results of Energy Audit in the Student Halls of Residence (Daniel Hall)*

There are 10 halls for students' residence (5 male halls and 5 female halls) and each accommodates over 1,000 students. The building structure of the halls is the same. Because of this, Daniel Hall was chosen to represent the other halls for energy consumption assessment. Figure 16.14 presents the building envelope of Daniel Hall. The building envelope is primarily made up of windows and the walls. The building has many open spaces and corridor spaces in the middle, but walls surround it. Hence, it is susceptible to the application of daylighting. The population density in the hall is also very high, with about 400 rooms and 1,000 students.

Figures 16.15 and 16.16 show the energy end-use pattern and walk-through energy data of Daniel Hall. The result was generated from eQUEST software based on energy consumption data and occupancy profile provided. From Figures 16.15 and 16.16, it is seen that plug load, also known as miscellaneous equipment (such as a laptop, iron, electric kettle, etc.), is the highest energy consumer (laptop – 27%). This is followed by lighting fixtures (fluorescent bulbs – 23%). There are no air conditioners in the students' halls of residence; hence, space cooling does not contribute substantially to the energy consumption in the building.

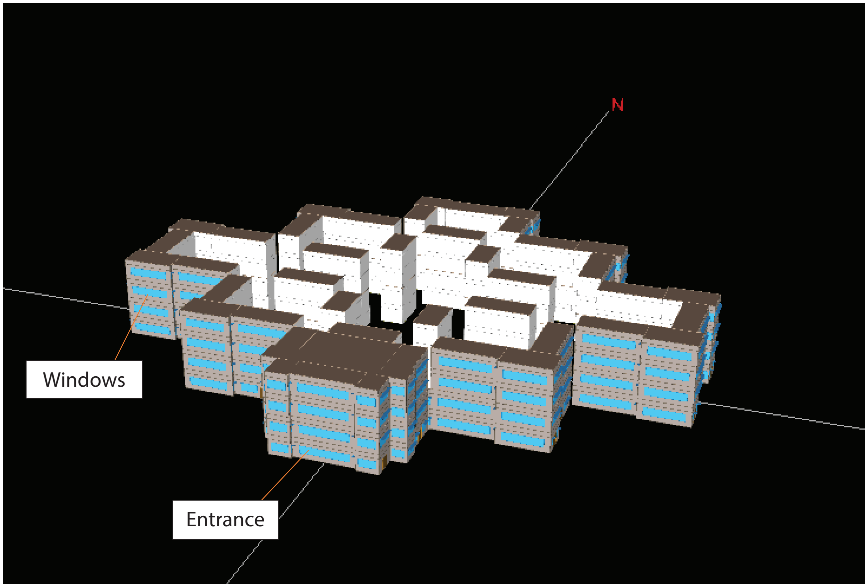


**Figure 16.14** Building envelope of Daniel Hall.

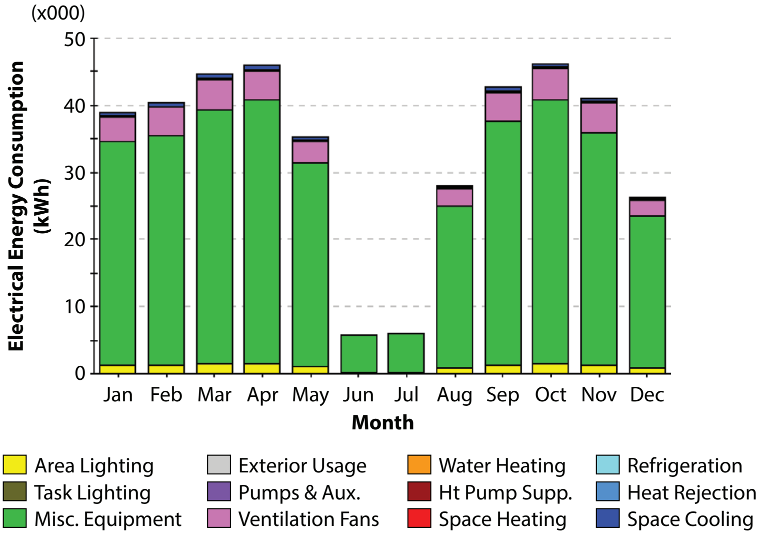


**Figure 16.15** Energy end-use of Daniel Hall.

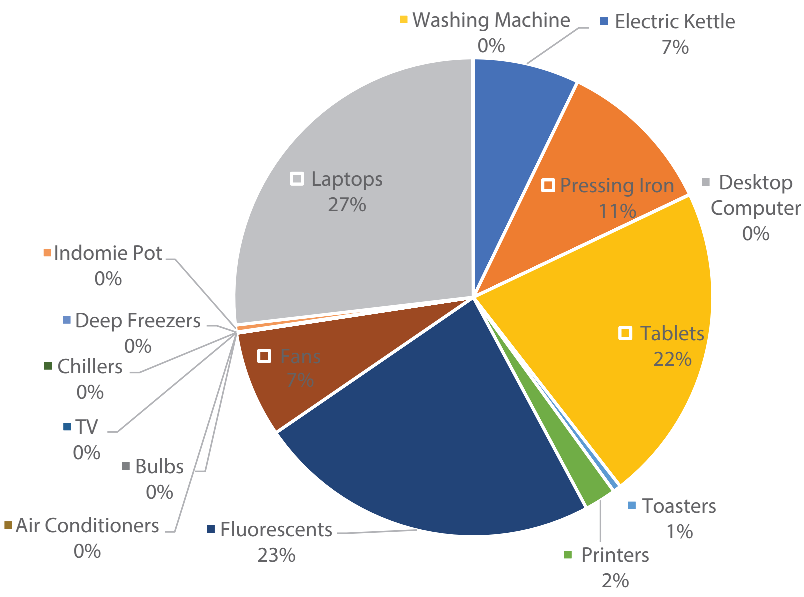


**Figure 16.16** Energy audit data of the Daniel Hall.

Based on the building's structure and students' attitude toward inefficient energy utilization in the hall, to reduce energy consumption in the hall of residence, there should be an increased energy awareness among the students about the environmental impacts of wasting energy. The management