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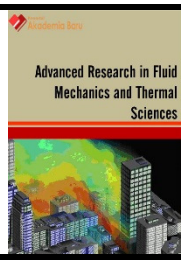

Investigation of Energy Conservation Potentials in Kaduna Polytechnic, Nigeria

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ABSTRACT

Energy conservation in buildings is given utmost importance today by organizations all over the world because an effective energy management in an enterprise leads to significant cost savings in addition to indirect benefits, such as extended equipment life, increased comfort, safety, and productivity. An effective and successful energy management program begins with an energy audit, which is a systematic approach for assessing energy end-use efficiency of all concerned systems/equipment.to identify energy conserving measures (ECMs). This paper analyzed the data obtained based on the extracted electricity utility bills and Automotive Gas Oil (AGO) consumption records for 7 years (i.e. from 2009 to 2015) for Kaduna Polytechnic, being the two energy sources, as well as site surveys and analysis of the energy end users present. The records have shown that, the institution consumes annually an average electrical energy of 1445448 kWh and an average of 11093.14143 liters of AGO, which is equivalent to 118918.48 kWh during normal operation. The result of the investigation and analysis of the energy conservation potentials in the institution have shown that, energy savings of up to 7.5% of the total energy can be achieved by switching-off all security lights during the day. While turning off the air conditioners in the early morning hours of between 8am to 10am would provide a saving of up to 10% of the total energy. Furthermore, a saving of 19.5% of the total energy can be achieved when the incandescent lamps are replaced with the energy efficient ones. The energy conservation measures (ECMs) followed in this research had shown significant savings in terms of both energy and cost, and if well implemented, can pave the way for a sustainable future towards energy management in the institution.

Keywords:
Office buildings, electricity, energy conservation, audit, savings

1. Introduction

The importance of energy conservation in our contemporary world cannot be overemphasized, efficient utilization of energy has significant impact in improving economy at all levels of human endeavor [1]. No doubt, adequate and appropriate utilization of energy especially electrical energy boost up any country's developmental activities [2]. In recent years, research interest has emphasis

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towards efficient energy utilization and energy conservation as the effective means of reducing energy consumption in buildings, thereby reducing its maintenance cost [3, 4]. Studies on energy evaluation conducted on buildings in hot and humid climates had identified energy conservation measures by establishing proper ways and efficient usage of electrical energy consuming devices within these buildings [5]. For example, an energy evaluation conducted on some hotel buildings in Qatar using these energy conservation measures have shown an energy saving between the ranges of 19.69% to 24.12% of their total energy consumption [8].

In addition, studies on energy conservation and cost saving measures of buildings in the Middle East region had been reported extensively in literature [6, 7]. This led the United Arab Emirate (UAE) government for example, to implement an energy ratings system for domestic electrical appliances, air conditioning systems and lightings [8]. On the other hand, the research conducted by Bin and Dowlatabadi [9], indicated that, the United States (US) buildings consume nearly half of the country's total energy consumption through heating, cooling and power. The studies estimated that about 30% of this consumption could be saved by using energy conservation measures and/or through using sustainable building designs and operations [10]. In another research, the United Kingdom (UK) for example, consumes more than 60% of its energy for cooling/heating the indoor environment [7]. In addition, reports from some studies had found that more than 50% of all delivered energy in Europe and the United States had been associated with buildings [3,9]. However, it was shown that, the air conditioning systems were responsible for about 40% of the substantial share of the energy usage [8]. Therefore, it can be clearly understood that, the energy efficiency of the ventilation and air-conditioning systems are clearly of global importance in our contemporary world. On the other hand, an extensive studies carried out on energy conservation and efficiency measures in institutions had also revealed a significant energy savings on their total energy consumptions, and as such, resulted to a huge cost savings [11, 12].

