ECONOMICS OF USING ENERGY SAVING LOADS FOR ELECTRICAL SERVICES

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ABSTRACT

One major practice these days for effective utilization of the available electrical energy is the use of energy saving electrical loads. This work examined the economic advantage of using the energy saving electrical loads for electrical services design. Using College of Agricultural Management and Rural Development (COLAMRUD) and College of Engineering (COLENG) at Federal University of Agriculture, Abeokuta (FUNAAB) in Nigeria as a case study, load audits and energy efficiency calculations were carried out considering both the conventional and energy saving components for electrical services. Economic benefits of using the energy efficiency components was determined by calculating the Mean Absolute Percentage Saving (MAPS) of electrical energy consumption. Results of the analysis showed that an average of about 38% of the electrical energy that was to be consumed in the two colleges would be saved if the energy saving components were employed for use instead of the conventional electrical load.

***Keywords**: Load audits, Energy management, Energy saving, Efficiency, Mean absolute percentage saving.*

1. INTRODUCTION

In Nigeria, the wide electric power supply–demand gap is one of the lingering crises of the electricity sector yet to be addressed. This challenge is multi-faceted, with causes that are technological, financial, structural, and socio-political, none of which are mutually exclusive (Julia et al., 2008). The inadequate and unstable power supply has forced a large portion of industries, businesses and households to rely on diesel and petrol generators as primary or back-up sources of electricity. Due to this deficiency, the utility company is facing difficulties to cope with the ever increasing electricity demand which results in load shedding and low voltage at the consumers' end (UNDP, 2011). Hence, as a result of electric power supply shortage in Nigeria, several energy efficiency and management schemes have been advanced by various stakeholders to address this problem.

While much of government's attention is geared towards increasing electricity generation in Nigeria, not much effort is being given to how the few available energy could be managed effectively to serve the masses (Adejumobi *et al*., 2011).

This work presents the economic advantage of using the cost effective energy saving components over the conventional electrical loads for electrical services design.

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2. ENERGY EFFICIENCY AND MANAGEMENT

Energy efficiency is a concept which involves the utilization of energy in the most economical way for efficient service delivery, thereby reducing energy wastage and the overall consumption of primary energy resources. Energy efficiency improvements particularly focus on available technology to make such improvements, with some technology options being well-known and proven effective over many years of application, and some of which may be relatively new and less well-known. The major barrier to energy efficiency improvements in many situations has been attributed to lack of information (Yamba, 2006). However, experiences in many countries of supply and demand-side activities show that existing plants, buildings and equipment can often be improved substantially through simple low-cost or no-cost actions that have little bearing on technology (UNDP, 2011). Nonetheless, there are important opportunities for raising energy efficiency throughout the economy in every country, developed or developing, by adopting better energy management practices. Energy efficiency interventions are best promoted in a strategic and integrated manner to use more efficient energy technologies and management practices within the context of an energy efficiency programme.

Energy efficiency technologies and management programmes can be classified into supply-side activities and demand-side activities (Yamba, 2006). Supply-side interventions are typically technical or management interventions, which are implemented by generators, grid operators and utility providers. Demand-side interventions address aspects of energy efficiency, which can be implemented and achieved through changes in operating procedures and technologies by the consumer.

The overall goal of any energy efficiency scheme is to foster efficient utilisation of the scanty available energy at the lowest possible economical cost and this is achievable with the use of energy saving electrical loads which have capability of utilising lesser energy for operation in comparison with conventional electrical loads.

2.1 Energy Saving Techniques and Technology

Various technologies and techniques have been advanced over the years to mitigate the effect of the inadequate energy supply in the country (Obadote, 2009). Such strategies include commissioning of new power generating stations and funding of various renewable energy projects. They seek to improve on the generation but with lesser effort on how to optimize the use of the little available energy to the consumers. Improving the efficiency of energy conversion process will result in lower loading levels of electrical equipment and lower energy consumption. Such improvements include the use of automatic controls or energy strips to switch off or secure electrical equipment or appliances when not in use to ensure efficient use of available energy, the replacement of old gadgets with modern energy efficient ones e.g. the replacement of old monitors with modern and energy efficient liquid crystal display monitors, using smart motor controllers for loaded induction motors, reducing air infiltration into air-conditioned rooms and reducing leakage from compressed air systems, replacing throttling valves in pumping systems by variable speed AC drives, replacement of incandescent and fluorescent lamps with suitable compact fluorescent lamps (CFLs) and other energy saving lamps, and the use of energy saving electrical loads to mention few (Suresh, 2014).