could create an association of energy-enthusiastic students. Hebron Energy Club is the proposed name for this association which bears a resemblance to Stanford Energy Club and MIT Energy Club, which are already in existence. Furthermore, inefficient lighting fixtures should be replaced with more energy-efficient LED bulbs with automated control in places to control corridor lights.

### 16.3.2 Comparison of Energy Use Among the University Buildings

Figure 16.17 shows a comparison of energy use among the selected buildings in Covenant University. From Figure 16.17, it can be seen that students' halls are the highest consumers of energy (female halls – 38%; male halls – 28%) among the selected buildings during this study. This is due to the fact that all students reside on campus and there is high population density in the hostels. Moreover, every student has at least one laptop with a tablet, pressing iron and electric kettle; hence, the number of plug loads is high. The energy consumption in the students' halls is as high as 7800 kWh

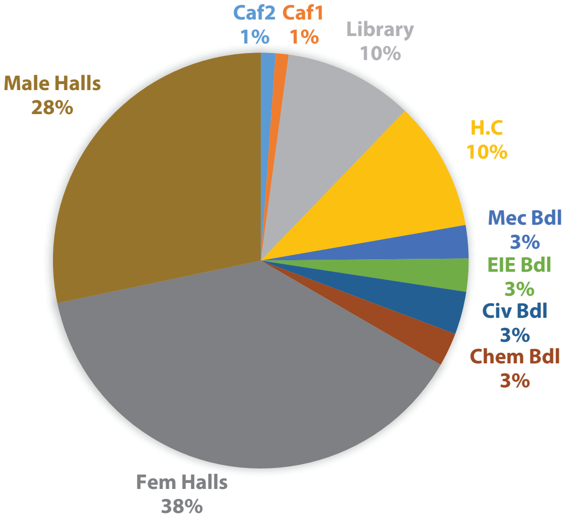


**Figure 16.17** Comparison of energy use among selected buildings.

(female halls) and 5700 kWh (male halls). Cafeteria 1 is the lowest energy consumer (202 kWh).

### 16.3.3 Results of Greenhouse Gas Emissions

Figure 16.18 shows the monthly $CO_2$ emission based on actual electric energy consumption on Covenant University campus. As the energy consumption fluctuated within the period under consideration, so also $CO_2$ emission varied. Among the factors that influence $CO_2$ emissions in buildings on campus include campus population (students and staff), building structure, building energy intensity, students and staff attitude towards energy saving, etc. The amount of $CO_2$ emission and gases from the effects of the greenhouse are the adverse effects of energy use from electricity, heating and other means of producing energy.