Thus, effective energy management in an enterprise can lead to significant energy and cost savings in addition to the indirect benefits, such as extension of the equipment's service life, reduction in maintenance costs, improving comfort and environmental safety [13]. Hence, electrical energy in any enterprise must be efficiently managed and utilized so as to minimized losses, maintenance cost and efforts. However, it should be understood that, any effective and successful energy management program begins with an energy auditing, which is a systematic approach for assessing energy end-use efficiency of all concerned systems and equipment. Energy retrofits and the implementation of energy conservation measures has been found as the cost-effective means of reducing energy consumption in buildings which therefore, minimized the maintenance cost. Also, as reported in literature, changing building HVAC (Heating, Ventilation and Air Conditioning) facilities with those that have energy saving devices and adjusting their operating strategies had work well in producing huge savings as a result of peak load reductions [10, 14, 15].

It is a known fact that, lack of adequate electricity supply is a persistent problem in Nigeria. Therefore, Kaduna Polytechnic as an institution in Nigeria has not been an exception, the Polytechnic has been suffering from persistent power failure which affects the smooth running of the institution when compared with its counterparts across the globe. Owing to the above problems, it became necessary for the Departments, Faculties and/or the Polytechnic as a whole to resort to the use of high kVA generators to cater for their energy need, which of course has been reported as the most expensive means of alternative source of energy/power generation. Furthermore, the situation became worst due to the lack of efficient and appropriate utilization of the energy end-users in the institution. For these reasons therefore, it has become imperative for the management of the Polytechnic to actually embrace the contemporary conservation methods for efficient and proper utilization of energy which will pave ways for cost savings in the institution. Energy audit is one of the

key methods for improving energy efficiency and management in buildings [16]. The aim of the study is to identify and recommend efficient, less expensive and/or more environmentally friendly energy conserving measures (ECMs) for use in the Polytechnic in order to minimized energy usage and cost.

2. Materials and Methods

2.1 Data collection

The first stage in the study was collection of data, this was feasible with the cooperation of the estate manager's office from the works Department of the Polytechnic. Utility bills of the institution for seven years (2009 to 2015) were requested, collected and analysed. Furthermore, each section of the institution was physically investigated and examined using a walk-through data taking exercise, from which, information about the HVAC, electrical equipment and lightings were obtained. These data provided sufficient information on the historical energy consumption within the Polytechnic. Finally, the architectural and engineering drawings for the institution were studied and obtained information regarding the floor areas of the buildings there present.

Several ECMs were considered during the investigation exercise, based on the data obtained, energy pattern and usage, nature of the environment in which the institution was situated as well as the human behaviour, the following ECMs were used for the evaluation of the energy conservation potentials in the Polytechnic.

2.2 Evaluation of Energy Conservation Potentials

2.2.1 No cost conservation measures

These are measures that can be implemented through operational and behavioural means without the need for system or building alterations and, therefore, do not require extra cost for its implementation [16]. For the Polytechnic campus, the following measures were identified for implementation.

ECM #1: Switching-off of all equipment not in use and to remove the ones which their life span have expired from office.

ECM #2: Scheduling of the operation of building lightings and electrical equipment is normally ignored, but the importance of this ECM in any enterprise cannot be over emphasized. In this context the Polytechnic was no exception, for the investigated buildings therefore, it was found that the lighting and electrical equipment were left in full operation even during the unoccupied and low occupancy hours.

ECM #3: Adjusting the Set Point Temperature (SPT) in the air conditioning systems in such a way that, the cooling temperatures during the hot and cold season months are set at 21°C and at 24°C respectively as against the base case SPT of 18°C.

ECM #4: Minimizing the effect of indoor air infiltration while the air conditioning systems are in operation. It has been observed that at many times doors were left open while the air conditioning systems were under operation, this caused large amount of energy requirements by the systems so as to cater for the proper comfort needed in the indoor environment, and directly it affects the energy consumption rate through hiking the total annual energy consumption.

2.2.2 Low cost measures

These are measures which require substituting/changing some of the building fittings or the modification of the building itself, and thus, it required extra but low cost for their implementation [17]. For the Polytechnic campus, the following measures were identified for implementation.

EMC #1: The use of energy-efficient lighting lamps and ballasts, the addition of reflective devices and de-lamping are measures considered.

ECM #2: Research have shown that the use of a passive cooling measure tends to reduce the thermal cooling load and also minimize gains from outside. This is a measure whereby the walls are protected from the direct impact of ultra-violet rays of the sun through the use of roofing running over the doors and windows or by planting trees placed at 2m or 3m away from the walls.