For the purpose of this work, the technique involving the use of energy saving electrical loads was considered because of the lesser energy consuming capability of these loads.

2.2 Energy Saving Components

One way to achieve energy efficiency in residential and public sectors is through the use of energy saving equipment and mechanism such as refrigeration appliances, air conditioners, lighting, electronic motors, heating appliances and fans among others, being used in residential and public buildings in Nigeria (Elebeke, 2011). Modern technologies have led to the development of some energy efficient end-use equipment called energy saving components that utilize lesser energy in the most cost effective and environmental friendly manner to provide same service as conventional electrical loads. Research is on-going on the suitability of some of these energy saving components in our environment due to some claimed hazardous health effects on their users.

2.3 Environmental Effects of Energy Saving Components

A mercury-free CFL is not possible with current technology; some mercury is required for the lamp to work with some lamps containing as much as 30 mg, while others may contain as little as 1 mg of this toxic metal element; however efforts are progressively being made by the lighting industry towards mitigating effects (Groth, 2008). Although, no mercury is released during normal operation but the consumers can be exposed to mercury if a fluorescent tube or CFL is broken (Groth, 2008). Literatures have shown that the use of double-envelope CFLs largely or entirely mitigates any other risks (Greenfacts, 2009).

3. MATERIALS AND METHOD

In this section of the work, we present energy efficiency calculation for energy saving components. This involves the calculation and analysis of lighting design and other energy saving components employed for the work. Lighting design has an extreme importance due to the high cost of implantation and maintenance of the illumination installations. However, recent studies showed that the computational facilities are still dependent on the creativity and experience of the engineer (Elebeke, 2011), which hinder a better performance from the design to implementation.

3.1 Lighting Design

For the analysis of lighting design in this work, some important parameters such as room index, utilization coefficient, number energy saving bulbs, lamp efficiency etc. which are crucial towards obtaining better and sufficient illumination from the luminaries were considered. Details on these parameters are available in literatures (Uppal and Garg, 2011; Odunsi and Babalola, 2005; Theraja and Theraja, 2005).

3.2 Power Design Calculation

The input power demand for an energy saving components such as air-conditioner unit is calculated using equation (1) (Odunsi and Babalola, 2005; Theraja and Theraja, 2005):

$$P_i = \frac{P_o \times 746}{\varepsilon \times p.f} \quad (1)$$

Where P_i is input power demand (VA)

P_o is output power (hp)

ε is efficiency (%)

p.f is power factor

3.3 Percentage Energy Saving

The Percentage Energy Saving (PES) is used for examining the performance of energy saving components and it is given by equation (2) (Yamba, 2006). The difference between the actual and energy saving power demand is taken to be the amount of energy saved.

$$PES(\%) = \frac{P_{actual} - P_{ee}}{P_{actual}} \times 100 \quad (2)$$

Where P_{actual} is the actual load and P_{ee} is the load when energy saving components are used.

3.4 Mean Absolute Percentage Saving: Since the characteristics of the loads vary, energy saving observation is important for energy efficiency analysis. The Mean Absolute Percentage Saving (MAPS) is used to study the performance of the energy saving components based on the characteristics of individual components and it is given by equation (3) (Mohsen and Yazdan, 2007):

$$\text{MAPS} = \frac{1}{N_{oc}} \sum_{i=1}^{N_{oc}} \frac{E_{actual} - E_{ee}}{E_{actual}} \times 100\% \quad (3)$$

Where E_{actual} is actual energy consumed (kWh)

E_{ee} is energy consumed by energy saving components (kWh)

N_{oc} is the number of components

3.5 Load Audit

A load or energy audit is an essential activity for any organization wishing to control energy and utility costs (Aiyedun *et al.*, 2008). A Load audit is an inspection, survey and analysis of energy flows for energy efficiency in a building, a process or system to reduce the amount of energy input into the system without negatively affecting the output(s) (Suresh, 2014). It assists in evaluating energy consumption and provides guidelines on how to improve energy efficiency. The process of the auditing is determined by the type of the load considered which may be domestic, commercial or industrial loads.

