Energy Audit of Commercial Buildings (A Case Study of Global Fleet Oil Ltd. and National Mirror Houses)

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ABSTRACT

The dearth and cost of energy supply in Nigeria calls for planning and management through energy audit. The object of this paper is to carry out a comprehensive energy audit of the two commercial buildings commonly referred to as Energy House and Mirror House which are the head offices of the Global Fleet Oil & Gas Ltd. Company and National Mirror Newspaper respectively, using their 2011 energy consumption data. The power supplies to both offices are from the same generators which provide two-third of the power supply to the building in 2011 but with different transformers of 1000 kVA each for the PHCN power supply. The facilities load were assessed by direct inspection and conversion were done where necessary. The capacities of the available three generators were 400, 640 &1000 kW respectively (using 0.8 power factor) and the maximum load of the facility at any time in a day is 398 kW. This study has revealed the monumental financial waste on the un-utilized energy and facilities that could be replaced with energy saver equipment. Therefore, it is imperative that a holistic energy planning and regular assessment of energy requirements are considered as key components of building projects.

Keywords: *Power Holding Company of Nigeria (PHCN), Generators, Maximum Load, Energy Conservation Opportunities (ECO)*

1. INTRODUCTION

Buildings account for almost half of the total primary energy use and related greenhouse emissions worldwide. Although current energy systems are improving, they still fall disappointingly short of meeting acceptable limits for efficiency (Moncerf, 2010). Alexandri et al (2011) reported in their work that energy savings in the building sector has been a priority of the European Union over the last decade, and many measures have been set up to decrease a building's energy needs and gas emissions to the environment. Office buildings have characteristically high consumption for heating and especially for cooling, due to their high internal gains. Additionally, their intermittent time table makes their energy needs and consumption profile more special, with more energy needed to heat-up or cool-down space in the morning hours. The re-use of a building, initially designed as dwelling, as an office building, depicts its own not so ordinary characteristics and energy consumption needs. In their paper, the energy demand and consumption profile of such a building is given a due attention. Through the energy audit procedure, the actual electrical and oil consumption were measured and through the thermal simulation, energy saving scenarios were thoroughly examined. Energy is an important foundation resource of human society's development. According to the *International Energy Agency (2004),* the world energy consumption will be increasing from 10.24 billion tons of oil equivalent in 2001 to 16.2 billion tons of oil equivalent in 2005 and the world energy consumption will increase by 54% in 2001-2025. Reducing the use of energy is an essential task for the future as the world's greatest environmental impact originates from the use of energy (*OECD, 2004*). Due to increased globalization, industries as a whole are facing greater competition that is forcing companies to decrease their expenses in order to increase their profits (*Patrik et al., 2009).* In the

Nordic countries, such as Finland, Sweden, Iceland and Norway Heat Ventilation and Air Conditioners (HVAC) are considered to be necessary in all building due to their weather condition. In Sub-Sahara country like Nigeria, installation of heating equipment within all building is not popular. This brings a slight difference factor and facilities consideration in Energy Audit in Nigeria from that of Nordic and other part of Europe. Therefore Nigeria and other Sub-Sahara countries will need energy auditing for the sake of dearth in energy supply and the concomitant hike cost. Nigeria is well endowed with energy resources (UNDP, 1983). Conversely, the price of energy commodities (electricity, petrol, diesel, kerosene etc) are very expensive compare with abundant existence of energy resources sparsely located around the country. Currently, the tariff of PHCN in Nigeria varies between ₦ 4 to ₦ 23 for residential consumer class ₦15 to ₦20 for commercial consumer class, ₦15 to ₦22 consumer class industrial, ₦15 to ₦ 22 for special consumer class like government house and hospital and ₦ 11 to ₦ 17 for street lighting per KWH depend on the number of phases and location (NERC, 2012). These costs are too huge especially to sustain company's profit and user's comfort. The price of petroleum products grossly becoming unbearable as the government withdraws from subsidizing the products. Petrol (PMS), Diesel (AGO) and Kerosene (DPK) currently stand as ₦97, ₦160 and ₦100 per litre (PPPRA, 2012). The efficient use of energy is of prime importance in all sector of the economy .The imperative of an energy shortage situation calls for energy conservation measure, which essentially means using less energy for the same level of activity. A comprehensive energy audit of Vitamalt Nigeria Plc, Agbara was carried out by Olugbenga et al (2012) using portable thermal and electrical instruments with the objective of studying the present pattern of energy consumption and identifying the possibilities of saving energy in the plant. The normalized performance indicator (NPI) calculated over the span of five years gave an average of 1.2 GJ/m^2 indicating a FAIR range in energy performance level classification (1.0 - 1.2) while significant savings and improvement in energy usage is achievable. Maximizing efficiency of existing system, optimizing energy input requirement and significant capital investment in procuring new energy conserving equipment must be made for the energy performance level to fall into a good range classification (less than 0.8).