As earlier mentioned under the electricity consumption pattern in Covenant University, the trend of $CO_2$ emission also shows the seasonal variation with each season depicting the times when the university is in academic session and out of academic session. From Figure 16.18, the highest $CO_2$ emission occurs from January to April (295.2 tons – 1794.3 tons) and August to December (181.1 tons – 1509.2 tons) while the least $CO_2$ emission occurs during the summer break from May to July (174.7 tons – 259.9 tons). Results of this study show that the amount of $CO_2$ emitted

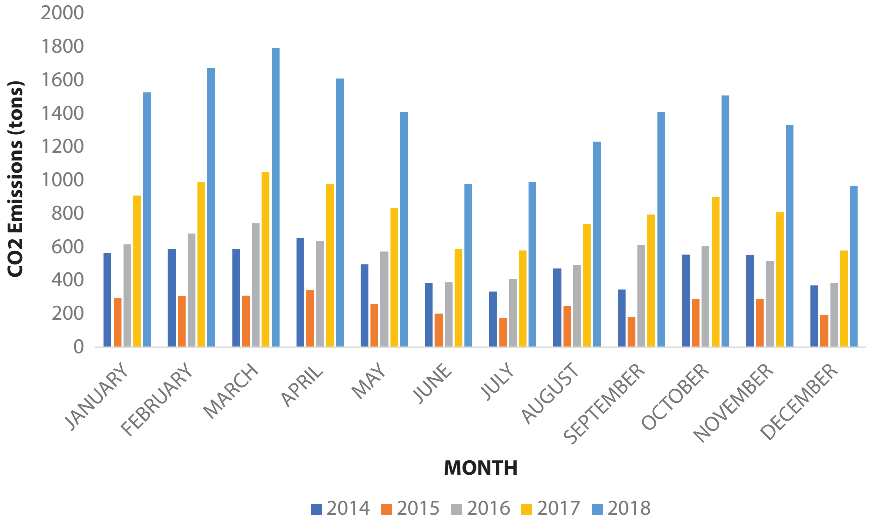


**Figure 16.18** $CO_2$ Emissions Monthly for five years to the Corresponding Active Energy Consumptions.

between 2014 and 2018 varied from 3,093.6 tons to 16,437.8 tons. Such an increase in emission could make the university campus unsustainable. Further to achieve a sustainable campus in Covenant University, the university management needs to work through reducing emissions of greenhouse gases ($CO_2$), cut down the use of energy, introduce more renewable energy in the energy mix and emphasize the importance of sustainable energy sources.

### 16.3.4 Qualitative Recommendation Analysis

Based on the results of the energy audit carried out on the selected buildings in Covenant University, several recommendations were made to reduce economic and environmental impacts. However, some of these recommendations cannot be evaluated economically because of their nature. An example is an increase in awareness of energy efficiency in the students' hostels which would take a lot of time and experiments to evaluate. However, two of the suitable recommendations are evaluated for their economic justification: replacement of lighting fixtures with LED bulbs and installation of solar panels on the roofs of the selected buildings.

#### *16.3.4.1 Replacement of Lighting Fixtures with LED Bulbs*

Further, to assess cost savings from the replacement of existing lighting fixtures with LED bulbs, equations (16.4) – (16.6) are used. While equation (16.3) is used to compute the payback period. Table 16.2 shows the economic analysis of lighting fixtures replaced with LED bulbs.

The following are considered for the above computation:

- Number of active school days in a year = 240 days
- The cost of a 10W LED bulb = ₦600
- The cost of electricity in Covenant University = ₦30/kWh
- The exchange rate is $1 to ₦370

Based on the assumptions and results presented in Table 16.2, replacement of the lighting fixtures with LED bulbs in the selected facilities would yield annual savings of over $19,000 (7 million naira) with a payback period of 0.99 years.

Equation (16.10) is used to compute $CO_2$ emission saving (tons) for the replacement of existing lighting fixtures with LED bulbs. Table 16.3 presents the environmental analysis of lighting fixtures replaced with LED bulbs.