3.6 Energy Supply Situation in Federal University of Agriculture, Abeokuta (FUNAAB), Nigeria

Federal University of Abeokuta is located in Ogun State, South West Nigeria. Presently, the University has ten colleges in addition to some other servicing centres. The energy consumption is currently estimated at about 2.5 MW. The source of the supply is from Ibadan Electricity Distribution Company (IBEDC), which is back up with three standby generators providing 0.5 MVA, 0.8 MVA and 1 MVA respectively due to unstable and insufficient power supply from IBEDC. Due to the present situation, the cost of fuelling the standby generators is very high and becoming uneconomical for an institution that is not a profit making business organization. Hence, any step taking to economize the energy being used to service the University's electrical loads will go a long way towards reducing the current overhead cost. Therefore, the need to adopt the use of energy saving electrical components cannot be overemphasized.

4. RESULTS AND DISCUSSION

Load audits were carried out in two Colleges of FUNAAB as a case study. These include College of Engineering (COLENG) and College of Agricultural Management and Rural Development (COLAMRUD). The data contains peak daily load consumption taken for a period of one month, March 2015 when the University was fully in academic session. The audited loads were used as base data with the considered lighting design parameters and equations (1) to (3) to determine the actual energy saving for the two Colleges. The audited loads for the two Colleges are respectively presented in Tables 1 and 2, whereas load analyses when energy saving components were used for the two Colleges are presented in Tables 3 and 4 respectively. The percentage energy saving for COLAMRUD and COLENG are presented in Tables 5 and 6 respectively. While Tables 7 and 8 respectively show comparison of actual and energy efficient load of COLAMRUD and COLENG using MAPS, Tables 9 and 10 respectively show cost analysis of energy consumption of COLAMRUD and COLENG.

Table1: Load Audit for COLAMRUD

S/No	Description	Wattage per Pts	No of Pts	D.F	Total wattage (W)	Usage time per day (Hrs)	Energy consumed per day (kWh)	Remarks
1.	Lighting	2 x 36	91	1	6552	8	52.416	Twin 4ft Fluorescent fftg.
		1 x 36	287	1	10332	8	82.656	Single 4ft Fluorescent fftg.
		1 x 60	69	1	4140	12	49.680	Incandescent bulb
		1 x 18	73	1	1314	8	10.512	Pin type CFL bulb
		1 x 125	2	1	250	12	3.000	Security lamp
		1 x 160	4	1	640	12	7.680	Security lamp
2.	A/C Unit	1hp	59	1	78714.26	6	472.286	Window Unit
		1.5hp	10	1	19982.1	6	119.892	Window Unit
		2hp	5	1	13321.45	6	79.929	Window Unit
	Incubator	1.5KW	3	-	4500	8	36.0	Laboratory Incubator
3.	Refrigerator	150W	5	-	750	8	6.0	Small size fridge
		115W	4	-	460	8	3.680	Small size fridge
4.	Computer	600W	6	-	3600	6	21.600	Hp Desktop Computer
	(CPU&Monitor)	650W	8	-	5200	6	31.200	Compaq Desktop Computer
5.	Ceiling fans	100W	130	1	13000	6	78.000	1400mm Sweep Ceiling fans
6.	Printer	600W	4	-	2400	2	4.800	Canon desk jet printer
		550W	6	-	2200	2	4.400	Hp desk jet Printer
7.	Photocopier	1000	5	-	5000	8	40.000	Canon Photocopier Machine
		1150	3	-	3450	2	6.900	
8.	13A Socket Outlet	300W	180	0.6	32400	2	64.8	Switch Socket Outlet
	Total Wattage (W) =	417258.81 W				Total Energy consumed per day (kWh) = 1175.431 kWh		