The suggested Solar Power source, according to Melodi and Famakin,(2011) is still at expensive side and provides not serious comparative cheaper price. Based on Reference Growth Scenario, GDP growth of 7% p.a, Nigeria energy demand for year 2010 was 15,730MW (Sambo; 2008). Meanwhile the average energy supply in last one year does not exceed 4,300 MW (Eyo, 2012). This implies that consumer will have to source for the 11,430MW from independent power generation. In spite of inadequate supply of electricity to the economy, Nigeria exports about 70MW to Niger Republic and 560MW to Republic of Benin which are members of the West African Power Pool (WAPP) with Nigeria (Sambo, 2008). Energy auditing and planning has been found to be the best strategic approach to manage available energy at relatively low cost. Tahsin and Vedat (2005) expanded further that energy audits provides an accurate account of energy consumption and reveal the detailed information needed for determining the possible opportunities for energy conservation. However, approaches to the process of energy auditing of a building depend on the environment and purpose of the building. A building could be residential, commercial and Industrial building. Energy Consumers, whose energy bills use up a large part of their income, and especially those customers whose energy bills represent a substantial fraction of their company's operating costs, have a strong motivation to initiate and continue an ongoing energy cost-control program (Wayne, 2007).

In this paper, energy supply, demand and utilization data for year 2011 of a commercial building (Energy House and Mirror House) were collected (see figure 1a & fig 1b). The information comprises data on PHCN Electrical Power bill and cost of running on the available three generators when there is power outage from PHCN. The research discovered the magnitudes energy wasted in terms of kilo-watt and cost; and suggest the way to correct the further wastage. The result of this finding will then be of immense valuable to the company in saving money on energy bills of their two complex buildings.

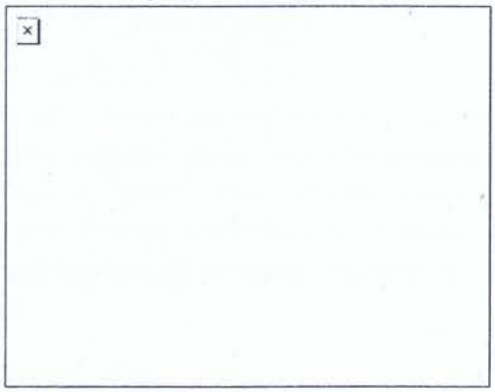


Fig1 (a) Energy House

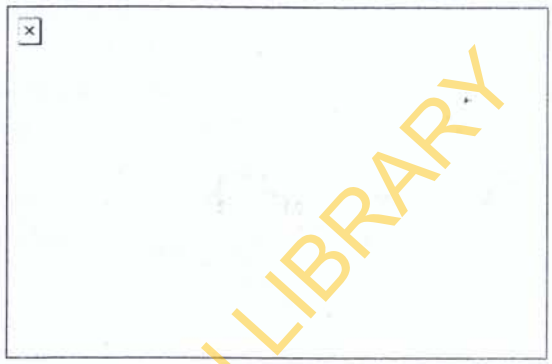


Fig1 (b) National House

2. THEORETICAL BACKGROUND

2.1 Electrical Unit Conversions

For single phase:

$$KiloWatt = Volts \times (Amperes) \times Powerfactor/(10^3) \quad (1)$$

For two-phase (For 208-240 Power Sources, 220 volts is used for calculations)

$$KiloWatt = Volts \times (Amperes) \times Powerfactor\sqrt{2}/(10^3) \quad (2)$$

For three-phase:

$$KiloWatt = Volts \times (Amperes) \times Powerfactor\sqrt{3}/(10^3) \quad (3)$$

For purposes of this paper, power factor of 0 .8 is used which is more peculiar to the Nigeria power requirement. The kVA value is always higher than the value for kW.