2.2.3 Major investment measures

ECM #1: Replacement of 1.5 kW (2 hp) Air-conditioning (AC) systems with 1.13 kW (1.5 hp) AC systems. It is a known fact that, modern office equipment do have energy saving devices, and therefore changing the older ones with the new ones should be encouraged in the Polytechnic and similar establishment, although it require careful analysis before a decision can be taken due to the substantial cost involve[17].

2.3 Sample Calculation for Percentage Savings

For example, the energy savings achieved due to change of 100W electric bulbs with that of 35W and the one achieved for offing security lights when not needed are 216817.2 kWh and 108408.6 kWh respectively. Which therefore indicates electric energy savings of 15% and 7.5% respectively from the total electric energy consumption in the institution as can be verified using the sample calculations below.

The average annual electric energy consumption in the Polytechnic was found as 1445448 kWh, thus the percentage energy savings due to change of high Wattage electric bulbs with lower Wattage ones and the offing of the security lights when not needed were evaluated as follows:

The percentage savings due to changes of high Wattage bulbs with low Wattage ones is given by

$$=\frac{216817.2}{1445448} \times 100\% = 15\%$$

While the percentage savings due to the schedule of security lights is given by

$$=\frac{108408.6}{1445448} \times 100\% = 7.5\%$$

2.4 Conversion of Automotive Gas Oil (AGO) in Litres to Kwh

To have a uniform units for calculation, it is a common practice to convert kWh used into mega joules (MJ) and or convert litres of fuel used into equivalent kWh. Hence, in this study, the consumption figures of the AGO were converted to equivalent kWh for ease of comparison and analysis. Since the equivalent energy value of 1L of AGO is 38.6 MJ [18], and 3.6 MJ is equivalent to 1 kWh, then 1 litre of AGO is equivalent to 10.72 kWh.

3. Results and Discussion

From the result of the investigation using the recommended ECMs, the energy savings achieved in the study was encouraging. For example, from the analysis, it was found that, when the security lights were turned off during the day, a savings of up to 7.5% of the total annual energy consumption was achieved. In addition to that, when the air conditioners were turned off during the early morning hours (between 8:00am to10:00am), a savings of up to 10% of the total annual energy consumption was achieved.

Table 1
Average monthly electric energy consumption for 2009 to 2015

Electric energy consumption [kWh]							
	2009	2010	2011	2012	2013	2014	2015
JAN	2009	2010	2011	2012	2013	2014	2015
FEB	33678	130600	90000	62720	95000	99082	138700
MAR	38234	107300	136400	131570	115256	95741	178139
APR	45554	109000	140000	135570	120698	55345	101487
MAY	47684	109600	165340	137020	175564	41111	98253
JUN	49100	65400	188560	140729	206987	47269	99897
JUL	48900	83600	198400	155200	210340	65979	135325
AUG	38300	112400	185400	160000	220304	85000	142600
SEP	33800	133529	122800	165199	200750	115564	169100
OCT	35000	142700	181300	171298	187968	95489	197500
NOV	34900	140300	177100	182391	175635	113965	119700
DEC	29876	135300	141500	174210	149600	130539	149900
TOTAL	27456	135200	91180	112231	99000	115231	156598

On the other hand, when a 100W bulbs were replaced with 35W compact fluorescent, an energy savings of up to 15% of the total annual energy consumption was achieved. Also, when fluorescent lamps of 40W were replaced with those of 35W, a 4.5% reduction in the total annual energy consumption was achieved. Fluorescent lamps can last for 5000 to 6000 hours while compact fluorescent lamps can last up to 8000 hours. This means in terms of duration of use, power consumption and even cost, compact fluorescent can replace the conventional fluorescent tubes.

However, the energy savings due to the replacement of 1.5 kW (2 hp) AC systems with 1.13 kW (1.5 hp) AC systems on different AC systems in the Polytechnic was recorded at 26% from the total annual energy consumption during the hot season months, a time which recorded the highest usage of the AC systems in the Polytechnic. But this is a measure which require huge financial investment for its implementation. And therefore, is recommended to be implemented only through system

renovation, future building constructions and retrofitting building's ventilation and air conditioning installations.