Table 2: Load Audit for COLENG

S/No	Description	Wattage per Pts	No of Pts	D.F	Total wattage (W)	Usage time per day (Hrs)	Energy consumed per day (kWh)	Remarks
1.	Lighting	2 x 36	63	1	4536	8	36.288	Twin 4ft Fluorescent fftg.
		1 x 36	40	1	1440	8	11.520	Single 4ft Fluorescent fftg.
		1 x 60	9	1	540	12	1.152	Incandescent bulb
		1 x 18	8	1	144	8	6.480	Pin type CFL bulb
2.	A/C Unit	1.5hp	14	1	27975	6	167.850	Window Unit
		2hp	2	1	5330	6	31.980	Window Unit
		1600W	2	1	3200	6	19.200	Split a/c Unit
3.	Refrigerator	150W	2	-	300	8	2.400	Small size fridge
		115W	2	-	230	8	1.840	Small size fridge
4.	Computer (CPU&Monitor)	650W	12	-	7200	6	43.200	Hp Desktop Computer Compaq Desktop Computer
5.	Ceiling fans	65W	2	1	130	6	0.780	OX Standing fan
		100W	39	1	3900	6	23.40	1400mm Sweep Ceiling fans
6.	Printer	600W	4	-	2400	2	4.800	Hp desk jet Printer
7.	Photocopier	1320	2	-	2640	8	21.100	Canon Photocopier Machine
		1150	2	-	2300	2	4.600	
8.	13A Socket Outlet	300W	127	0.6	22860	2	45.72	Switch Socket Outlet
	Total Wattage (W) =	85125 W				Total Energy consumed per day (kWh) = 422.33 kWh		

Table 3: Load Analysis for COLAMRUD Using Energy Saving Components

S/No	Description	Wattage per Pts	No of Pts	D.F	Total wattage (W)	Usage time per day (Hrs)	Energy consumed per day (kWh)	Remarks
1.	Lighting	1 x 85	26	1	2210	8	17.680	Pin type 85W Energy Saving bulb
		1 x 28	334	1	9352	8	74.816	Pin type 26W Energy Saving bulb
		1 x 18	113	1	2034	12	24.410	Pin type 18W Energy Saving bulb
2.	A/C Unit	1hp	74	1	64565.74	6	387.394	Window Unit

3.	Incubator	1.5KW	3	-	4500	8	36.0	Laboratory Incubator
	Refrigerator	130W	9	-	1170	8	9.36	Small size fridge
4.	Computer							
	(CPU&Monitor)	350W	14	-	4900	6	29.400	Hp Desktop Computer
5.	Ceiling fans	80W	130	1	10400	6	62.400	1400mm Sweep Ceiling fans
6.	Printer	450W	10	-	4500	2	9.000	Hp desk jet Printer
7.	Photocopier	980	5	-	4900	8	39.200	Canon Photocopier Machine
		980	3	-	2940	2	5.880	
8.	13A Socket Outlet	300W	180	0.6	32400	2	64.8	Switch Socket Outlet
	Total Wattage (W) =	144171.74 W				Total Energy consumed per day (kWh) = 754.996 kWh		

Table 4: Load Analysis for COLENG Using Energy Saving Components

S/No	Description	Wattage per Pts	No of Pts	D.F	Total wattage (W)	Usage time per day (Hrs)	Energy consumed per day (kWh)	Remarks
1.	Lighting	1 x 28	107	1	2996	8	23.968	Pin type 26w energy saving bulb
		1 x 18	52	1	936	12	11.232	Pin type 18W Energy Saving bulb
2.	A/C Unit	1hp	16	1	13960	6	83.761	Window Unit
		1600W	2	1	3200	6	19.200	Split a/c Unit
3.	Refrigerator	115W	4	-	460	8	3.680	Small size fridge
4.	Computer	650W	12	-	7200	6	43.200	Hp Desktop Computer
	(CPU&Monitor)							Compaq Desktop Computer
5.	Ceiling fans	65	2	1	130	6	0.780	OX Standing fan
		80W	39	1	3120	6	18.72	1400mm Sweep Ceiling fans
6.	Printer	450W	4	-	1800	2	3.600	Hp desk jet Printer
7.	Photocopier	980	2	-	1960	8	15.680	Canon Photocopier Machine
		980	2	-	1960	2	3.920	
8.	13A Socket Outlet	300W	127	0.6	22860	2	45.72	Switch Socket Outlet
	Total Wattage (W) =	60582 W				Total Energy consumed per day (kWh) = 253.749KWh		

Table 5: Percentage Energy Saving for COLAMRUD

	Energy Consumption (kWh)			
	Daily (kWh)	**Weekly (kWh)**	**Monthly (kWh)**	**Yearly (kWh)**
E_{actual} (kWh)	1175.431	6308.515	25234.06	302808.72
E_{ee} (kWh)	754.996	3934.98	15739.92	188879.04
Energy saved (kWh)	420.435	2373.535	9494.14	113929.68
% Energy Saved				37.62%