2.2 Energy Cost

This analysis explains the cost detail of how much is the cost of the energy produced, consumed, utilized and wasted. The bill from the PHCN is the cost of the energy consumed. But for individual power generation, the cost of energy produced can be calculated by summing the fixed cost (Depreciation, Taxes, and Insurance) and operational cost (Fuel cost, Operating Labour cost, Maintenance cost, Supervision) (Raja A.K, et al., 2006), (Albert and Meht, 2008). Source of power supply to the commercial building are: Power Holding Company of Nigeria and Company's Generators. Cost of Energy supplied by PHCN is summation of all monthly bills for 2011. In costing energy supplied by the generators, fixed cost and

operational cost are determine and summed up. To find the fixed cost, depreciation of the generators is calculated using sinking value method. i.e.

$$Annual\ sinking\ fund\ depreciation\ reserve = \square initial\ cost - Salvage\ value\square \times r/(((1+r)\wedge n - 1)) \quad (4)$$

Or

$$Straight\ Line\ Method = (Initial\ Cost - Salvage\ Value)/Number\ of\ Years\ of\ Useful\ Life \quad (5)$$

Where r is the interest rate and n is the number of the years. According to Gupta, (1983), the economic life span of electrical equipment such as generators ranges between 20 to 25year and salvage value of 15% while *Thomsen, (1997) opined* 20, 000 running hours for overhauling and regular services are carried out at 200 hours interval. Other charges on the fixed cost can be neglected as the equipments are very new. The operation costs are calculated by summing the respective figures of the cost spent on the operational activities.

3. METHODOLOGY

In this paper, information about a facility's operation and its past record of PHCN utility bills were collected. The collected data were then analyzed to get a picture of how the facility uses or possibly wastes energy, as well as to help the company learn what areas to examine to reduce energy costs. Data were collected on hourly power demand (taken on the generator for over a period of time), fuel consumptions per month, facilities load by direct assessment of the power rating of the facilities and PHCN monthly Bill. The data collected help in calculation of the Hourly–load table (see table 2), Energy cost from PHCN (see table 3) and Company's generators (see table 4).

The facilities and the equipment in the building which were found in the course of the gathering of the information for the auditing exercise were majorly those thing that are common to commercial building. In the Energy House, there are four-feet fluorescent tube, two-feet fluorescent tube, split unit A/Cs, central cooling A/Cs, standing fans, air- extractors, Computers, TV, Portable Radio, water Dispensers etc. In the Mirror's House, Compass printing Machine, Compressors, Computer, Scanners, Printer, A/Cs, ceiling fan, four-feet fluorescent tube, two-feet fluorescent tube, etc. all these facilities are grouped and their percentages were also determined as tabulated in table 1.

Table 1: **Categories of Loads of the Facilities in the Building**

Facility	Load(W)	Percentage %
Illumination	46332	4.3
HVAC	578220	54.2
Office Accessories	289794	27.2
Office Comfort	3645	0.3
Service Facilities	119145	11.2
Production Facilities	29762	2.8
	1066898	100

The Total Connected Load in KW=1,066.898KW

Table 2: **Average Hourly Load of the Buildings per Day**

Time(Hour)	Load (kW)	Time(Hour)	Load (kW)
1	181.11	13	260.44
2	182.89	14	279.11
3	82.22	15	276.89
4	73.55	16	346.00
5	51.11	17	398.00
6	114.00	18	218.44
7	107.33	19	178.89
8	180.00	20	268.44
9	343.11	21	258.22
10	351.78	22	242.89
11	397.78	23	255.78
12	270.89	24	184.89
		Total	5,503.80

Maximum Load is 398kW and is at 5pm (17th hour). At this time, the staff in the Energy House is still in the office while National Mirror workers have also commenced the production work for the publication of the second day newspaper edition. This justifies the figure for the maximum load which is equivalent to Power Consumes in KWh daily.

Table 3: **PHCN Bill for Year 2011 for Mirror and Energy House**

S/N	Months	Energy House (₦)	Mirror's House (₦)	Total Bill
1	January	926,460.00	603,000	1,529,460.00
2	February	411,751.40	700,000	1,111,751.40
3	March	405,431.40	750,000	1,155,431.40
4	April	600,500.90	850,000	1,450,500.90
5	May	757197.70	900,000	1,657,197.70
6	June	757197.70	900,000	1,657,197.70
7	July	295,174.64	720,000	1,015,174.64
8	August	434,973.21	1,490,000	1,924,973.21
9	September	501,064.41	997,000	1,498,064.41
10	October	1,252,296.26	1,300,000	2,552,296.26
11	November	876906.03	900,000	1,776,906.03
12	December	785730.96	950,000	1,735,730.96
		8,004,684.61	11,060,000	19,064,684.61

Generators Fixed Cost: Using equation (5) to solve for Depreciation gives N2, 932,500 while operational costs is calculated by summing the relevant figure of the monthly cost and are tabulated in the table 4.