Investigations have revealed that, energy wise, the Polytechnic is being run on two energy carriers namely Electricity from National grid and AGO. However, energy consumption analysis in the institution have revealed that the total average electric energy consumption was found as 1445448 kWh while the average energy consumption from the AGO was fund as 118918.48 kWh.

Table 1 shows the details of the annual electric energy consumption in the institution on monthly basis from 2009 to 2015. From the table, it was observed that, the peak energy consumption occurred mostly between the months of April to August. This can be attributed mainly to the high energy demand to comfort indoor environment during the period stated, being a hot session period in Nigeria. Furthermore, with the exception of year 2014 and 2015, in which Nigeria experienced the most challenging energy downturn, it was observed that, the annual electric energy consumption kept increasing annual basis. This can be attributed to the continuous growth of the institution in an effort to cater for the increasing demands in terms of human and infrastructure. In addition, figure 1 depicts the monthly comparison of the electric energy consumption pattern in the institution for the years under review. As was explained earlier, the electric consumption shows distinct variation, with the months between April and August indicating the highest consumption.

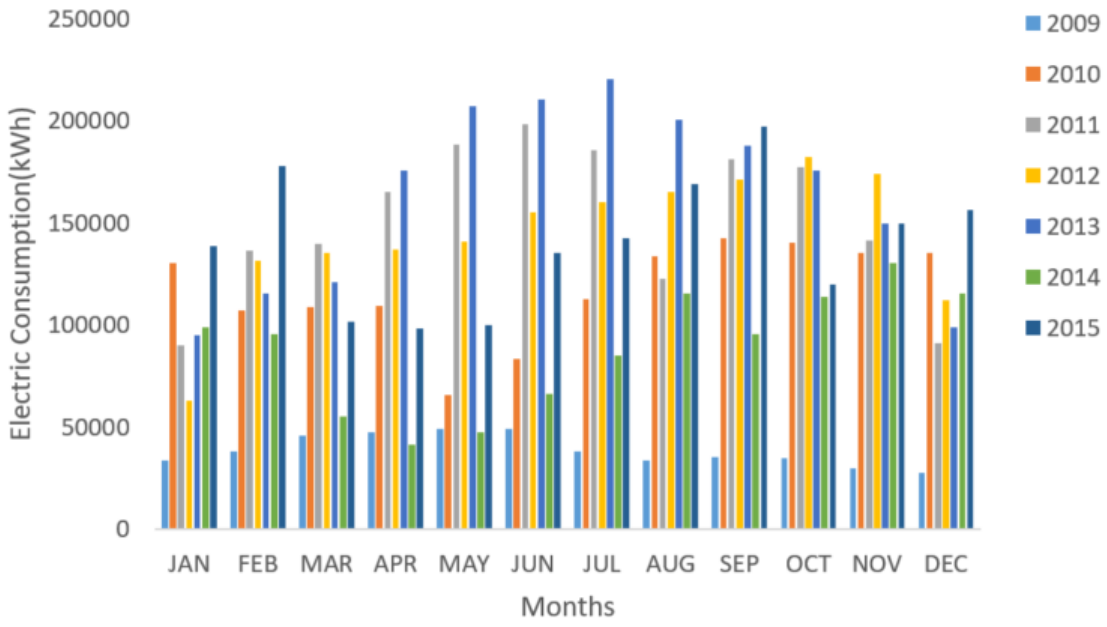

Fig. 1. Average monthly electric energy consumption for 2009 to 2015

Table 2 shows the details of the annual AGO consumption in the institution by the generators on monthly basis from 2009 to 2015. From the table, it was observed that, the peak AGO consumption occurred mostly between the months of March to August between the period under consideration. This can be attributed mainly to the high energy demand to comfort indoor environment during the period stated, being a hot session period in Nigeria. Furthermore, it can also be observed that 2009 has the highest AGO consumption, then followed by 2013, 2014 and 2010 respectively. This is an indication that, there was no specific order for the use the generators in the institution. In addition, figure 2 depicts the monthly comparison of the AGO consumption pattern in the institution for the

years under review. As was explained earlier, the AGO consumption shows distinct variation, with the months between March and August indicating the highest consumption.