**Table 16.2** Economic Analysis of Lighting Fixtures Replacement with LED bulbs.

| Fixtures | No. of fixtures | Daily Energy Saved (MWh) | Cost of Replacement of Lighting Fixtures with LED Bulbs | Total Cost Saved Annually for Replacing the Lighting Fixtures with LED Bulbs |
|---|---|---|---|---|
| Fluorescents | 11266 | 951.42 | $18,269.19 (₦6,759,600.00) | $18,514.03 (₦6,850,190.26) |
| CFL Bulbs | 472 | 37.31 | $765.41 (₦283,200.00) | $726.00 (₦268,620.69) |
| Special Bulbs | 22 | 5.19 | $35.68 (₦13,200.00) | $100.94 (₦37,346.40) |
| Total | 11760 | 993.91 | $19,070.27 (₦7,056,000.00) | $19,349.97 (₦7,156,157.35) |

**Table 16.3** Environmental Analysis of Lighting Fixtures Replacement with LED bulbs.

| Fixtures | No. of fixtures | Daily Energy Saved (MWh) | $CO_2$ savings (tons) |
|---|---|---|---|
| Fluorescents | 11266 | 951.42 | 119.42 |
| CFL Bulbs | 472 | 37.31 | 4.68 |
| Special Bulbs | 22 | 5.19 | 0.65 |
| Total | 11760 | 993.91 | 124.76 |

In this study, $CO_2$ emission factor used is 0.523kg of $CO_2$/kWh.

From Table 16.3, it is seen that replacing inefficient lighting fixtures with more efficient LED Bulbs would save the environment from pollution to the order of 125 tons of $CO_2$ emission annually.

#### *16.3.4.2 Installation of Solar Panels on the Roofs of Selected Buildings*

Electrical energy from the solar panels could be fed directly into the grid system of the university campus during peak demand which usually occurs in the afternoon, thereby eliminating the need for batteries in the solar

**Table 16.4** Economic and Environmental Analysis of Solar Panels Installation.

| Power (W) | Cost of solar panels | Energy Savings (kWh) | Cost Saved for installation of solar panels | $CO_2$ savings (tons) |
|---|---|---|---|---|
| 530505.21 | $358,449.47 (₦132,626,303.46) | 763927.51 | $61,940.07 (₦22,917,825.24) | 406.41 |

system. The large amounts of electrical energy consumed in the halls of residence would not make rooftop solar panels an economically feasible recommendation; hence, the other facilities apart from the halls are evaluated.

Equations (16.7), (16.8) and (16.10) are used to analyze the cost and $CO_2$ emission savings with the installation of solar panels on the roofs of selected buildings. Table 16.4 shows the economic and environmental analysis of solar panels installed on the roofs of buildings chosen in covenant university.

The following are considered in the above computation:

- The cost of solar panels/W of energy = ₦250/W
- Average daily sun hours = 6 hours
- School days in a year = 240 days
- Cost of energy (₦/kWh) = ₦30
- The exchange rate is $1 to ₦370

The analysis above shows that installing rooftop solar panels would save the university about USD 62,000 (23 million naira) annually with a payback period of 5.79 years. Also, the implementation of this recommendation would save the environment about 400 tons of $CO_2$ annually.

## 16.4 Conclusion

In this study, an energy audit of selected buildings in Covenant University has been carried out to proffer energy-saving strategies to reduce the cost of energy and environmental pollution. In the course of this study, it was observed that there is a lot of energy wastage due to use of inefficient and energy-intensive appliances, lack of awareness of energy conservation strategies among students and staff, and multiple uses of inefficient heating equipment, among others.

Results of this study show that electricity consumption and $CO_2$ emission increased from 334MWh to 3431 MWh and 3093.6 tons to 16,437.8 tons, respectively, from 2014 to 2018. Furthermore, it is inferred that buildings that are more operational consume more electricity as more types of appliances are used for different functions on the campus. Space cooling and lighting have the highest percentage of electricity consumption of the total energy demand in the university. Results of this study further show that energy and cost savings and $CO_2$ emission reduction for replacement of traditional fluorescent tube light (FTL) and incandescent bulbs with LED bulbs and installation of solar panels on the roofs of the selected buildings are about 993.91 MWh, $19,349.97 (₦7,2 Million), 124.76 tons and 763.93 MWh, $61,940.07 (₦22,9 Million), 406.41 tons, respectively, while the payback periods are 0.99 years and 5.79 years for replacement of all conventional FTLs with LED bulbs and installation of solar panels, respectively.

Based on the results of this study, it is concluded that the adoption of energy-efficiency measures as integral parts of the university developmental policy strategy would cause a substantial reduction in electricity demand, electricity bills and environmental pollution. Moreover, enhancing the efficiency of electrical appliances, utilization of daylighting, maximizmg natural ventilation and better management practices can drastically reduce the economic and environmental impacts of energy consumption in the university.

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