Table 4: **Operational Cost on the Generators for Year 2011**

S/N	Months	Maintenance Cost (₦)	Cost of Repair (₦)	Cost of fuel (₦)	Operators Allowance(₦)	Operational Cost(₦)
1	January	309,541.66	0	4114800	30,000	4,454,341.66
2	February	309,541.66	0	4241800	30,000	4,581,341.66
3	March	309,541.66	0	4191000	30,000	4,530,541.66
4	April	309,541.66	700,000	4216400	30,000	5,255,941.66
5	May	309,541.66	99,750	4653000	30,000	5,092,291.66
6	June	388,609.38	73,000	4653000	30,000	5,144,609.38
7	July	388,609.38	0	5075000	30,000	5,493,609.38
8	August	388,609.38	0	5075000	30,000	5,493,609.38
9	September	280,000.00	0	4950000	30,000	5,260,000.00
10	October	280,000.00	2,000	4,500,000	30,000	4,812,000.00
11	November	280,000.00	0	4805000	30,000	5,115,000.00
12	December	0.00	0	5037500	30,000	5,067,500.00
		3,553,536.43	874750	55512500	360,000	60,300,786.44

Total Cost of Energy Supplied by generators is sum of fixed cost and operational cost totaling ₦ 63, 232,786.44. Total Cost of Energy due for year 2011 is the sum of PHCN Bill and Generator Cost of Power supplied which gives ₦ 82, 297,471.050

4. RESULTS AND DISCUSSION

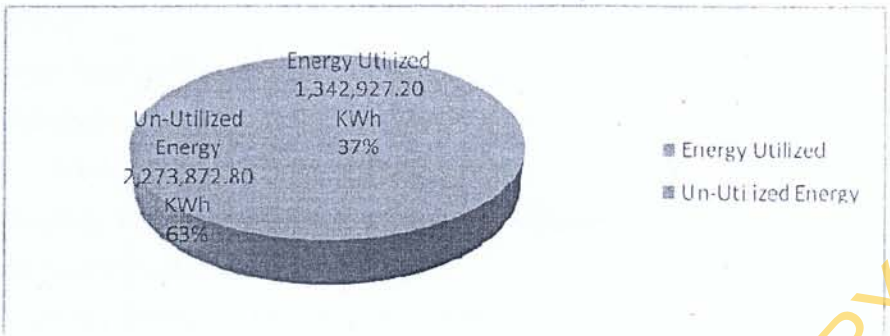
The power supply by the generators and PHCN are on average of 16hours and 8 hours daily respectively. The number of hours the power was supplied by the PHCN $365X1/3 = 121Hours$ and cost ₦ 19, 064,684.61 for the period of 2011. The number of hours the power was supplied by the generators $365X2/3 = 244Hours$ and cost ₦ 82, 297,471.050 for year 2011. Moreover, to find actual energy wasted from the generator and its concomitant cost, power capacities of individual generator over the year are considered and the result of the effect and the cost estimate implication are tabulated in table 5 and shown in figure 2.

Table 5: **Power Distribution from Generators**

Generators in KVA (KW)	Working Days	Energy Supply(KWh) in working days	Energy consumed in the working days(KWh)	Un-utilized Energy (KWh)
1250(1000)	86	2,064,000	473,326.80	1,590,673.20
800 (400)	5	48,000	27,519	56,481
500(400)	153	1,468,800	842,081.40	626,718.60
Total	365	3,580,800	1,342,927.20	2,273,872.80
Cost (₦)		63, 232,786.44	39,836,655.46	23,396,130.98

From the hourly-load daily consumption, average energy consumes is 5,503.8KWh.

Fig 2: The Pie Chart Showing Energy Utilization Status



5. CONCLUSIONS

The finding from the result of the auditing reveals how huge money is wasted on the un-utilized energy and facilities that could be replaced with energy saver equipment. The present situation arose from lack of energy planning and regular assessment of the energy requirement within the building.

Most of the illumination equipments are incandescent bulb, 2-feet and 4-feet fluorescent tubes with power rating of 100W, 18W and 36W respectively. These equipments could be replaced with modern energy savers bulbs with 20W power rating and still achieved the same illumination effect. HVAC equipments usage should be based on need. If actions are taken on the above recognized ECO, the PHCN bill will dropped.

In this research, maximum of 398KW was found to be required by the building at any time in a day. but the generating plant within the complex are capable of supplying not less than 400KW at any time with high operational cost. Therefore to curtail the energy wastage from the 1250kVA generator of superfluous capacity, two generators of capacities 500KVA (400kW using power factor 0.8) and 550kVA (440kW using power factor 0.8) will be sufficient for the energy needed by the buildings throughout a year provided no additional energy demand arise. The 550kVA should be used in the evening when we have the maximum load to give tolerance to the demand.

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