Table 2
Average monthly AGO consumption for 2009 to 2015

Diesel fuel consumption (Liters)							
	2009	2010	2011	2012	2013	2014	2015
JAN	726	605.22	483.78	580.8	689.7	665.28	520.08
FEB	759	632.73	505.77	607.2	721.05	695.52	543.72
MAR	1066.56	889.12	710.72	853.25	1013.23	977.36	764.04
APR	1473.12	1228.04	981.63	1178.5	1399.46	1349.91	1055.29
MAY	1572.12	1310.58	1047.6	1257.7	1493.5	1440.63	1126.21
JUN	1552.32	1294.07	1034.41	1241.86	1474.7	1422.49	1112.03
JUL	1523.28	1269.86	1015.06	1218.62	1447.11	1395.88	1091.22
AUG	1512.72	1261.06	1008.02	1210.18	1437.08	1386.2	1083.66
SEP	818.4	682.25	545.35	654.72	777.48	749.95	586.27
OCT	778.8	649.24	518.96	623.04	739.86	713.66	557.94
NOV	731.28	609.62	487.3	585.02	694.72	670.12	523.86
DEC	686.4	572.21	457.39	549.12	652.08	628.99	491.71
TOTAL	**13200**	**11004**	**8795.99**	**10560.01**	**12539.97**	**12095.99**	**9456.03**

4. Conclusion

The energy conservation potentials in Kaduna Polytechnic had been investigated. It was established that up to 7.5% and 10% of the total energy in the institution can be saved by switching-off of security lights and air conditioning systems respectively during the time when they are not needed. Furthermore, a saving of 19.5% of the total energy can be achieved when the incandescent lamps are replaced with the energy efficient ones. Hence, a total of an estimated savings of 37% of the total energy can be achieved when the prescribed energy conservation measures are implemented successfully.

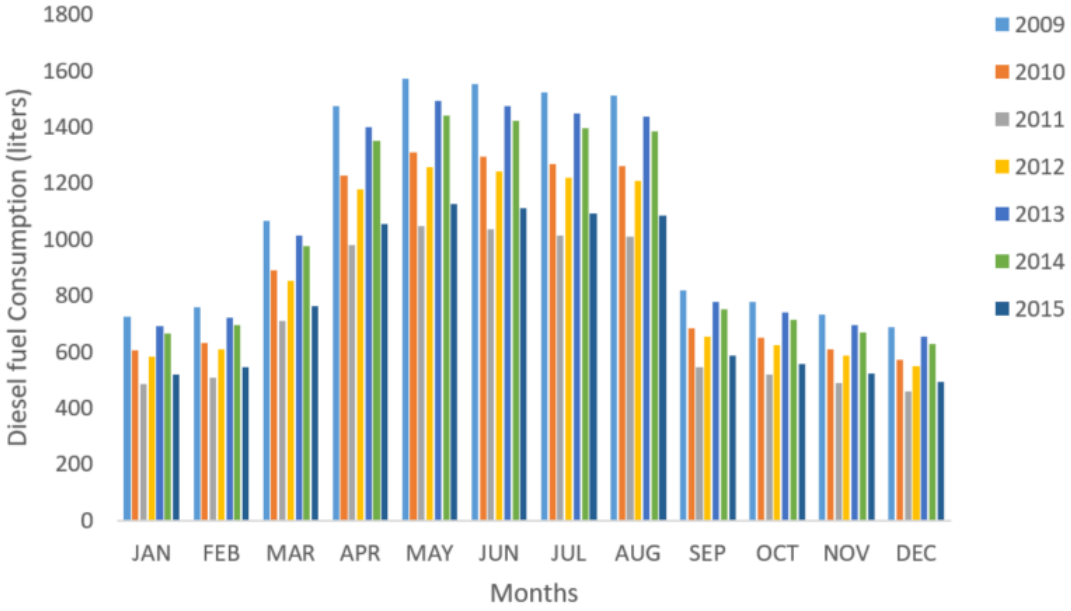

Fig. 2. Average monthly AGO consumption for 2009 to 2015

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