Table 6: Percentage Energy Saving for COLENG

	Energy Consumption (kWh)			
	Daily (kWh)	**Weekly (kWh)**	**Monthly (kWh)**	**Yearly (kWh)**
E_{actual}(kWh)	422.33	2119.65	8478.6	101743.2
E_{ee} (kWh)	253.749	1282.745	5130.98	61571.76
Energy saved (kWh)	168.581	836.905	3347.62	40171.44
% Energy Saved				39.48%

Table 7: Comparison of Actual and Energy Efficient Load of COLAMRUD Using Mean Absolute Percentage Saving (MAPS)

	Lighting	**A/C**	**Fridge**	**Computer**	**Fan**	**Printer**	**Photocopier**
E_{actual} (KWh)	205.944	672.107	45.680	52.800	78.000	9.200	46.690
E_{ee} (KWh)	116.906	387.394	45.36	29.400	62.400	9.000	45.080
Energy Saved	89.038	284.713	0.320	23.400	15.600	0.200	1.610
% Reduction	43.23%	42.36%	0.70%	44.32%	20%	2.17%	3.45%
MAPS = 22.32%							

Table 8: Comparison of Actual and Energy Efficient Load of COLENG Using Mean Absolute Percentage Saving (MAPS)

	Lighting	**A/C**	**Fridge**	**Computer**	**Fan**	**Printer**	**Photocopier**
E_{actual} (kWh)	55.440	219.030	4.240	43.200	24.180	4.800	25.720
E_{ee} (kWh)	35.200	102.961	3.680	25.200	19.500	3.600	19.600
Energy Saved	20.240	116.069	0.560	18.000	4.680	1.200	6.120
% Reduction	36.51%	53.00%	13.20%	41.67%	19.35%	25.00%	23.79%
MAPS = 30.36%							

Table 9: Cost Analysis of Energy Consumption of COLAMRUD

	E_{actual}	E_{ee}	**Energy Saved**
Monthly Consumption (kWh)	25234.06	15739.92	9494.14
Cost = ₦(kWh x 16.73)	422,165.82	263,328.86	158,836.96
Yearly Consumption (kWh)	302808.72	188879.68	113929.68
Cost = ₦(kWh x 16.73)	5,065,989.89	3,159,957.05	1,906,043.55

Table 10: Cost Analysis of Energy Consumption of COLENG

	E_{actual}	E_{ee}	Energy Saved
Monthly Consumption (kWh)	8476.6	5130.98	3347.62
Cost = ₦(kWh x 16.73)	141,813.52	85,841.30	56,005.68
Yearly Consumption (kWh)	101743.2	61571.76	40171.44
Cost = ₦(kWh x 16.73)	1,702,163.74	1,030,095.54	672,068.19

From the above analyses, it was revealed that the daily energy consumptions of COLAMRUD and COLENG are respectively 1,175.431 kWh and 422.330 kWh with the use of conventional electrical loads whereas the use of energy saving loads will reduce the daily energy consumptions of COLAMRUD and COLENG to 754.996 kWh and 253.749 kWh respectively, giving percentage yearly energy saving for COLAMRUD as 37.62% and COLENG as 39.48%. The cost implication is that FUNAAB would save ₦1,906,043.55 on COLAMRUD and ₦672,068.19 on COLENG of the electricity bill paid to the utility authority if use of energy saving loads is encouraged.

5. CONCLUSION

This work compared the use of energy saving components with conventional electrical loads for electrical services for the purpose of efficiently managing the inadequate available electric power in Nigeria, using FUNAAB as a case study. The audited loads of two of the University Colleges namely COLAMRUD and COLENG with conventional electrical services design equations were used to analyse the energy consumptions of the colleges. When compared with the conventional electrical loads, the analytical results showed that the use of energy saving loads will save about 37.62% for COLAMRUD and 39.48% for COLENG of the energy being currently consumed in the university. The economic advantage of this energy usage reduction of two Colleges is that ₦1,906,043.55 and ₦672,068.19 would respectively be saved on COLAMRUD and COLENG of the electricity bill the University authority paid to the electricity utility. The work suggested the implementation of the energy efficiency and management techniques using energy saving components to mitigate the effect of the inadequate electric power not only in FUNAAB but in Nigeria as a whole.

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